eBook*plus*
www.jacplus.com.au

O'KEEFFE | NELSON | WALSH | GUTHRIE
QUINLAN | CLEARY | MILLAR

LIVE IT UP 2

VCE PHYSICAL EDUCATION UNITS 3 & 4

4TH EDITION

+ study on

ACHPER Victorian Branch Inc.

jacaranda
A Wiley Brand

LIVE IT UP 2

VCE PHYSICAL EDUCATION | UNITS 3 & 4

4TH EDITION

Michelle O'KEEFFE
Sally NELSON
Kirsty WALSH
James GUTHRIE
Mark QUINLAN
Vaughan CLEARY
Sam MILLAR

CONTRIBUTING AUTHORS
David Smyth | Wayne Judge | Fiona Shepherd

ACHPER Australia Victorian Branch Inc.

jacaranda
A Wiley Brand

Fourth edition published 2017 by
John Wiley & Sons Australia, Ltd
42 McDougall Street, Milton, Qld 4064

First edition published 2000
Second edition published 2006
Third edition published 2011

Typeset in 10.5/12pt BerkeleyStd-Book

National Library of Australia
Cataloguing-in-publication data

Creator:	O'Keeffe, Michelle, author.
Title:	Live it up 2: VCE physical education. Units 3 & 4 / Michelle O'Keeffe, Sally Nelson, Kirsty Walsh, James Guthrie, Mark Quinlan, Vaughan Cleary, Sam Millar.
Edition:	4th Edition
ISBN:	978 0 7303 2930 5 (set) 978 0 7303 2931 2 (paperback) 978 0 7303 2933 6 (ebook) 978 0 7303 4827 6 (studyON)
Notes:	Includes index. For secondary school age.
Subjects:	Physical education and training – Victoria – Study and teaching (Secondary) Physical education and training – Victoria – Textbooks. Physical education and training – Textbooks.
Other creators/ contributors:	Nelson, Sally, author. Walsh, Kirsty, author. Guthrie, James, author. Quinlan, Mark, author. Cleary, Vaughan, author. Millar, Sam, author. Smyth, David, contributor. Judge, Wayne, contributor. Shepherd, Fiona, contributor.

Cover images: © pio3 / Shutterstock; © Ahmed Kelly

Internal design images: © Image 100; the Wiley Art Studio

Illustrated by Harry Slaghekke (pages 29, 40, 44–7, 50, 57–8, 61–2, 161, 165–6, 172, 177, 205, 254, 397–8, 400–1, 406–8, 411, 427, 433, 435, 444), various artists, Aptara and the Wiley Art Studio

Typeset in India by Aptara

Printed in Singapore by
C.O.S. Printers Pte Ltd

10 9 8 7 6 5 4 3 2 1

CONTENTS

About eBookPLUS and studyON vii
How to use this resource viii
Acknowledgements x
Preface xiii

UNIT 3 MOVEMENT SKILLS AND ENERGY FOR PHYSICAL ACTIVITY 1

Chapter 1 Movement skills 3
- **1.1** Classification of movement skills 4
- **1.2** Influences on movement 11
- **1.3** The link between motor skill development, participation and performance 14
- **1.4** Qualitative analysis of movement skills 17

KEY SKILLS 24
CHAPTER REVIEW 26
Chapter summary 26
Exam preparation 26

Chapter 2 Biomechanical principles 31
- **2.1** Introduction to biomechanics 32
- **2.2** Using kinetic concepts studied in biomechanics for analysis of human movement 33
- **2.3** Newton's laws of motion 43
- **2.4** Using kinematic concepts studied in biomechanics for analysis of human movement 48
- **2.5** Using principles of equilibrium, levers, stability and balance for analysis of human movement 57

KEY SKILLS 65
CHAPTER REVIEW 67
Chapter summary 67
Exam preparation 67

Chapter 3 Coaching and instruction 71
- **3.1** The direct (traditional) approach to instruction 72
- **3.2** The constraints-based approach to instruction 76
- **3.3** Stages of learning 87
- **3.4** Sociocultural influences on skill development 91

KEY SKILLS 101
CHAPTER REVIEW 102
Chapter summary 102
Exam preparation 103

Chapter 4 Practice and feedback 107
- **4.1** Practice amount and distribution 108
- **4.2** Practice variability 116
- **4.3** Feedback 128
- **4.4** Frequency and timing of feedback 134

KEY SKILLS 139
CHAPTER REVIEW 140
Chapter summary 140
Exam preparation 141

Chapter 5 Energy systems and interplay of energy systems 145
5.1 Adenosine triphosphate (ATP): the body's energy currency 146
5.2 Energy fuels: converting food to energy 148
5.3 Energy systems and pathways 155
5.4 The ATP–CP system 159
5.5 The anaerobic glycolysis system 164
5.6 The aerobic system 170
5.7 Energy systems at work: interplay of energy systems 179
5.8 The significance of lactate 184
KEY SKILLS 187
CHAPTER REVIEW 188
Chapter summary 188
Exam preparation 192

Chapter 6 Acute physiological responses to exercise 197
6.1 Acute responses of the cardiovascular system: heart rate, stroke volume and cardiac output 198
6.2 Acute responses of the cardiovascular system: blood pressure, redistribution of blood flow, arteriovenous oxygen difference 203
6.3 Acute responses of the respiratory system 206
6.4 Maximum oxygen uptake 209
6.5 Oxygen uptake at rest, oxygen deficit, steady state and excess post-exercise oxygen consumption 213
6.6 Acute responses of the muscular system 216
KEY SKILLS 218
CHAPTER REVIEW 219
Chapter summary 219
Exam preparation 220

UNIT 4 TRAINING TO IMPROVE PERFORMANCE 225

Chapter 7 Activity analysis 227
7.1 What is activity analysis? 228
7.2 Methods of activity analysis: skill frequency 231
7.3 Methods of activity analysis: movement patterns 233
7.4 Methods of activity analysis: heart rates 237
7.5 Methods of activity analysis: work-to-rest ratios 240
7.6 Netball case study 242
KEY SKILLS 247
CHAPTER REVIEW 248
Chapter summary 248
Exam preparation 249

Chapter 8 Fitness components 253
8.1 Aerobic power and anaerobic capacity 254
8.2 Muscular strength, muscular power and muscular endurance 259
8.3 Speed and agility 265
8.4 Flexibility and balance 269
8.5 Body composition, coordination and reaction time 272
KEY SKILLS 276
CHAPTER REVIEW 277
Chapter summary 277
Exam preparation 278

Chapter 9 Fitness assessment: rationale and tests 281

9.1 The types of fitness testing 282
9.2 The purpose of fitness testing 285
9.3 How to conduct fitness testing 289
9.4 Fitness tests 291
9.5 Muscular strength, power and endurance tests 305
9.6 Speed and agility tests 319
9.7 Flexibility and body composition tests 326

KEY SKILLS 339

CHAPTER REVIEW 340
Chapter summary 340
Exam preparation 340

Chapter 10 Monitoring and planning a training program 343

10.1 The design of a training program 344
10.2 Periodisation of training 348
10.3 Components of an exercise training session 353
10.4 Strategies to monitor and record training 359

KEY SKILLS 366

CHAPTER REVIEW 368
Chapter summary 368
Exam preparation 369

Chapter 11 Training program principles and methods 373

11.1 Specificity, intensity and type of training 374
11.2 Time/duration and frequency 380
11.3 Progression (progressive overload), overtraining and variety 382
11.4 Diminishing returns, reversibility or detraining, maintenance and individuality 386
11.5 Continuous and interval training 389
11.6 Resistance (or weight) training 397
11.7 Flexibility and plyometrics 406
11.8 Circuit and fartlek training 413

KEY SKILLS 416

CHAPTER REVIEW 417
Chapter summary 417
Exam preparation 418

Chapter 12 Chronic adaptations to training 423

12.1 Chronic training adaptations 424
12.2 Chronic adaptations to aerobic training: cardiovascular 427
12.3 Chronic adaptations to aerobic training: respiratory 433
12.4 Chronic adaptations to aerobic training: muscular 435
12.5 Chronic adaptations to aerobic training: cardiovascular, respiratory and muscular 439
12.6 Chronic adaptations to anaerobic training 442
12.7 Chronic adaptations to resistance training: neuromuscular 446

KEY SKILLS 448

CHAPTER REVIEW 449
Chapter summary 449
Exam preparation 452

Chapter 13 Performance enhancement and recovery strategies: psychological, nutritional and hydration 457

13.1 Nutritional needs of athletes: a balanced diet 458
13.2 Nutritional needs of athletes: carbohydrates 460
13.3 Nutritional needs of athletes: protein 466
13.4 Nutritional recovery in relation to the type of sport or activity 470
13.5 Hydration needs of athletes 477
13.6 Psychological strategies to enhance performance and aid recovery: sleep, confidence and motivation 484
13.7 Psychological strategies to enhance performance and aid recovery: optimal arousal, mental imagery and concentration 490

KEY SKILLS 499

CHAPTER REVIEW 500
Chapter summary 500
Exam preparation 501

Glossary 507
Index 515

About eBookPLUS and studyON

Access your online Jacaranda resources anywhere, anytime, from any device in three easy steps:

STEP 1 Go to **www.jacplus.com.au** and create a user account.
STEP 2 Enter your registration code.
STEP 3 Instant access!

eBookplus + studyon

eBookPLUS is an electronic version of the textbook, together with a targeted range of supporting multimedia resources.

eBookPLUS features:

- **eBook** — the entire textbook in electronic format
- **Digital documents** designed for easy customisation and editing
- **Interactivities** to reinforce and enhance students' learning
- **eLessons** — engaging video clips and supporting material
- **Weblinks** to relevant support material on the internet

eGuidePLUS features assessment and curriculum material to support teachers.

studyON is an interactive and highly visual online study, revision and exam practice tool designed to help students and teachers maximise exam results.

studyON features:

- **Concept summary screens** provide concise explanations of key concepts, with relevant examples.
- **Access 1000+ past VCAA questions** or custom-authored practice questions at a concept, topic or entire course level, and receive immediate feedback.
- **Sit past VCAA exams** (Units 3 & 4) or **topic tests** (Units 1 & 2) in exam-like situations.
- **Video animations and interactivities** demonstrate concepts to provide a deep understanding (Units 3 & 4 only).
- **All results and performance in practice and sit questions** are tracked to a concept level to pinpoint strengths and weaknesses.

NEED HELP? Go to www.jacplus.com.au and select the Help link.

- Visit the JacarandaPLUS Support Centre at **http://jacplus.desk.com** to access a range of step-by-step user guides, ask questions or search for information.
- **Contact** John Wiley & Sons Australia, Ltd.
  Email: support@jacplus.com.au
  Phone: 1800 JAC PLUS (1800 522 7587)

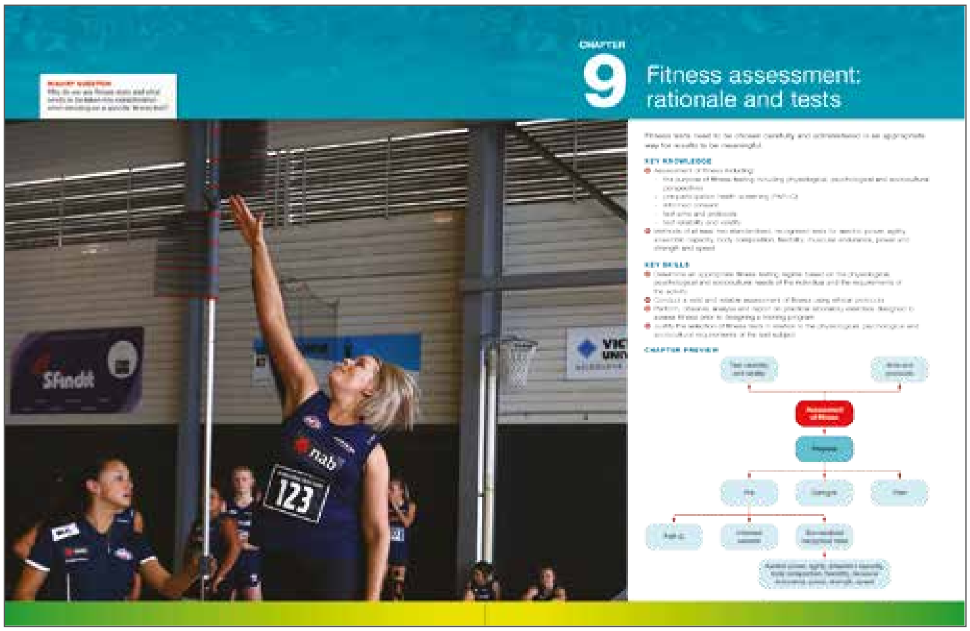
Minimum requirements

JacarandaPLUS requires you to use a supported internet browser and version, otherwise you will not be able to access your resources or view all features and upgrades. Please view the complete list of JacPLUS minimum system requirements at **http://jacplus.desk.com**.

HOW TO USE THIS RESOURCE

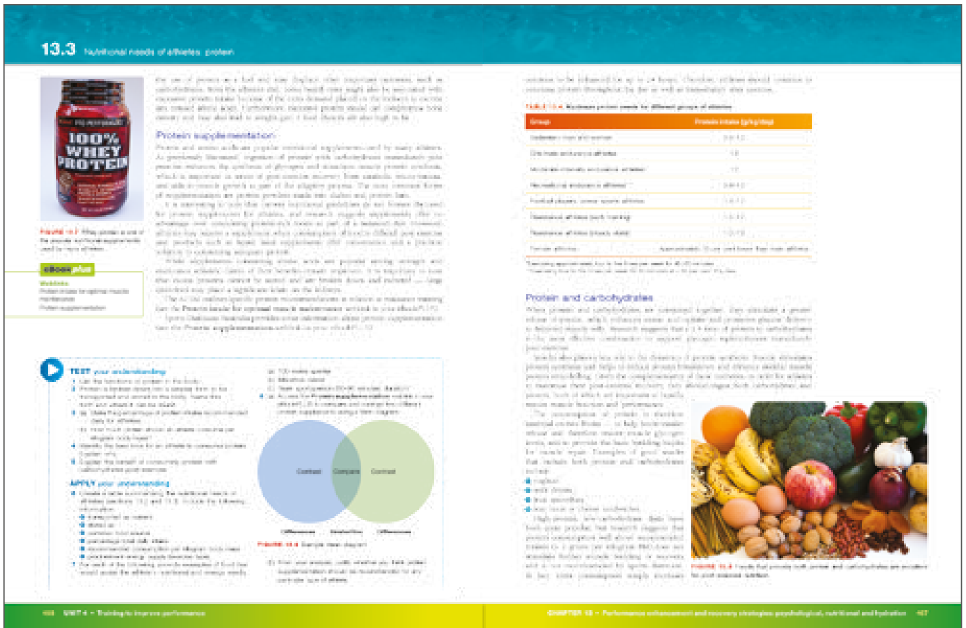
The following examples highlight the structure and main features of *Live It Up 2, Fourth Edition*. An electronic version of the textbook and a complementary set of targeted digital resources — the eBookPLUS — are also available online at the JacarandaPLUS website, www.jacplus.com.au. Your eBookPLUS resources include:

- eLessons, featuring video interviews with sports professionals, that help students apply key concepts to real-world fitness industry scenarios
- interactivities to help students understand key concepts and definitions
- weblinks to key fitness and health organisations and updated data and statistics.

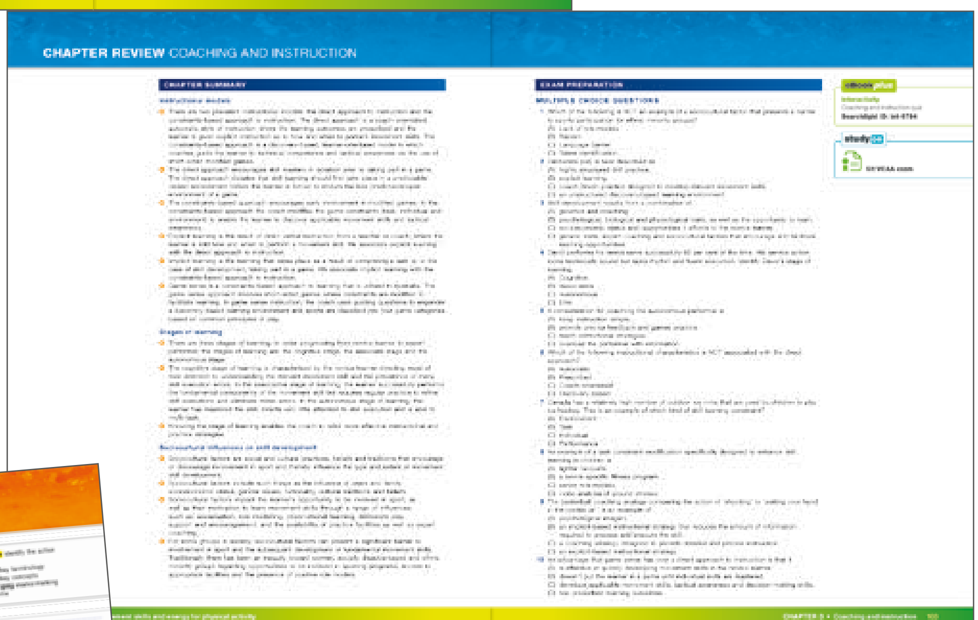


An engaging image introduces each chapter to capture students' interest. The Key Knowledge and Key Skills from the VCE Physical Education Study Design (Units 3 & 4, 2018–2021) that are covered in this chapter are listed, along with a chapter preview diagram that gives a snapshot of the chapter content at a glance.

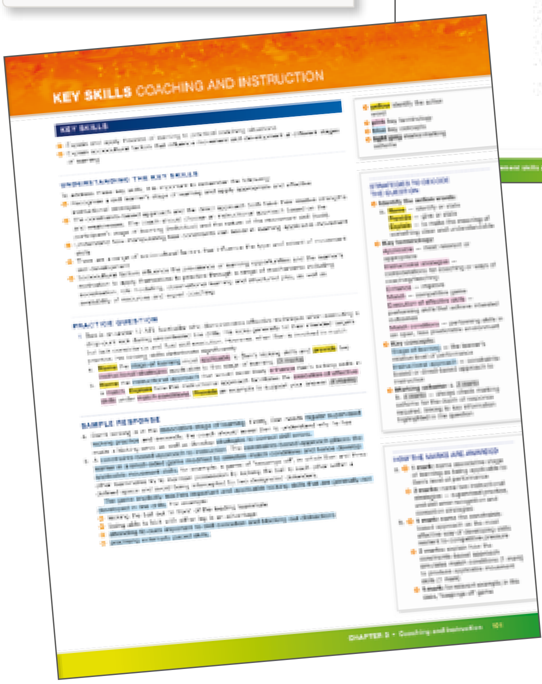
All lessons come complete with clear and colourful diagrams to assist visual learning. Key terms are bolded and definitions can be found in the margins. studyON references are placed beside key concepts to direct students to summaries and practice questions online.

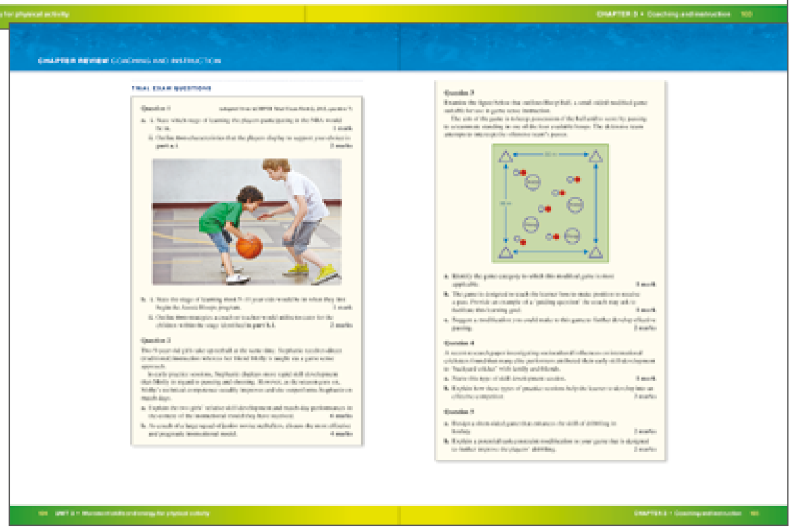


Three levels of questions — Test your understanding, Apply your understanding and Exam practice — encourage students to practice and apply the concepts they are learning and include practical activities. Digital documents, interactivities and videos are placed within sections of content that can be enhanced by presentation in a different form, to ensure students of varying learning styles are catered for.



At the end of each chapter is a substantial revision section which will assist all students in revising content. Key skills are covered in detail, with an annotated explanation, a practice question and a sample response. Students will also find a full chapter summary, a set of multiple choice questions and practice exam questions invaluable in revising each topic.





ACKNOWLEDGEMENTS

The authors and publisher would like to thank the following copyright holders, organisations and individuals for their assistance and for permission to reproduce copyright material in this book.

Images

• Alamy Australia Pty Ltd: **2**, **17**/ipm; **7**/Christopher Perks; **7**/Les Gibbon; **7**/Ady Kerry; **7**, **134**/PCN Photography; **8**/Blend Images; **8**/cello; **12**/David Levenson; **12**/Jim Corwin; **13**/Jonathan Larsen/Diadem Images; **15**/Ian Allenden; **17**, **17**, **70**, **496**/Hero Images Inc.; **20**/GraficallyMinded; **20**/lewis jackson; **21**/James Worsfold; **32**/imageBROKER; **34**, **80**, **120**, **120**, **125**, **351**, **370-371**, **376**, **413**, **420**/PA Images; **35**/Foto Arena LTDA; **41**/dpa picture alliance archive; **41**/Brian T. Humek; **46**, **358**/Cultura RM; **51**, **53**, **111**, **117**, **136**, **338**, **341**, **456**, **475**, **475**/dpa picture alliance; **60**/MERVYN REES; **60**/Micheko Productions, Inh. Michele Vitucci; **61**/Lucy Calder; **73**/Images-USA; **76**/Stock Foundry Images; **77**, **345**, **349**, **471**, **471**/Action Plus Sports Images; **83**/Ben Welsh Premium; **87**/mainpicture; **88**/Zoonar GmbH; **109**/Andrey Moisseyev; **109**/Adrian Sherratt; **113**, **229**, **347**/ZUMA Press, Inc.; **114**/Andor Bujdoso; **119**/Cal Sport Media; **121**/Paul Quayle; **121**/Thomas Eisenhuth/dpa/Alamy Live News; **123**/Greatstock; **129**/Telephoto Images; **135**, **423**/ITAR-TASS Photo Agency; **137**/Kumar Sriskandan; **160**/Robert Timoney; **209**/Ammentorp Photography; **210**/Image Source; **211**/Extreme Sports Photo; **217**/Neil Smith; **333**/Mediscan; **355**/Guido Rosa; **359**/venimo; **359**/Olekcii Mach; **376**/Dan Cooke; **378**/Tim Hester; **379**/James Azzurro; **397**/Tetra Images; **398**/grant pritchard; **423**/George S de Blonsky; **423**/Eye Ubiquitous; **441**, **441**/Sport In Pictures; **467**/Dudley Wood; **468**/The Photo Works; **470**/Roger Sedres; **473**/Matthew Chattle; **474**/Richard Sharrocks; **479**/PhotoAlto; **488**/Wavebreak Media ltd; **496**/Neil Tingle • Australian Bureau of Statistics: **272** Australian Health Survey: Updated Results, 2011–2012, CAT, 4364.0.55.003. • Australian Sports Commission: **5**, **125**, **463–464** • Canadian Society for Exercise Physiology: **289** • Catapult: **358** • Copyright Clearance Centre: **255**; **460**/D. L. Costill, J. M. Miller, Nutrition for Endurance Sport: Carbohydrate and Fluid Balance, Int J Sports Med 1980; 011: 2–14. • Ergoflex: **485** • Getty Images: **150**/Floortje; **151**/Kelly Cline; **152**/Andy Dean • Getty Images Australia: **41**/FABRICE COFFRINI/AFP; **97**/Michael Willson/AFL Media; **128**, **282**/Robert Cianflone; **137**/Adrian Dennis/AFP; **284**/Robert Cianflone; **487**/Darrian Traynor • Getty Media Manager: **89**/Racheal Grazias/Shutterstock; **276**/Kitzero/Shutterstock • GPSports: **235** • GU Energy Labs: **464**/© GU Energy Labs • Human Kinetics: **11**/Reprinted, with permission, from K.M. Haywood and N. Getchell, 2009, Life span motor development, 5th ed. Champaign, 6.; **162**/Reprinted, with permission, from J.H. Wilmore, D.L. Costill, and W.L. Kenney, 2008, Physiology of sport and exercise, 4th ed. Champaign, [page 52].; **199**/Reprinted, with permission, from J.H. Wilmore, D.L. Costill, and W.L. Kenney, 2008, Physiology of sport and exercise, 4th ed. Champaign, pp.163; **200**/Reprinted, with permission, from J.H. Wilmore, D.L. Costill, and W.L. Kenney, 2008, Physiology of sport and exercise, 4th ed. Champaign, pp. 164; **201**/Reprinted, with permission, from J.H. Wilmore, D.L. Costill, and W.L. Kenney, 2008, Physiology of sport and exercise, 4th ed. Champaign, pp. 167; **203**/Reprinted, with permission, from J. Hoffman, 2002, Physiological aspects of sport training and performance Champaign, pp.50; **204**/Reprinted, with permission, from J. Hoffman, 2002, Physiological aspects of sport training and performance Chapaign; pp. 44; **214**/Reprinted, with permission, from J.H. Wilmore, D.L. Costill, and W.L. Kenney, 2008, Physiology of sport and exercise, 4th ed. Champaign, pp. 109 • iStockphoto: **150**/Elena Elisseeva; **150**/Carlos Alvarez; **150**/© EuToch; **150**/© Sarah Lee • James Guthrie: **117**, **117**, **118** • John Wiley & Sons Australia:

304/c Photo by Jo Patterson • John Wiley and Sons Australia: **305**/c Photo by Jo Patterson • Kirsty Walsh: **301**, **301**, **307**, **307**, **307**, **310**, **310**, **310**, **311**, **311**, **311**, **311**, **312**, **312**, **313**, **313**, **314**, **314**, **317**, **317**, **318**, **318**, **330**, **335**, **335**, **335**, **337**, **337** • Manitoba Education, Citizenshi: **385**/Reference: Bouchard, C., and T. Rankinen. • MedBio.info: **175** • National Health and Medical Research Council: **459**/Source: National Health and Medical Research Council • Netfit: **357**, **392**, **392**, **392** • Newspix: **165**/News Ltd • Palgrave Macmillan: **132** • Public Domain: **161**, **174** • RAD sports performance: **242**, **242**, **242**, **242**, **242** • Shutterstock: **1**/Rob Marmion; **4**/nenetus; **5**/ANURAK PONGPATIMET; **5**/Iakov Filimonov; **5**/Max Topchii; **5**/altanaka; **6**/paintings; **7**/Markus Gann; **8**/SeeArkay; **9**, **380**/BrunoRosa; **18**, **267**, **267**/Lilyana Vynogradova; **19**/Igor N Gapchich; **30**/Eugene Onischenko; **33**, **73**, **111**, **122**/Leonard Zhukovsky; **35**/J. Henning Buchholz; **36**/ESB Professional; **37**/Daxiao Productions; **37**/Pavel Shchegolev; **38**, **259**, **274**/Mitch Gunn; **43**/Milkovasa; **49**/3103; **52**/lightpoet; **53**/sportpoint; **62**, **257**/Peter Bernik; **63**/CHEN WS; **72**/Diego Cervo; **73**, **73**/Microgen; **73**/Maxisport; **74**, **144**/Neale Cousland; **74**/Dziurek; **78**/muratart; **78**/Tukaram.Karve; **79**/xc; **80**/Viacheslav Nikolaenko; **81**/Solis Images; **82**/Monkey Business Images; **83**/Fotokostic; **87**/Dreams Come True; **87**/lev radin; **91**/GTS Productions; **92**/krumcek; **93**/Lopolo; **93**/akturer; **95**/Grushin; **96**/Odua Images; **97**/SasinTipchai; **98**, **112**/Mitch Gunn; **100**/Pal2iyawit; **104**/Robert Kneschke; **106**/Daniel Huerlimann-BEELDE; **108**/d13; **114**, **114**/David W. Leindecker; **114**/David W. Leindecker; **116**/SUSAN LEGGETT; **122**/MANDY GODBEHEAR; **130**/photogolfer; **131**/Artem Avetisyan; **131**/wavebreakmedia; **150**/TADDEUS; **150**/monticello; **150**/Ronnarong Thanuthattaphong; **150**/amphaiwan; **150**/MaraZe; **150**/kuvona; **150**/Hydromet; **151**/Rafa Irusta; **151**/Jiri Hera; **152**/alexpro9500; **152**/alexpro9500; **162**/Copyright Shane White, 2010. Used under license from Shutterstock.com; **196**/Corepics VOF; **225**/arek_malang; **226**/Andrey_Popov; **228**/dotshock; **229**/Brian A. Witkin; **237**/Maridav; **252**/Zaretska Olga; **254**/stockyimages; **254**/Radu Razvan; **256**/bikeriderlondon; **257**/FCG; **257**/TORWAISTUDIO; **257**/Gino Santa Maria; **257**/mezzotint; **257**/Pavel L Photo and Video; **261**/Neale Cousland; **261**/© Johnny Lye; **262**/lazyllama; **262**/AusVideo; **265**/testing; **265**, **495**/Stefan Holm; **266**/A.RICARDO; **267**/makieni; **269**, **269**/Leonard Zhukovsky; **270**/CP DC Press; **270**/Lucky Business; **273**, **350**/Mai Groves; **273**/FlashStudio; **335**/eveleen; **353**/mehmet dinler; **353**, **382**/lzf; **353**/fizkes; **353**/Air Images; **360**/venimo; **372**/pdrocha; **373**/phoelixDE; **373**/Athanasia Nomikou; **373**/Athanasia Nomikou; **377**/Maridav; **389**/Jacob Lund; **407**/Sebastian Gauert; **431**/photoiconix; **435**/PIYAPONG THONGDUMHYU; **440**/Artem Furman; **444**/Designua; **482**/Galina Barskaya/Shutterstock • Topend Sports: **295**, **327** • Wolters Kluwer: **179**/'Figure 4.1: Rest to exercise transitions in ATP production' from pp. 76 of 'Exercise Physiology: Basis of Human Movement in Health and Disease' by Brown, Miller and Eason, Lippincott Williams & Wilkins, 2006 • ylmsportscience: **486**

Text

• ABC: **481** • ACHPER: **127**, **142**, **192**, **221**, **239**, **278**, **343**, **418-419**, **451-452**, **504-505** • American College of Sports Medicine: **490-491**/Reprinted with permission of the American College of Sports Medicine. Copyright © 2014 American College of Sports Medicine. This brochure is a product of ACSM's Consumer Information Committee. Visit ACSM online at www.acsm.org • American Diabetes Association: **154**, **462** • Australian Institute of Fitness: **287** • Australian Sports Commission: **347**, **462** • Copyright Clearance Centre: **189**, **305** • Creative Commons: **474**/Brianna Newland/The Conversation • ExRx.net: **291**/'Use with permission by ExRx.

net, LLC' on the page it appears • Headspace.com: **494** • Human Kinetics: **211**, **437**/Reprinted, with permission, from J.H. Wilmore, D.L. Costill, and W.L. Kenney, 2008, Physiology of sport and exercise, 4th ed. Champaign, pp. 241 • International Tennis Federation: **21**/Bruce Elliott, ITF Coaching and Sport Science Review 2010; 50 18: 5–6. • John Wiley & Sons: **123** • Kirsty Walsh: **335**, **336**, **339** • Physical & Health Education Canada: **6** • RAD sports performance: **236** • Topend Sports: **294**, **295**, **296**, **300**, **309**, **318**, **322**

Every effort has been made to trace the ownership of copyright material. Information that will enable the publisher to rectify any error or omission in subsequent reprints will be welcome. In such cases, please contact the Permissions Section of John Wiley & Sons Australia, Ltd.

PREFACE

Live It Up 2, Fourth Edition is an exciting and valuable resource for teachers of senior Physical Education. The student textbook and support material have been written for the re-accredited Victorian Certificate of Education Physical Education Study Design (2018–2021). This edition contains resources suitable for the modern educational environment. The supporting eBook utilises the advantages of digital technologies to provide students and teachers with stimulating and engaging learning activities.

The author team of *Live It Up 2, Fourth Edition* is made up of highly experienced, practising teachers. The Australian Council for Health, Physical Education and Recreation (ACHPER) Victorian Branch acknowledges Michelle O'Keeffe, Sally Nelson, Kirsty Walsh, James Guthrie, Mark Quinlan, Vaughan Cleary and Sam Millar for their outstanding contribution to the development of this learning resource.

ACHPER Victoria is the professional association for educators working in physical education, health education, sport and recreation. It supports educators in these areas in terms of professional learning, resources and other services, aiming to promote healthy lifestyles.

Trevor Robertson
President
ACHPER, Victorian Branch

Unit 3

Movement skills and energy for physical activity

OUTCOME 1

Collect and analyse information from, and participate in, a variety of physical activities to develop and refine movement skills from a coaching perspective, through the application of biomechanical and skill acquisition principles

OUTCOME 2

Use data collected in practical activities to analyse how the major body and energy systems work together to enable movements to occur, and explain the factors causing fatigue and suitable recovery strategies

INQUIRY QUESTION
How can movement skills be analysed?

CHAPTER 1

Movement skills

Movement skills can be classified in many different ways and are influenced by individual, task and environmental factors. Understanding different types of skills and skill development helps to analyse and improve your own skill level, and that of others.

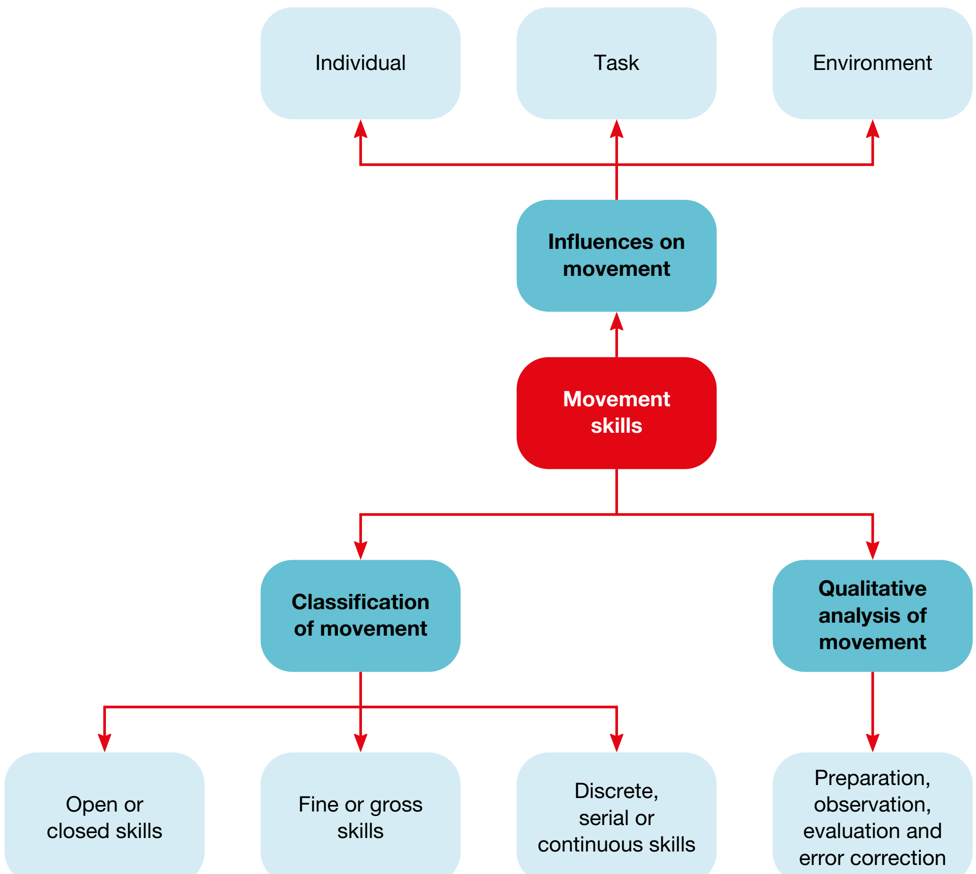
KEY KNOWLEDGE

- Classification of movement skills including fundamental movement skills, sport-specific skills, open and closed skills, gross and fine skills, and discrete, serial and continuous motor skills
- Influences on movement including individual, task and environmental constraints on motor skill development
- The link between motor skill development and participation and performance
- Qualitative movement analysis principles (preparation, observation, evaluation and error correction)

KEY SKILLS

- Analyse and classify movement skills
- Analyse individual, task and environmental factors influencing movement skill development
- Analyse the link between motor skill development and participation and performance
- Perform a qualitative analysis of a movement skill using video and systematic observation to analyse and improve a variety of movement skills

CHAPTER PREVIEW



1.1 Classification of movement skills

KEY CONCEPT Some movements are performed in an environment where there are very few factors that affect the outcome of the movement. Other movements are more complex. The complexity of a movement skill is determined by the level of coordination required and the external factors that influence the movement. Researchers of skill acquisition use these factors to categorise types of movement skills.

Types of movement skills

Skill is required for all movement. The nature of the skill varies depending on the type of movement, the required outcome and the environment in which the movement is performed.

Not all movements are the same. Some movement skills require a small number of muscles and others require the coordination of full body movements. For example, darts requires few muscle groups compared to a forward roll in gymnastics, which requires many muscle groups. The external environment affects some skills while others are performed in an closed environment where the performer has full control of the outcome.

Movement skills can be classified as open, closed, gross, fine, discrete, serial or continuous. The classification of a skill is based on:

- the way that the movement is organised
- the importance of the motor and cognitive elements
- the level of environmental predictability.

studyon

Unit 3	Fundamental and sport-specific movement skills
AOS 1	
Topic 1	
Concept 1	

FIGURE 1.1 Elite archers can practise their delivery action in a reasonably controlled environment.

Fundamental movement skills (FMS) are movement patterns that involve different body parts. They are the foundational movements to more specialised sports-specific skills.

Fundamental movement skills and sport-specific skills

Fundamental movement skills (FMS) are the skills that are the basis of all movements in sport. They are basic movement patterns that are learned and form the foundation for further sport-specific skills. There is no single list of skills that are universally understood to be fundamental movement skills. Skills that are identified as fundamental movement skills can vary, depending on the institution/researcher that is identifying the skills or the context in which the skills are performed. For example, fundamental movement skills identified in the Canadian education system include some skills that are performed on ice and in snow. Fundamental movement skills in Australia do not typically include these skills. The figure below shows the list of skills that the Australian Sports Commission identifies as being fundamental movement skills.

FIGURE 1.2 The fundamental movement skills according to the Australian Sports Commission

Sport-specific skills utilise a range of fundamental movement skills in a sequence.

These skills are often the priority of primary school physical education programs and coaching of primary school-aged children. Fundamental movement skills are sometimes categorised for the purposes of teaching, research or professional discussion.

Sport-specific skills often utilise a range of fundamental movement skills in a sequence of movement; for example, a kick in AFL football requires running, balance, control of the ball in the hand and coordination of the leg muscles to perform the kicking action. For this reason, successful skill execution in sports requires well-developed fundamental movement skills and a knowledge of the specific requirements and techniques associated with the particular sporting skill.

Fundamental movement skills form the basis of sport-specific skills. Can you think of a sport-specific skill and identify the fundamental movement skills that are used for it?

Figure 1.3 is an example. The sport-specific skill of rebounding in basketball requires the fundamental movement skills of running, jumping, catching, dodging other players, dynamic balance, stopping, landing and twisting.

FIGURE 1.3 The sport-specific skill of rebounding in basketball uses a range of fundamental movement skills.

Physical literacy is a term that is used in the field of motor learning and performance.

Physical literacy is the ability of an individual to move competently and confidently in all types of environments — it is the literacy of movement. The key components of physical literacy — the letters and words, if you will — are the fundamental movement skills. When children are in primary school, they learn the basics of reading and writing so that they can go on to read books and write essays. In relation to movement skills, children who are of primary school age learn the fundamental movement skills so that they can then go on to learn sport-specific skills which enable them to participate in and enjoy physical activity and sports.

'Individuals who are physically literate move with competence and confidence in a wide variety of physical activities in multiple environments that benefit the healthy development of the whole person.

- Physically literate individuals consistently develop the motivation and ability to understand, communicate, apply and analyse different forms of movement.
- They are able to demonstrate a variety of movements confidently, competently, creatively and strategically across a wide range of health-related physical activities.
- These skills enable individuals to make healthy, active choices that are both beneficial to and respectful of their whole self, others and their environment.'

Source: PHE Canada, www.phecanada.ca, 2016

Closed and open skills

Closed motor skills are motor skills that are performed in a predictable, self-paced environment.

Open motor skills are motor skills that are performed in an environment that is constantly changing and is externally paced.

Closed motor skills are performed in a predictable, self-paced environment where there are no interruptions or changes in the surroundings; for example, in indoor archery. The skill being performed is often a static one where there is little movement observed, such as a stationary softball on a T-stand in T-ball, and is internally paced. The athlete often tries to replicate the exact movement each time in a closed skill; for example, a gymnast tries to perform the exact same vault with perfect form, or a golfer tries to replicate their best swing when teeing off.

Open motor skills are performed in a constantly changing and externally paced environment; for example, the changing proximity of an opponent, the changing speed and height of a wave in surfing or the varying speed of a ball in hockey. These changes force the performer to adapt his or her basic motor skills (figure 1.4).

FIGURE 1.4 A spectacular manoeuvre gives Taj Burrow a win at the Billabong Pipe Masters in Hawaii — a reward for adapting his surfing skills to the variable wave conditions.

Closed/open skill continuum

Not all sports skills, whether classified as closed or open, are identical in their ease or difficulty of execution. Some skills can be classed as more closed than others. For example, ten-pin bowling is more closed than outdoor archery as it does not have external wind conditions to contend with. Equally, netball seems much more on the open scale than windsurfing. The netballer must contend with the unpredictability of both opponents and team mates, whereas the windsurfer has no one else to consider, but must respond to the different wind conditions.

It is clear that most sports and skills lie somewhere along a continuum, with classically closed and open skills being at each end of the continuum (figure 1.5). Indeed, the same skill can vary in its position along the continuum depending on circumstances. For example, practising batting using a T-stand is a more closed skill than facing a pitched ball from a ball machine which, in turn, is more closed than facing a pitcher on the mound.

Closed skills are simpler to learn as they are practised under predictable conditions and lack the external pacing of open skills. This means that the learner can concentrate on the skill components or subroutines themselves, without having to worry about where their team mates or opponents are. In addition to this, the learner can perform the skill in their own time, learning the correct sequence and timing of the motor program. Open skills should be 'closed down' as much as possible for beginners so that they have more control over the skill they are practising.

study on

Unit 3
AOS 1
Topic 1
Concept 2

Closed and open skills

eBook plus

Interactivity
Open and closed skills
Searchlight ID: int-1836

FIGURE 1.5 The closed/open skill continuum

As skill development progresses, the learner should practise the skill in situations that more closely resemble the game situation. This is called 'opening up' the skill and is essential if the athlete is to correctly and effectively apply the skills in the real game. For example, the beginner tennis player should first drop the ball and hit it over the net. Once this skill is mastered then the coach could hit the ball to the learner while they practise their forehand. The next stage would be to hit forehands from a tennis ball machine. The final stage of learning would have the athlete hitting forehands randomly to a variety of positions from all corners of the court. In this way they are mimicking the demands of the real game.

FIGURE 1.6 Performers exhibiting open and closed skills

Fine and gross motor skills

Skills can also be classified according to the number of muscles or muscle groups involved in the activity. The two major classifications are fine and gross motor skills. **Fine motor skills** involve the cooperative use of small muscle groups and the senses of sight and touch (visual motor tracking). The performer must also balance the use of force and fine touch control. Examples include writing by hand and typing on a keyboard (predominantly fine touch control), or shooting in archery (predominantly force).

Gross motor skills involve a combination of large muscle actions that result in a coordinated movement. Examples include skipping, break dancing, throwing, hitting, kicking, catching and tumbling in gymnastics. Many sporting activities combine fine and gross motor skills, so fine motor skills may indirectly improve. Spin bowling, for example, requires both gross movements and the precise manipulation of the ball by the spinning fingers.

Fine motor skills are delicate, precise movements that engage the use of small muscle groups.

Gross motor skills are movements involving the use of large muscle groups that result in a coordinated action.

eBook*plus*

Interactivity
Gross and fine motor skills
Searchlight ID: int-1837

FIGURE 1.7 There is a clear difference between fine and gross motor skills.

Discrete, serial and continuous motor skills

Another method of classifying skills is to determine whether the phases of movements are discrete and/or serial, or continuous.

- **Discrete motor skills** involve movements of brief duration, and they are easily defined by a distinct beginning and end; for example, a throw, kick or catch.
- **Serial motor skills** are a series or group of discrete skills strung together to create a more complicated, skilled action. The duration of the activities is prolonged but each individual movement in the series has a definite beginning and end. Examples include performing a gymnastics routine or dodging your opponent, leading to the ball, jumping to catch the ball and throwing the ball to a team mate in netball.

eBook*plus*

Interactivity
Discrete motor skills
Searchlight ID: int-1838

Discrete motor skills involve movements of brief duration that are easily defined by a distinct beginning and end.

Serial motor skills are a series or group of discrete skills strung together to create a more complicated, skilled action.

FIGURE 1.8 Swimming is an example of a continuous skill.

studyon

Unit 3 | AOS 1 | Topic 1 | Concept 3

Fine and gross motor skills

studyon

Unit 3 | AOS 1 | Topic 1 | Concept 4

Discrete, continuous and serial motor skills

Continuous motor skills have no distinct beginning or end. These movements may continue for several minutes, often involving tracking movements. Examples include swimming, running and pedalling a bicycle.

Figure 1.9 summarises the classification of skills.

Continuous motor skills have no distinct beginning or end.

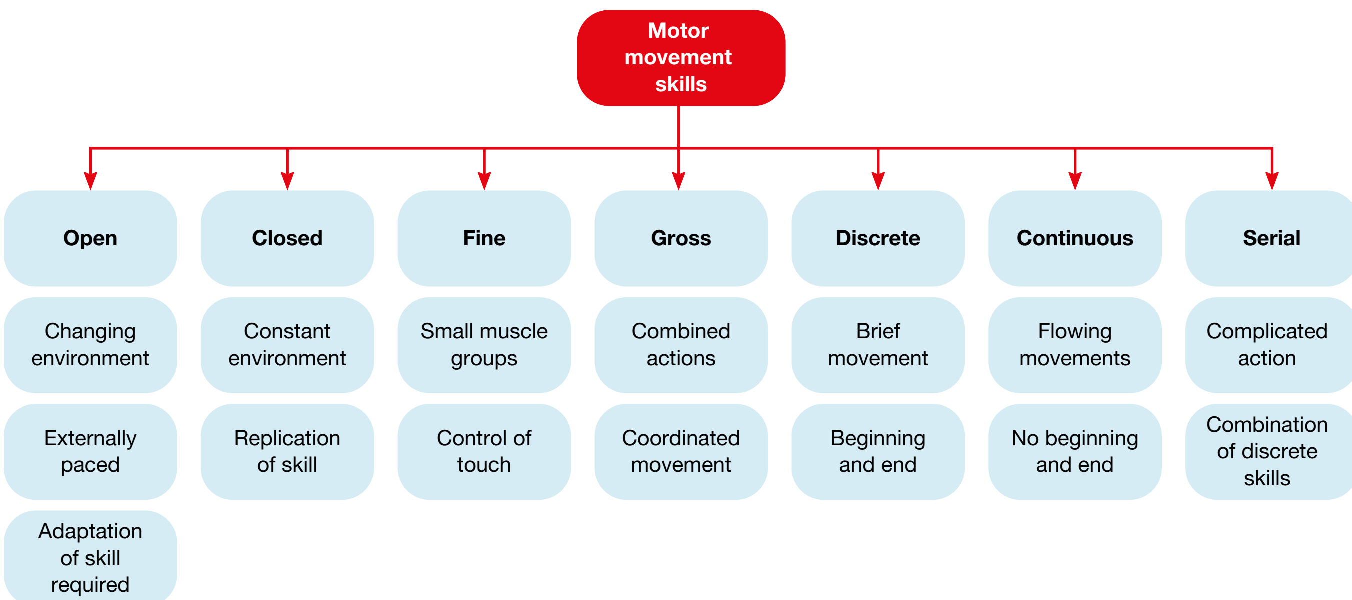


FIGURE 1.9 Summary of skill classifications

TEST your understanding

1 Provide examples of one fine and one gross motor skill and compare the characteristics of these skills.
2 What is the difference between a discrete and continuous motor skill?
3 Which type of skills would be easier to develop: discrete or serial? Explain your answer.
4 Identify the type of skill that you perform most regularly: discrete, serial or continuous.
5 Choose a team sport and identify eight skills that are required. Categorise each of those skills as discrete, serial or continuous.
6 Identify two sports for which gross motor skills are important for performance.
7 Choose two sports, and provide examples of how fine motor skills are important for performance in each.

APPLY your understanding

8 Create a table into which you can place the following sports or actions according to whether they are open, closed, fine, gross, discrete, serial or continuous skills. They may fit into more than one category.
   (a) Archery
   (b) Table tennis
   (c) Darts
   (d) Tennis doubles
   (e) Tennis singles
   (f) Squash
   (g) Springboard diving
   (h) Platform diving, inside
   (i) Platform diving, outside
   (j) Netball
   (k) Netball training
   (l) Track cycling
   (m) Tour de France
   (n) Gymnastics, uneven bars
   (o) Gymnastics, horizontal bar

9 **Learning activity: classification of skills, part A**
   Examine the photographs in figure 1.6.
   (a) Which images are examples of open skills? Which are closed skills?
   (b) For each activity, what characteristics of the movements involved justify your classification?
   (c) A continuum is a line with two open ends, like a number line. The two extreme descriptors indicate the most 'open' or the most 'closed' examples used, as shown in the figure below. Delivering a lawn bowl would be at the closed end of the continuum, for example, and making a save in water polo would be towards the open end of the continuum.

Closed ←——————————————→ Open

   Copy the continuum from the figure above and then make a list of open and closed skills along the line.

10 **Practical activity: classification of skills, part B**
   (a) Participate in a tabloid sport competition comprising eight different sports skills from different sports.
   For example, students participate in each of the following activities for 10 minutes.
   - Station 1: Earthball
   - Station 2: Tug of war and three-legged bands
   - Station 3: Parachute
   - Station 4: Communication games
   - Station 5: Modified sports
   - Station 6: Ropes, hoops and quoits

   Afterwards, brainstorm for a few minutes about the physical skills you used during the tabloid sports.
   (b) Draw up a table allocating a column to each of the skill classifications, then list the tabloid skills in the relevant columns. Do any skills fall into two categories? If yes, explain why this occurs.
   (c) Name some different activities you participate in during your recreation time. Classify your skill level in these activities as novice, beginner, competent performer or expert. Identify two or three skills that are important for each activity and classify each of these skills as open or closed.

EXAM practice

11 **ACHPER Trial Exam, 2015**
Outline the difference between open and closed skills, using shooting in basketball as an example of each. **2 marks**
12 Using the sport of hockey, outline how a particular skill would be taught in a closed environment before progressing to an open environment. **3 marks**
13 Using gymnastics as an example, explain the difference between a discrete and a serial skill. **4 marks**

1.2 Influences on movement

KEY CONCEPT Performance of movement is dynamic. It is often difficult to determine the factors that influence performance.

Physical Education teachers and experts in motor learning often refer to Newell's model of **movement constraints** (figure 1.11) to explain the individual differences in movement patterns and skill development and as a tool to assist players to improve performance. This model shows that there are three main factors that influence a movement: individual constraints, task constraints and environmental constraints.

Movement constraints are factors related to the individual, task and environment that influence movement.

Individual, task and environment

Individual constraints are those that are internal to the performer. These include body structure, fitness, psychological factors and genetics.

Individual constraints can be categorised as being structural or functional. Structural constraints relate to the body structure of the individual. Individual growth patterns, body size, flexibility, physiological capacity and body composition are examples of structural constraints. Functional constraints relate to behaviours. Skill learning, attention, anxiety and perceptual ability and information-processing skills are examples of functional constraints.

Task-related constraints include the rules of the game, equipment used and the speed and accuracy required.

Environmental constraints are those that are external to the individual such as the weather, sociocultural restraints and gravity.

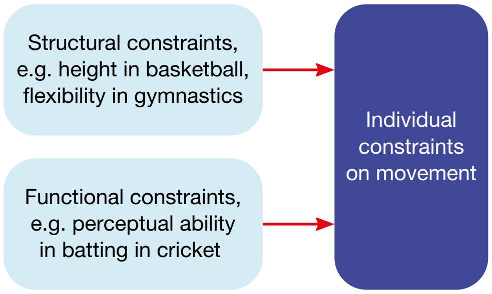


FIGURE 1.10 Individual constraints on movement

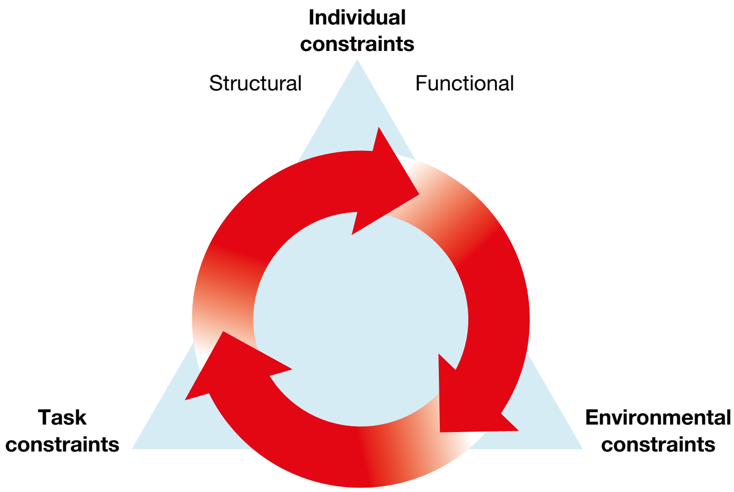


FIGURE 1.11 Newell's Model of Constraints

Applications of Newell's Model of Constraints

Coaches. A coach may have an athlete who has an unorthodox yet effective technique. A coach may come to the realisation that the body structure of this athlete is the reason for their style (individual constraint — structural). Instead of forcing the athlete to use a more traditional technique, they may work with the uniqueness of the individual and adapt their coaching to make further improvement.

FIGURE 1.12 An understanding of the constraints on movement can affect a coach's ability to teach skills and tactics.

Physical Education teachers. A Physical Education teacher who is teaching softball to a group of primary school students may change the environment by using a tee rather than having a pitcher. This change to the environment will help the students to experience success and improve their skill. A teacher may also change the task by reducing the boundaries of the field to provide students with the opportunity to develop the skills of completing offensive plays in a confined space (task constraint).

studyon

Unit 3
AOS 1
Topic 1
Concept 5

Influences on movement

FIGURE 1.13 Modifying the task can help children to improve skills.

Athletes. If athletes are able to understand the factors that affect performance, they are able to 1) make the correct decisions and 2) adapt their technique in various conditions. If an athlete is able to gather information about their environment, including weather conditions and proximity of a team member, then they are able to select the appropriate skill to use (environmental constraint). For example, when kicking a soccer ball in the wet, a player will need to change the way he or she kicks the ball because the ball will bounce differently when it lands.

FIGURE 1.14 Environmental constraints such as weather conditions can affect the skills that are performed by athletes in a range of sports.

TEST your understanding

1. Provide examples of one individual, one task and one environmental factor that influence movement skills.
2. For each of your examples in question 1, explain how they affect the outcome of the movement.
3. Using a softball hitter who is standing at the base facing a pitch as an example, explain how individual, task and environment interact to determine the outcome of the skill.
4. Use the information that you have learnt about factors that affect movement to describe how you would teach a basketball free throw to three year 9 students.

APPLY your understanding

5. **Practical activity: modified sport**
   Participate in a modified (small-sided) version of AFL, soccer or hockey. Identify the task constraints that have been modified and provide a justification for the use of constraints-based coaching for junior athletes.
6. **Practical activity: tennis**
   Participate in a doubles and a singles match of tennis. Following your participation, compare (similarities and differences) the constraints for the doubles and singles matches.

EXAM practice

7. The Kellysville Kolts Baseball Club has programs for people of various ages. Their Modball competition is for under-10 boys and girls. The game is played on a diamond with 60-foot base paths, with minor, age-appropriate variations to rules to provide a deeper learning opportunity. The game introduces the player to a pitched ball, developing their understanding of the strike zone, as well as introducing the position of catcher with proper protective equipment. A parent of the batting team pitches the ball to the batter, thus encouraging the player to hit, rather than a pitcher trying to strike the batter out.
   (a) Choose three of the modifications that have been made and identify whether they are related to task, individual or environmental constraints on movement. **3 marks**
   (b) Individual constraints can be assigned to two categories. Identify and explain these categories. **2 marks**
   (c) The Modball program has been designed to assist the under-10s to progress towards regular baseball. Explain two ways in which the introductions that have been made to the Modball program can help the players to overcome movement constraints in the game of baseball. **4 marks**

1.3 The link between motor skill development, participation and performance

KEY CONCEPT Motor skill development is related to participation in physical activity, sport and exercise.

An **enabler** is something or someone that has a positive effect on one's movement skills.

A **barrier** is something or someone that has a negative effect on one's movement skills.

Motor skills, participation and performance are interrelated. Central to this relationship is the fact that motor skills can be an **enabler** or a **barrier** to movement. For a person to participate in sports and some forms of physical activity, they need to have a basic level of skill. It is also true that people are more likely to enjoy these activities if they have the skills that are required for a level of success in the activity. The more they enjoy the activities, the more likely they are to participate and hence the more likely they are to further develop skills — and so it goes on. This relationship is discussed in section 1.3.

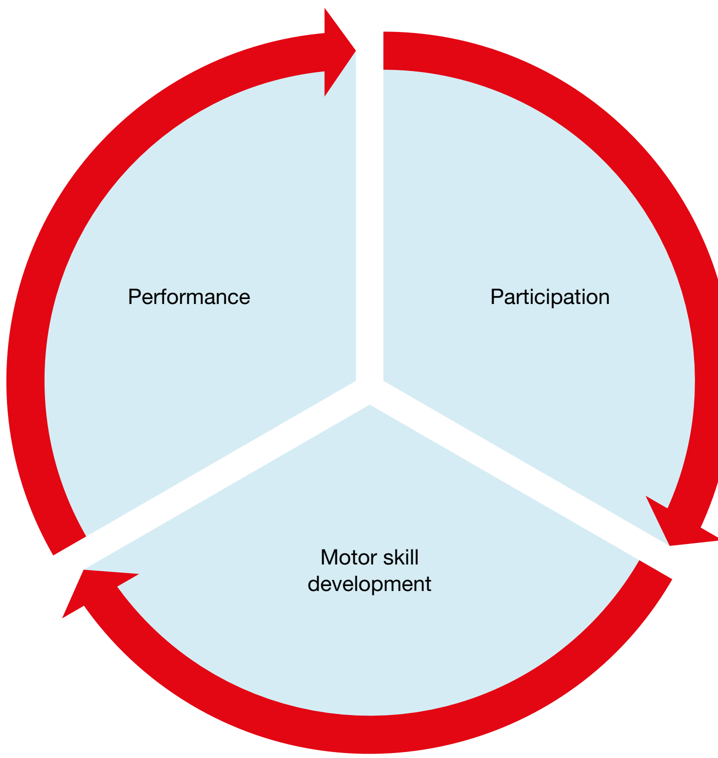


FIGURE 1.15 The development of motor skills will enable a person to participate, participation will lead to greater development of skills and, hence, better performance and maybe to increased participation.

A person who was not given the opportunity to develop their motor skills at a young age may not have the confidence to participate in sports and exercise. This may mean that they are less likely to develop the fitness and confidence required to participate in sports. Their lack of engagement in activity at a young age may have led them to develop habits associated with a sedentary lifestyle. In this regard, their lack of motor skills would have reduced their performance and been a barrier to participation in sport, exercise and physical activity.

The link between motor skills, performance and participation is an important consideration for Physical Education teachers. Some school programs focus on participation, others on developing an understanding of strategies and tactics,

eBook*plus*

Weblink
The relationship between movement skills, enjoyment and lifelong physical activity

and others prioritise the development of fundamental motor skills. Many schools try to achieve all of these objectives. The objective that most schools have in common is to provide students with the knowledge and experience necessary to maintain a healthy, active lifestyle.

Primary and secondary school students who develop their fundamental motor skills — for example, running, kicking and throwing — are most likely to increase their performance and participation in physical activity, sport and exercise. This fact has been supported by many recent studies that have shown participation in physical activity is most likely by students who have been taught by Physical Education teachers who are skilled at increasing the fundamental motor skills of students.

The quotes below are taken from Australian and international studies into the relationship between the development of motor skills in Physical Education classes and participation in physical activity.

- 'Fundamental motor skill proficiency has been associated with subsequent physical activity and also with change in physical activity over time, highlighting that children with high fundamental motor skill proficiency show little decline in physical activity. In addition, positive associations have been established between fundamental motor skill proficiency and objectively measured physical activity in overweight children' (Morgan, 2014).
- 'If these fundamental motor skills are not mastered first, then children will not be able to perform in major games or feel confident enough to participate in other forms of physical activity' (Bryant et al., 2013).
- 'We contend that the development of motor skill competence is a primary underlying mechanism that promotes engagement in physical activity' (Stodden, 2008).
- 'Youth with better motor abilities may find it easier to be physically active and may be more likely to engage in physical activity, compared with peers with poorer motor competence' (Brian H. Wrotniak, 2006).
- 'It is clear from this review and other research that movement skill development needs to remain a key focus of PE curriculum for children and adolescents to acquire the movement skills necessary to lead physically active lives' (Sallis and McKenzie, 1991; Pate et al., 1995).

FIGURE 1.16 The improvement of motor skills in Physical Education classes has an impact on performance and participation.

Familial advantage

Familial advantage is the term used to explain the influence that parents and/or siblings can have on movement skill development. Most people who follow sport would be aware of siblings or families who are elite sportsmen or -women. The research is inconclusive when it comes to quantifying the advantages of growing up as a son or daughter of an elite sportsperson or as a brother or sister of a talented athlete. It could, however, be proposed that having elite performers in the family who role model effective technique and competitiveness, convey a positive self-concept, provide support or set up deliberate play or age-appropriate modifications would enhance the development of movement skills.

eBook*plus*

Weblink
Family support for sporting success

1.3 The link between motor skill development, participation and performance

studyon

Unit 3	Link between motor skill development, participation and performance
AOS 1	
Topic 1	
Concept 6	

The excerpt below was taken from Adelaide newspaper *The Advertiser*. Gretel Tippett, who is an elite netball player, has two brothers who play AFL football. It provides an insight into familial advantage.

'IF Gretel Tippett seems exceptionally physical and aggressive playing in the Australian Youth Olympic Festival, she says to blame her footy star brothers, Sydney Swans forward Kurt and North Kangaroos player Joel. "They've been a major influence on me. I've been looking up to them all my life. I've been watching how aggressive they are, how much they want the ball and it has helped my game."'

TEST your understanding

1 In your own words, explain the relationship between movement skills, participation and performance.

2 Your school has asked you to complete a literature review for a paper on the relationship between movement skills and participation in physical activity. Use the statements made in section 1.3 to develop this review of the literature. As an extension task, you could do further research using the papers quoted in this section.

3 Outline the possible limitations of physical education programs that focus solely on participation.

APPLY your understanding

4 Research sporting families within Australia and internationally and investigate 'familial advantage', whereby parents and siblings influence skill development. Discuss the relationship between motor skills development, participation and performance among sporting and non-sporting families.

5 **Practical activity: training session**

Choose a sport and participate in a training session that is aimed at increasing the skills of the chosen sport. Participants then complete a survey and report the results to the class.

Assign class members to the following roles:

- ICT specialist — will investigate the type of survey that could be used and be responsible for managing the survey
- Survey developers — will develop the survey questions
- Coach — will run a training session
- Survey analyst — will analyse the results of the survey
- Reporter — will report the findings to the class.

The purpose of this task is to collect feedback about the influence that skill development has on participation. For this reason, the survey should contain questions related to each person's perceptions about their skill level, if the training session helped them to improve their skill and if they felt those improvements would make them more likely to participate in that sport in the future. Here's a tip… put some thought into the questions and develop a minimum of five.

After the activity, each class member could complete the following tasks:

(a) A summary of what the results showed about the relationship between skill development and participation. If the results did not show a clear relationship, you could comment on what you would expect to see if this training was to occur more regularly, drawing on your knowledge of the relationship between motor skills, participation and performance.

(b) The individual (structural and functional) constraints that determined the difference in skill between players.

1.4 Qualitative analysis of movement skills

KEY CONCEPT Analysis and feedback are important for the improvement of movement skills. Qualitative analysis provides coaches and sports scientists with a structured approach to the analysis and improvement of movement.

When a spectator says 'great catch' at a cricket match, they are using a simple and incomplete form of **qualitative analysis**. A more thorough qualitative analysis involves observing a movement and using a set of principles to provide feedback about the effectiveness of the movement. Many of the movements performed in sports are performed at a high speed. For this reason, video and other technology is used to collect the data.

Qualitative analysis is the systematic observation of the quality of human movement for the purpose of providing the most appropriate intervention to improve performance.

FIGURE 1.17 Qualitative analysis provides coaches with a framework to observe performance and provide feedback to an athlete.

Feedback about skills is an important aspect of skill development, and injury prevention and rehabilitation. It is important that coaches have the knowledge, skills and equipment necessary to assess a performer's technique so that they can make recommendations for improvement. Qualitative analysis is a method of movement analysis. Qualitative analysis involves a series of tasks that are widely recognised and used within the sports science community. These tasks provide sports scientists, coaches and medical staff with a template to analyse movement.

Coaches need an understanding of what the skill should look like. They must observe the athlete performing the skill and then use their knowledge of the skill to make recommendations to the athlete about possible improvements.

FIGURE 1.18 Coaches can make observations in real time but often require specialised equipment to film the athlete and then analyse the results for qualitative analysis.

studyon

Unit 3 | AOS 1 | Topic 1 | Concept 7

Qualitative analysis of movement skills

The four tasks of qualitative analysis

Several models of qualitative analysis exist within the sport science community. In this text, we use the four task model. This model provides a simple four task structure: preparation, observation, evaluation and error correction. This model of qualitative analysis can be used to improve athletic performance or in injury rehabilitation.

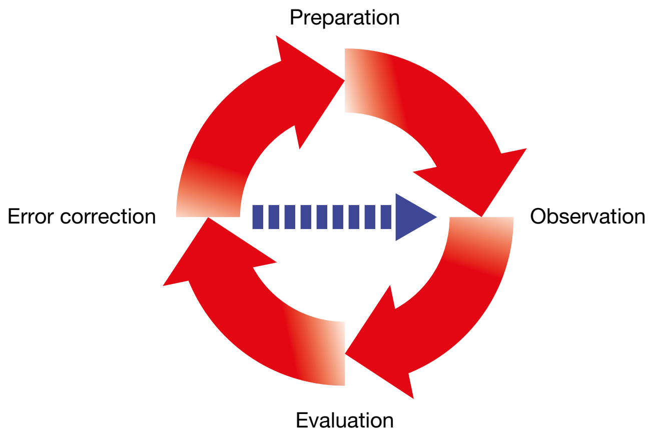


FIGURE 1.19 The four task model of qualitative analysis

Preparation

The first task in performing a qualitative analysis is to gather the relevant knowledge. During this phase, the analyst who is conducting the analysis should gather information about:

1 the critical features of the skill (parts of a movement that are important for success)
2 information about the performer/s
3 details about the observation stage
4 what constitutes effective instruction.

1 Information about the *critical features of the skill* can be gathered from experience, expert opinion or scientific research. The range of correctness of these features should also be considered — this is to cater for inherent variations in performers. At this time, a model of performance such as that shown in figure 1.20 may be established.

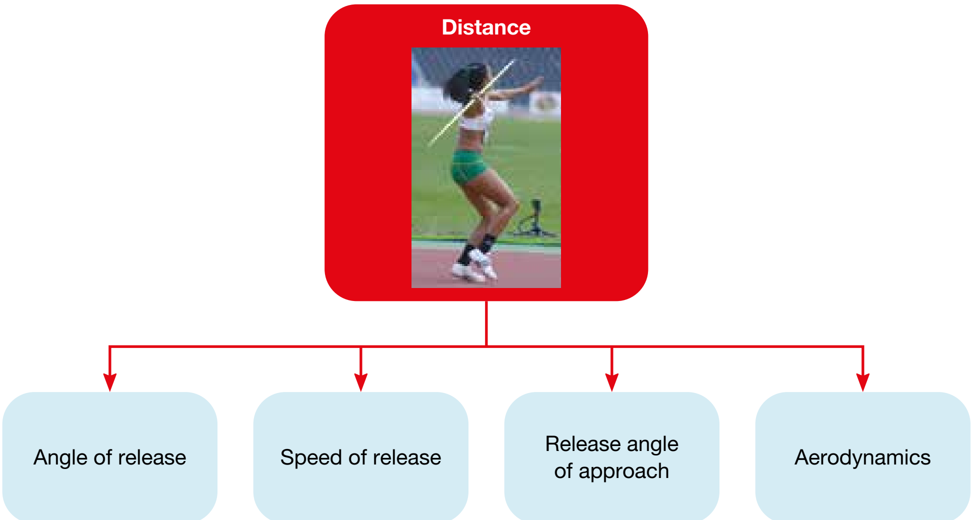


FIGURE 1.20 Model of performance of a javelin throw. This version has been simplified for the purpose of this text. The critical features for javelin are angle of release, speed of release, release angle of approach and aerodynamics. There are many factors that in turn affect each of the four critical features. A more detailed model would include these factors as well.

2 A coach will be most effective in analysing a skill if they have an understanding of the *physiological and psychological variables that influence movement skill performance*. Factors such as age, gender, strengths and weaknesses, skill level and body dimensions can affect the performance expectations, as well as the type of analysis and feedback given to the performer.

3 *Details of the observation strategy* will be outlined during the preparation stage. Those conducting the analysis will decide whether an individual player or a whole play will be recorded. They will also consider the vantage point from which the observation will occur, whether the data will be collected in the field or the laboratory and the number of observations made.

The analyst will document whether cameras will be used to make the observation. If so:

- how many cameras will be used
- which position will they be set up in
- will they film the whole field or just the player?

4 The *type of instruction and feedback* provided to the performer will vary dependent on their cognitive ability, knowledge of the sport, experience and motivation. In addition to this, there are different ways of presenting the information. During the preparation, consideration must be given to the best way to communicate. The analyst should consider how they will show results, how much information will be shared and the specific tools that they will use to help the performer improve their skill.

Observation

During this task, the skill is recorded/measured. This can occur by watching the performer or digitally recording them performing the movement. The details of the observation will have been planned during the preparation. The purpose of this task is to gather and organise the information. The observation task involves the actual recording/measurement of the skill.

Evaluation

The critical features that were established during preparation and the observations made during observation are used to identify errors and positive aspects of the performer's technique. This is achieved by using the sequential method or the mechanical method.

The sequential method involves comparing mental pictures of body positions throughout each phase of the movement. This is a common strategy for coaches, as it allows them to picture desirable body positions during the phases of a skill. The mechanical method involves the application of various mechanical principles, such as sequential rotation of body segments, optimal body positions for force development and joint range of motion.

Evaluation should be based on a small number of critical features (usually between four and eight). The performance of each critical feature can then be ranked as inadequate, within the desirable range or excessive. Critical features that are within the desired range are regarded as strengths and those outside the range are regarded as weaknesses.

Error correction

Now that the strengths and weaknesses of the performer's technique have been established, the analyst can use this information to improve the player's performance. They can provide verbal feedback and/or any of the following: physical conditioning, modified practice or provide the performer with a visual model, manual or mechanical guidance. Whichever method is chosen, error correction is an important part of the qualitative analysis and needs to be carefully planned, accurate, practical and relevant to the age and skill of the performer.

Feedback — providing verbal feedback is a common method of error correction. It can be given as corrective instruction with the aim of providing the performer with knowledge of performance and advice about how to improve their technique.

FIGURE 1.21 Verbal feedback is a common method of error correction.

FIGURE 1.22 A basketball player can modify practice by concentrating on a particular part of the shooting technique.

For optimal results, feedback should be concise, specific, immediate and it should be given often. It is also important that a positive approach is maintained.

Modify practice — during practice, the task can be broken into parts, made easier or there can be less focus on the outcome and more on the technique. Practice can be undertaken in a closed environment to focus on skill development.

Exaggeration or overcompensation — small modifications to a technique are difficult. For this reason, some coaches ask the performer to exaggerate the aspect of the skill that they need to learn. For example, a basketball player who needs to get more height when they shoot may be encouraged initially to shoot with a high arc.

Visual model — the instructor could demonstrate the correct execution or could show footage of correct technique. Video replay can also be considered as a video model.

Manual guidance — the coach can physically move the body parts of the performer so that they can work kinaesthetically to experience the correct action.

Mechanical guidance — a mechanical aide such as a brace could be used to help the performer maintain correct body position.

FIGURE 1.23 A tennis coach can help a player to get the feeling of a correct grip by providing manual guidance.

Qualitative analysis of movement skills in action — tennis serve

Biomechanical Analysis of Stroke Production

Introduction

- How do I modify stroke production to improve performance? That is, how does the player:
  a. hit the ball more powerfully with control;
  b. manoeuvre the ball to different parts of the court in order to create a better tactical game situation.
- How do I reduce the potential for injury in the following situations?
  a. During player development as the body matures
  b. For the tournament player, who is required to repeatedly perform — how do I reduce the incidence and severity of overuse injuries?

To achieve these results requires an effective analysis structure. A systematic approach to analysis generally requires five stages (figure 1.24) to permit the coach to 'see and then evaluate' what is happening during stroke production. Such an approach enables the coach to confidently analyse movements at all levels of development.

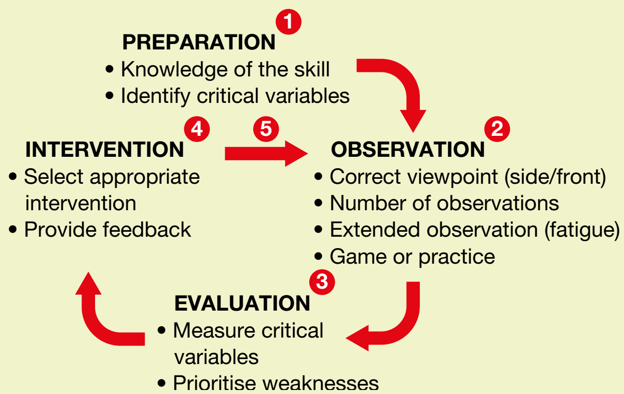


FIGURE 1.24 5-stage analysis process — a key to effective analysis (modified from Knudson & Morrison, 2002)

The Preparation Phase of the analysis process involves identifying the critical mechanical variables that underpin stroke development. Armed with the knowledge of these critical variables or key ingredients prepares you to observe and evaluate the performance of any stroke. Some of these critical variables include:

- level of rotation of the hip and shoulder alignments in ground strokes (separation angles)
- racket trajectory pre- and post-impact in creating 'heaviness' in stroke production
- level of knee flexion prior to the drive phase of the serve
- positioning of the 'line of drive' from the feet through the lower limbs to the trunk in the serve
- the alignment of the racket and hand in a volley.

All of these must be formatted in your mind prior to commencing the actual analysis and will likely change with player age (or even gender).

Remember:

- These critical features of stroke production will vary depending on the stage of player development. For example, in the serve, rhythm may be the most important aspect of early learning, whereas internal rotation at the shoulder may be an area needing development as players mature (i.e. for a 16-year-old).
- The need for variability in stroke production will dictate that selected mechanical factors be emphasised at various stages of development (Elliott, Reid & Crespo, 2009). For example in 'building' a forehand, it is important that this be achieved by hitting balls of various heights, spin types and court locations.

In the world of biomechanics a coach may approach the analysis of stroke production in a number of ways:

- Qualitative analysis: use of the eyes attached to a thinking mind (here, video may be used in the observation phase to provide more detailed and repeated viewings of performance). This is the type of analysis used by coaches on an everyday basis.
- 2D quantitative analysis: use of a video linked with appropriate software (e.g. Dartfish or Siliconcoach) to measure features of performance that are clearly 2D — that is, the movement is in one plane or by definition is planar. Obviously the software packages mentioned above may also be used to assist in qualitative analysis. For example you may draw a line on a sequence of frames (the head in a forehand drive) to qualitatively appraise some aspect of balance. Make sure that you place your camera perpendicular to the line of motion if you intend to measure any 2D angles or distances from the video.
- 3D quantitative analysis: this level of analysis would only be used with national level programs, where a player has problems with injury or power generation. Coaches can use data from 3D analyses of players to improve their ability to qualitatively analyse performance.

How then can a coach use biomechanics and the methods of analysis most readily available to them (Qualitative and 2D Quantitative) to shape their approach to technique development? Let me use a series of images from Andy Roddick's serve to explain. As a coach you may do some or all of the following. The points listed are examples of what may be performed and a comprehensive list can be found in Elliott, Reid & Crespo (2003, 2009).

With a sound understanding of the biomechanics of stroke production (preparation), the coach can analyse movement effectively (observe and evaluate) and then start the very difficult task of modifying motion (intervention) — by far the hardest part of the analysis structure. Remember, the learning pathway requires you to look for different mechanical aspects of stroke production at the various stages of development.

References

Elliott, B., Reid, B. & Crespo, M. (Eds) (2003). *Biomechanics of Advanced Tennis*. Valencia, Spain: ITF Publications.
Elliott, B., Reid, B. & Crespo, M. (2009). *Technique Development in Tennis Stroke Production*. Valencia, Spain: ITF Publications.
Knudson, D. & Morrison, C. (2002). *Qualitative Analysis of Human Movement*. (2nd Ed.) Champaign, IL: Human Kinetics.

Bruce Elliott (Winthrop Professor of Biomechanics, The University of Western Australia)

ITF Coaching and Sport Science Review 2010; 50 (18): 5–6

Roddick sequence Mechanical feature of interest	Qualitative analysis	2D quantitative analysis
	• Balance • Position of the racket and ball to body • Position of the feet relative to each other • Position of the hips and shoulders • Alignment of the trunk	• The distance between the feet • Alignment of the trunk (hips and shoulders)
	• Angle of the front arm (a characteristic of the Roddick serve, where he positions the ball closer to the body — permits good back-hip drive) • Knee flexion and position of both knees (drive-line to the ball) • Hip and shoulder alignment rotations (both horizontal and vertical) • Position of the back to the front foot	• The inclination angles of the shoulder and hip alignments • Rotation of hip and shoulder alignments • The height of the ball toss compared with player standing height • The level of knee flexion
	• Position of the racket relative to back (away from the back and with respect to the hips) • Level of external rotation at the shoulder • Leg and particularly back-hip drive • Position of the head and front arm	• The position of the racket to the back • The velocity of the back-hip during the upward drive • Alignment of the forearm to the court (indicator of maximal external rotation at the shoulder)
	• Position of the head • The rotation of the trunk from A to D (check movement of the trunk about the 3 axes of rotation, particularly shoulder-over-shoulder) • Presence of internal rotation	• Flexion angle of the trunk • Hip alignment • Position of the back compared with front hip joint
	• Body positions at impact (vertical, forward-back and laterally with respect to body) • Alignment of racket and forearm • Shoulder abduction angle • Trunk flexion • Position of head and non-racket arm	• Impact position (vertical, forward-back and laterally with respect to body) • Alignment of the racket and the forearm • Shoulder abduction angle
	• Follow through of racket (include forearm pronation and shoulder internal rotation) • Landing position and preparedness for next stroke • Arabesque of back leg (following landing — not in image shown here) • Balance	• Landing position in the court — both forward and lateral • Flexion angle of the trunk

TEST your understanding

1 Describe the key features of the preparation stage of qualitative analysis.
2 You will notice that figure 1.19 on page 18 has a dotted line between 'error correction' and 'observation'. Explain why this dotted line may be included in the model.
3 List the methods of error correction.
4 Identify four critical features of a golf swing.

APPLY your understanding

5 Choose a closed skill to analyse. You will then film the skill and complete a qualitative analysis. You should compile this as a report that uses the following headings: preparation, observation, evaluation and error correction.
   - You should write a preparation document, conduct an observation and evaluation and then document some feedback for the performer in the evaluation section.
   - Please note: you may not have the specialised equipment necessary for an accurate analysis; however, follow the steps and do your best with the resources that you have available.
   - Use the content of section 1.4 as a guide for what is required for each part of your analysis.
   - Once you have completed your report, it may be helpful to compare it to those of your classmates so that you can help each other correct errors in your knowledge and extend your understanding of qualitative analysis of movement.

EXAM practice

6 Define the term *qualitative analysis*. **1 mark**
7 List in order the four tasks of a qualitative analysis. **4 marks**

KEY SKILLS

- Analyse and classify movement skills
- Analyse individual, task and environmental factors influencing movement skill development
- Analyse the link between motor skill development and participation and performance
- Perform a qualitative analysis of a movement skill using video and systematic observation to analyse and improve a variety of movement skills

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- To perform a qualitative analysis of a movement skill, it is important to have an understanding of the four tasks. You would also have to identify the critical features of the skill.
- In order to classify movement skills, you would need to consider the factors in the environment that may affect the movement; for example, you could consider if there other players on the field, is there a crowd, would the physical environment affect the skill? The number and size of muscle groups required should also be considered.
- Identify the factors that influence a particular skill and classify them as individual, task or environment
- Consider how a coach, teacher or athlete may use their knowledge of the factors that affect a skill to modify training or improve performance
- Explain how each factor may influence performance
- Understand and explain the interrelationship between motor skills development, participation and performance
- Use practical examples to demonstrate the relationship

PRACTICE QUESTION

The winner of the long jump at the 2016 Australian Track and Field Championships was Fabrice Lapierre from NSW. His winning jump was 8.27 metres. In second place was Henry Frayne from Queensland; his best jump was 8.16 metres. Henry's current personal best is 8.23 metres — he achieved this in 2012.

Henry has qualified for the Olympics and is currently working with his coach to improve his jump. Henry's coach will make some changes to the training program and knows that these changes need to be based on a systematic observation of Henry's technique.

a. **Identify** a type of analysis that Henry's coach could perform and **outline** the tasks that he would undertake during this analysis. *(5 marks)*

b. **Identify** two critical features of a long jump. *(2 marks)*

c. Select one critical feature identified in part b and **outline** a possible error correction method that could be used to improve Henry's performance. *(2 marks)*

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

SAMPLE RESPONSE

a. Henry's coach would perform a qualitative analysis. Qualitative analysis involves four tasks: preparation, observation, evaluation and error correction.

Preparation — during this phase, the coach will research the critical features of the movement and have an understanding of times or other measures that Henry needs to achieve for each of these aspects of the skill. The coach may adapt these performance expectations to what he knows about Henry. He will also outline how the analysis will take place and the type of feedback that will be given.

Observation — this phase involves the actual recording of Henry's technique in accordance with what was outlined in the preparation stage. It would most likely involve using high speed video.

Evaluation — once the footage has been recorded, it will be evaluated. The data collected during the evaluation will be compared to the performance expectations outlined in the preparation phase. Each critical feature will be analysed. This will provide information about aspects of the performance that are adequate or those that could be improved.

Error correction — once the critical features that could be improved have been identified, the coach will provide Henry with feedback and make changes to his training regime. For example, he may modify practice.

b. Take-off speed and height of jump

c. Physical conditioning — Henry could train to increase his running speed, which would help him to increase his velocity at take-off.

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Outline — general description but not in detail
  Identify — determine the key characteristics or features
- **Key terminology** — systematic observation, critical features, preparation, observation, evaluation, error correction, qualitative analysis
- **Key concepts** — Qualitative analysis involves four tasks, critical features, actual recording, Each critical feature will be analysed, feedback, physical conditioning
- **Marking scheme** — 9 marks — always check marking scheme for the depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

a. **1 mark:** identifying that the type of analysis is qualitative analysis
4 marks: correctly identifying each task and providing the key components of each

b. **2 marks:** one mark for each component correctly identified

c. **1 mark:** choose from one of the methods listed in text
1 mark: provide practical example of what could be done to improve performance

CHAPTER SUMMARY

Classification of movement skills

- A motor skill is any activity involved in moving the body (or some parts of the body) to achieve a specific goal.
- Movement skills can be classified as:
  - closed skills performed in a predictable environment (e.g. gymnastics moves)
  - open skills performed in an environment that is constantly changing (e.g. a sport in which the speed of a ball varies)
  - fine skills that involve the cooperative use of small muscle groups and the senses of sight and touch (e.g. writing by hand)
  - gross skills that involve a combination of muscle actions which result in a coordinated movement (e.g. skipping and throwing).
- Generally, skills can be classified as:
  - discrete movements with a short duration and a distinct beginning and end
  - continuous — cyclic movement with no distinct beginning or end that may flow on for several minutes (e.g. swimming or running)
  - serial — a series or group of discrete skills joined together to create a more complicated action (e.g. a gymnastics routine) or in other words, fundamental movement skills combining to form a sports-specific skill.

Influences on movement

- The influences on movement can be classified as related to individual constraints, task constraints or environmental constraints.
  - Individual — internal factors such as body structure and fitness
  - Task — factors that are related to the nature of the task; for example, rules of a game and the equipment
  - Environmental — factors related to the external environment such as the ground surface and weather

The link between motor skill development, participation and performance

- Motor skill development is related to participation and performance.
- Factors such as familial advantage can influence participation and skill development, which can improve performance.
- Motor skill development is an important factor in determining lifelong participation in physical activity.

Qualitative analysis

- Qualitative analysis involves observing a movement and using a set of principles to provide feedback about the effectiveness of the movement.
- There are four tasks involved in a qualitative analysis. They are preparation, observation, evaluation and error correction.
- During the preparation phase, the investigator identifies critical features, compiles information about the performer and outlines the tasks that they will undertake during the observation, and prepares a plan to provide feedback to the athlete.
- During the observation phase, the data are collected.
- The purpose of the evaluation is to analyse the data that have been collected.
- These data are then used to provide feedback to the athlete and develop a strategy to correct errors in their technique. This fourth phase is called error correction.

EXAM PREPARATION

eBook*plus*

Interactivity
Movement skills quiz
Searchlight ID: int-6778

MULTIPLE CHOICE QUESTIONS

1 Select the correct definition of a motor skill.
(A) An activity involved in moving the body (or some parts of the body) to achieve a specific goal
(B) Skills that are the basis of all movements in sport. They are basic movement patterns that are learned and form the basis of further sport specific skills.
(C) A skill that is innate and largely determined by genetics
(D) Skills that utilise a range of fundamental movement skills in a sequence of movement

2 Which of the following is an example of an individual (functional) constraint?
(A) The inability of a child to use a full-size tennis racquet
(B) The placement of fielders too close to the batter in cricket
(C) The no-tackling rule in junior rugby
(D) An older adult who has a slower reaction time when taking off for a sprint

3 Identify the list of skills that contains the most fundamental movement skills.
(A) Tennis serve, spike in volleyball, running, kicking
(B) Tennis serve, jumping, spike in volleyball, running, rebounding
(C) Tennis serve, kicking, walking, spike in volleyball, running
(D) Tennis serve, kicking a soccer ball, walking, spike in volleyball, running, marking a football

4 The following list shows a mixture of open and closed skills in a game of soccer. Which list below best reflects the correct order from closed to open?
(A) Penalty kick, dribbling the down the wing, kick off, passing the ball to a team mate
(B) Kick off, penalty kick, dribbling the ball down the wing, passing the ball to a team mate
(C) Penalty kick, kick off, dribbling the ball down the wing, passing the ball to a team mate
(D) Kick off, penalty kick, passing the ball to a team mate, dribbling the ball down the wing

5 The following statement applies to which of the qualitative analysis tasks?
The performance of each critical feature can then be ranked as inadequate, within the desirable range or excessive. Critical features that are within the desired range are regarded as strengths and those outside the range are regarded as weaknesses.
(A) Preparation
(B) Observation
(C) Evaluation
(D) Error correction

6 A cricket coach who chooses to use a tennis ball rather than a cricket ball for primary school children is demonstrating an awareness of which type of constraint on movement?
(A) Environment
(B) Task
(C) Individual (structural)
(D) Individual (functional)

7 During practice, tasks can be broken into parts or made easier, or there can be less focus on the outcome and more on the technique. Practice can be undertaken in a closed environment to focus on skill development.
This statement relates to
(A) feedback.
(B) manual guidance.
(C) modified practice.
(D) the visual model.

8 An elite cricket player has to modify his technique to prepare for the Twenty20 games. His aim is to be able to hit more balls over the fielders' heads.
The most appropriate method of error correction would be
(A) manual guidance and feedback.
(B) mechanical guidance, visual model and feedback.
(C) feedback and over compensation/exaggeration.
(D) feedback, visual model and modified practice.

9 The most likely list of critical features for a high jump would be
(A) vertical angle at take-off, height of jump, angle of approach.
(B) vertical angle at take-off, height of jump, velocity at take-off.
(C) vertical angle at take-off, angle of approach and velocity at take-off.
(D) vertical angle at take-off, height of jump and angle of approach.

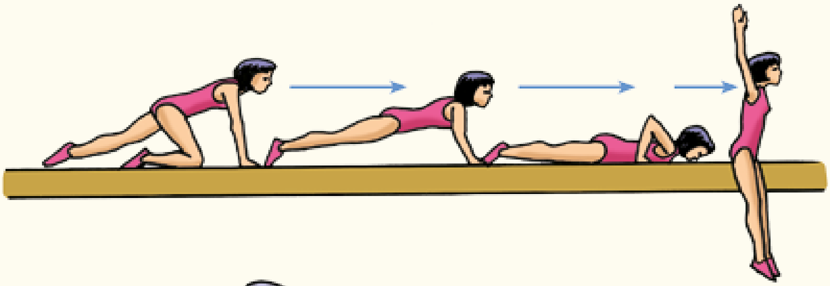
10 A psychologist who is working with an AFL player to improve his goal kicking in important moments in games in front of large crowds is attempting to overcome which kind of constraint?
(A) Individual (functional)
(B) Individual (structural)
(C) Environment
(D) Task

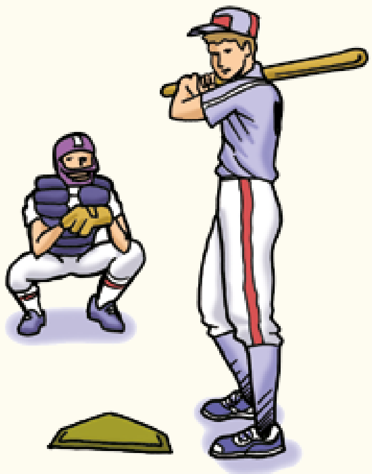
studyon

Sit VCAA exam

TRIAL EXAM QUESTIONS

Question 1





For each of the four images above, identify whether they are a more open or closed skill. Outline the reason for each of your selections. **8 marks**

a. ____

____

b. ____

____

c. ____

____

d. ____

____

INQUIRY QUESTION

How can an understanding of biomechanics help improve sports performance?

CHAPTER

2 Biomechanical principles

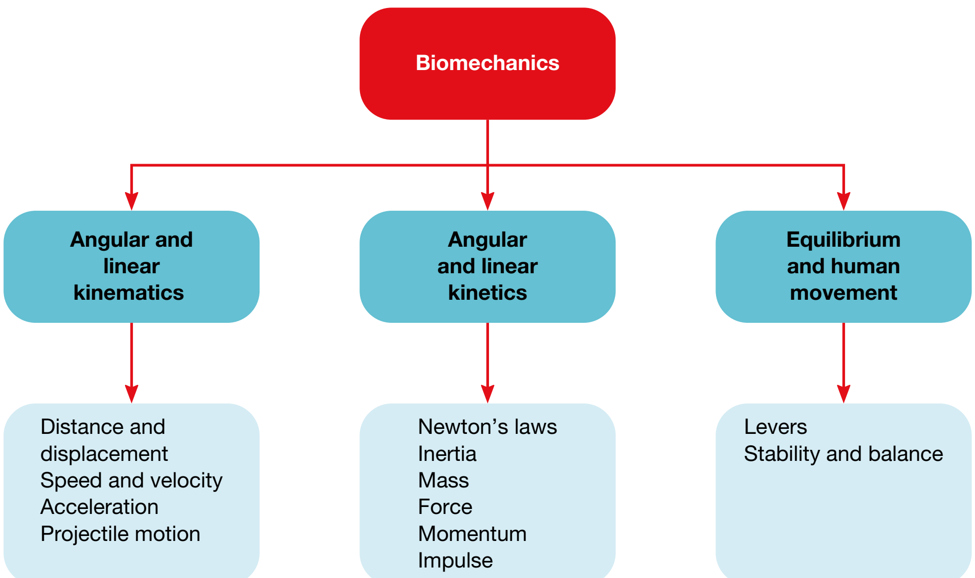
Biomechanics is the field of sports science that applies the laws of mechanics and physics to human performance in order to gain a greater understanding of performance in physical activity. It is the study of forces and the effect of those forces on and within the human body.

KEY KNOWLEDGE

- Biomechanical principles for analysis of human movement including:
  - angular and linear kinetic concepts of human movement: Newton's three laws of motion, inertia, mass, force, momentum and impulse
  - angular and linear kinematic concepts of human movement: distance, displacement, speed, velocity, acceleration and projectile motion (height, angle and speed of release)
  - equilibrium and human movement: levers (force, axis, resistance and the mechanical advantage of anatomical levers), stability and balance (centre of gravity, base of support and line of gravity)

KEY SKILLS

- Analyse, interpret and apply graphical, visual and physical representations of biomechanical principles to improve movement skills in a coaching context



2.1 Introduction to biomechanics

KEY CONCEPT There is a vast array of biomechanical principles that, when understood and applied, can be used to improve movement skills in a coaching context.

FIGURE 2.1 FIFA U-20 Women's World Cup, Germany versus Costa Rica, 2010

There are many ways in which an athlete can gain an advantage over competitors. These include the adoption of appropriate dietary and hydration techniques, using appropriate training and recovery methods, and working with coaches and specialists on acquiring higher levels of skills, tactical nous and mental strength required for optimal performance. Many athletes also analyse their own human movement in order to promote even higher levels of performance. To do so, an understanding of the principles that govern movement is required.

For many years, athletes, coaches and sports scientists have applied biomechanical principles to analyse human movement. The term **biomechanics** is derived from the Ancient Greek terms *bios* meaning 'life' and *mechanike* meaning 'mechanics'. It refers to the study of the mechanical principles that govern human movement. In exercise, play, recreation and sport, biomechanics contributes to the description, explanation and prediction of movement. Biomechanical principles are also used to determine optimal techniques in sport, with the aim of optimising human performance, in addition to developing and sustaining healthy movement patterns.

This chapter explores a range of biomechanical principles used for analysis of human movement. Working through this chapter you will learn about a branch of biomechanics called **kinetics**, which is the study of the forces that cause motion and also the forces resulting from motion. Forces cause changes in motion and a change in motion cannot occur without force. Forces cannot be created unless two or more bodies interact. Another branch of biomechanics called **kinematics** is the study of movement with reference to time, distance, displacement and velocity.

In the study of biomechanics, it is also important to look at the relationship between equilibrium and human movement, focusing on the use of levers and study of stability and balance.

Biomechanics is the study of the mechanical principles that govern human movement.

Kinetics is the study of forces that cause motion.

Kinematics is the description of motion.

TEST your understanding

1 What does the term *biomechanics* refer to?
2 Explain the benefits to coaches and athletes of having an understanding of biomechanical principles.

APPLY your understanding

3 There are two main branches of biomechanics that help athletes and coaches understand the mechanical principles that govern human movement. Name these and explain the differences between them.

2.2 Using kinetic concepts studied in biomechanics for analysis of human movement

KEY CONCEPT Angular and linear kinetic biomechanical concepts can help analyse human movement.

A key branch of biomechanics, referred to as kinetics, involves the study of the forces that contribute to motion. The term **motion** refers to a body's change in position in relation to time. Motion is typically described as linear or angular (or a combination of these) and relates to both living (animate) and non-living (inanimate) bodies. A human body or body segments are both animate bodies, while a baseball is an example of an inanimate body.

Motion refers to the change in position of a body in relation to time.

Linear motion, also commonly referred to as translation, takes place either in a straight line or curved path. Movement in a straight line is referred to as rectilinear motion, where all parts of a body travel the same distance, in the same direction, at the same time. Movement over a curved path is referred to as curvilinear motion.

Linear motion is motion that occurs either in a straight line or curved path.

Angular motion, also commonly referred to as rotation, occurs when a body moves along a circular path at the same angle, in the same direction, at the same time. Angular motion occurs around some type of axis, which can be either external or internal. An example of an external axis in sport is a gymnast rotating around a high bar, while an internal axis would be a joint in the body around which a body part rotates.

Angular motion takes place when a body moves along a circular path.

FIGURE 2.2 A gymnast rotating around a high bar would be using an external axis to promote angular motion.

In sport, true linear motion is rarer than angular motion, as movement is typically generated by angular motion of body parts or equipment. Far more common, however, is the combination of the two types of motion, referred to as general motion. An example of general motion is the running in a straight line seen in a 100-metre sprint caused by the angular rotation of the arms and legs.

FIGURE 2.3 Usain Bolt during the 100 m heats in the Rio 2016 Olympics. The angular motion of a runner's arms and legs promotes general motion.

Understanding angular and linear kinematic concepts of human movement

There are a range of angular and linear kinematic concepts of human movement. These include the concepts of:

- mass
- inertia
- force
- momentum
- impulse
- Newton's three laws of motion.

Mass

Mass is the quantity of matter found within a particular body.

The term **mass** is used to described the quantity of matter found within a particular body. Mass is typically measured in kilograms. A person with a large mass is composed of large quantities of matter, while a person with a small mass is composed of a small quantity of matter. There is a direct relationship between the amount of mass and inertia. A ball with a small mass has less inertia and therefore is easier to move than a ball with large mass and large inertia. Similarly, once moving, the ball with large mass and inertia will be much more difficult to slow down or stop than the ball with small mass and small inertia. Think of the challenges if you were asked to both throw and catch a shot instead of a tennis ball.

Inertia

Inertia is the resistance of a body to a change in its state of motion.

Velocity is the rate of the speed an object moves its position.

Inertia is a term that describes the reluctance of a body to change its state of motion and, as highlighted in the section on mass, the terms mass and inertia are closely linked. This includes a body at rest reluctant to move, and a body moving reluctant to change its direction or **velocity**. Examples of static inertia include the reluctance of a heavy piece of sports equipment to be moved, such as a barbell with weights on it, or the reluctance of a static wrestler to be shifted from their position in a contest. An example of dynamic inertia is the reluctance of a rugby player running quickly with the ball to be stopped (change of direction and velocity).

FIGURE 2.4 Sumo wrestlers aim to overcome the inertia of opponents with a large mass.

Force

Force is an effect on one body that results from the interaction of a second body. Inanimate and animate bodies are either in a state of rest (not moving) or a state of motion (moving). To change the state of a body, a force must be applied to it. A force can have either a pushing or pulling effect on a body with mass, causing it to accelerate (speed up), decelerate (slow down) and/or change direction.

Although forces have the capacity to alter motion, they need to be sufficient enough to overcome the inertia of a body. For example, a heavy barbell on the floor in a weightlifting competition will only be lifted if sufficient force is created to overcome its inertia.

Force is the product of mass and acceleration.

studyon

Unit 3 | AOS 1 | Topic 2 | Concept 2 — **Inertia, mass and force**

FIGURE 2.5 In the Rio 2016 Olympic men's weightlifting final, force is used to overcome inertia.

Forces can be defined in relation to the body of interest, as internal (interactions inside) or external (interactions outside). There are different types of internal and external forces that act on bodies. In sport, the force generated by the contraction of the skeletal muscles would generally be classified as an internal force. External forces include gravity, air resistance and friction.

The unit of force is called the Newton (N). It is the amount of force required to shift a 1 kg mass (1 unit of mass) to accelerate at 1 m/s^2 (1 unit of acceleration).

$$1\text{N} = 1\text{m} \times 1\text{a}$$

Momentum

Momentum is the product of mass and velocity; for example, a body with greater mass moving faster will have greater momentum than a lighter object moving slower.

The term **momentum** describes the quantity of motion a particular body of mass has. It is a combination of mass and velocity: mass (measured in kilograms) multiplied by velocity (measured in metres travelled per second).

This is written as:

$$\text{momentum (p)} = \text{mass (m)} \times \text{velocity (v)}$$

If an object has zero velocity (not moving), then it has zero momentum. The higher the mass and the higher the velocity, the greater the momentum will be. An example would be to compare athletes running in a 100-metre sprint, as shown in table 2.1. The product of the mass and velocity of the athlete in lane 3 means that he/she would possess the largest momentum of the four athletes.

TABLE 2.1 Comparison of athletes running in a 100-metre sprint

Lane	Athlete's mass (m)	Athlete's peak velocity (v)	Athlete's peak momentum (p)
1	80 kg	10 m/s	800
2	80 kg	9 m/s	720
3	90 kg	10 m/s	900
4	90 kg	8 m/s	720

In many ways, the momentum of the athletes above is irrelevant to their performance as the runner simply needs to get to the finish line first to win the contest. However, what if the aim of the competition was to stop each runner from moving when they are at peak (highest) velocity? In this case, the momentum is highly relevant as the athlete with the highest momentum would be the hardest to stop. This would be the athlete in lane 3, who has a momentum of 900 kg/m/s due to the combination of high mass and high velocity.

FIGURE 2.6 Ten-pin bowling is a good example to illustrate the principle of conservation of momentum.

Conservation of momentum

Whenever two bodies collide, the combined momentum of the two bodies is conserved (stays the same). This is referred to as the principle of conservation of momentum. An example of this is in ten-pin bowling. The momentum of the bowling ball and pin when combined are the same pre- and post-collision. The bowling ball when thrown has significant momentum due to its combined mass and velocity. The pin, however, has zero momentum due to its zero velocity. Once the bowling ball hits the pin, a significant quantity of momentum is transferred from the bowling ball to the pin, causing the pin to increase in velocity. The bowling ball will reduce its velocity. The combined momentum, however, will be the same.

Force summation

The principle of conservation of momentum is important in any sport that requires the transfer of momentum from one body part to another or the transfer of momentum from a body part to an inanimate object such as a ball, bat or racquet. **Force summation** is a vital ingredient of human movement where the correct timing and sequencing of body segments and muscles through a range of motion is evident. Experienced athletes spend countless hours practising the range of movements required in their sport to ensure the desired quantity of force is generated. In many instances, maximal force production is the aim, such as in throwing events like javelin or when kicking a penalty as hard as a player can in soccer. There are, however, many times where submaximal force is required, such as putting in golf or taking a free throw in basketball. Controlling the quantity of force generated is therefore often important.

FIGURE 2.7 A golfer aiming to propel the ball as far forward as possible will aim to apply maximal force when teeing off.

Force summation is the correct timing and sequencing of body segments and muscles through a range of motion.

FIGURE 2.8 Players shooting for a free throw in basketball will apply only submaximal force during a shot.

In some sporting examples, there are times when body parts are moved at the same time to perform an action. This is known as **simultaneous force summation**. Simultaneous summation of force occurs in athletics when a sprinter explosively moves multiple body parts at the same time at the start of the race. Other examples include a long jumper or high jumper propelling their body in the air after a run up.

Simultaneous force summation is the use of multiple body parts at the same time to produce force.

FIGURE 2.9 A high jumper demonstrates simultaneous summation of forces during the propulsive jump phase required in their event.

Sequential force summation is the activation of body parts that are used in sequence to produce force.

Far more common in sport is **sequential force summation**, where body parts move in a sequence to produce the desired degree of force. Adopting a technique that enables sequential force summation enables greater force to be developed. Sequential force summation is more successful, and produces the maximal amount of force, if a number of principles are adhered to.

These include:

- activating the stronger and larger muscles first
- using as many body parts as possible, enabling force to be generated over a greater time
- transferring momentum from one body part to another when at maximum velocity
- the presence of a stable base for maximal acceleration of body parts to occur so that momentum can be transferred successfully from one body part to another
- ensuring appropriate follow-through is used to prevent unnecessary deceleration of body parts.

Activating the stronger and larger muscles first

Activating the larger and stronger muscles first enables these muscles to generate a large amount of force that can be passed onto other body parts. These large body parts (with high mass and low acceleration) transfer momentum to smaller body parts (low mass and high acceleration). A golfer teeing off who is trying to hit the ball with maximal force will recruit the larger muscles of the lower body first, followed by the muscles of the torso, then the shoulders and finally the smaller muscles of the arms and hands.

The use of as many body parts as possible, enabling force to be generated over a greater time

Greater momentum can be produced by applying force over a longer period of time. By recruiting more body parts in sequence, the total time where momentum can be generated is increased, which can then be transferred to the desired action. Think of two athletes starting a race. Runner A decides to crouch and wait for the starter's gun to be activated, while runner B uses blocks. Runner A on hearing the gun pushes back and down to enable the full extension of the grounded leg and subsequent propulsion in the air. The runner would therefore leave the starting line quite quickly. Compare this to runner B who has their legs flexed more significantly at the knee joint. Once the starting gun goes off, the athlete takes longer to push down and back to enable the propelling leg to fully extend, therefore starting the race more slowly. The benefit to runner B, however, is that they are able to generate force over a longer period of time, resulting in greater momentum from the start. All other factors being equal, the runner with greater momentum (runner B) will end up performing better than runner A. For more details, see the section on *impulse* (pages 45–6).

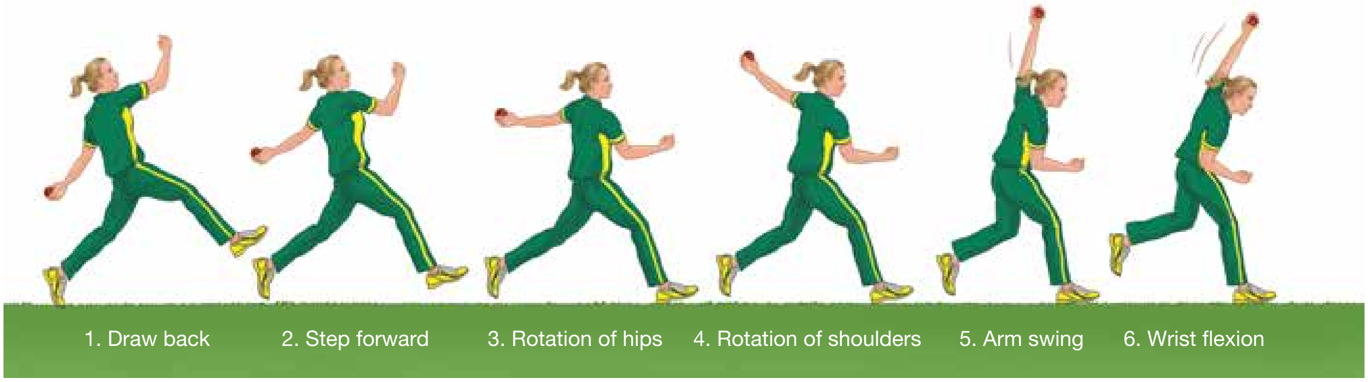


FIGURE 2.10 In this cricket bowl, there is a sequential transfer of momentum between different body parts, starting with the large muscles of the lower body, transference of force to the torso, then the smaller muscles in the arms before the momentum is transferred to the ball on release.

Transfer of momentum from one body part to another when at maximum velocity

If momentum is transferred at the wrong time, performance will be compromised. People often describe athletes with great skill as having terrific 'timing', a term that means that the athlete appears to sequence the movement of body parts just 'at the right time'. Athletes who do not have good sequencing ability are likely to either transfer momentum from one body part to another too early (before momentum is at its maximum) or too late (when the momentum drops due to a drop in velocity). The correct sequencing and timing of the transfer of momentum is also important when releasing or striking a projectile. A good example is a fast bowler in cricket who has to get their timing right to produce maximal force. If a bowler has too short a run-up, then less momentum is developed by the bowler for transfer to the ball, creating a slower speed of release. The bowler on the other hand who takes too long a run-up will experience a drop in momentum if velocity drops (due to a reduction in the speed of energy supply due to energy system limitations).

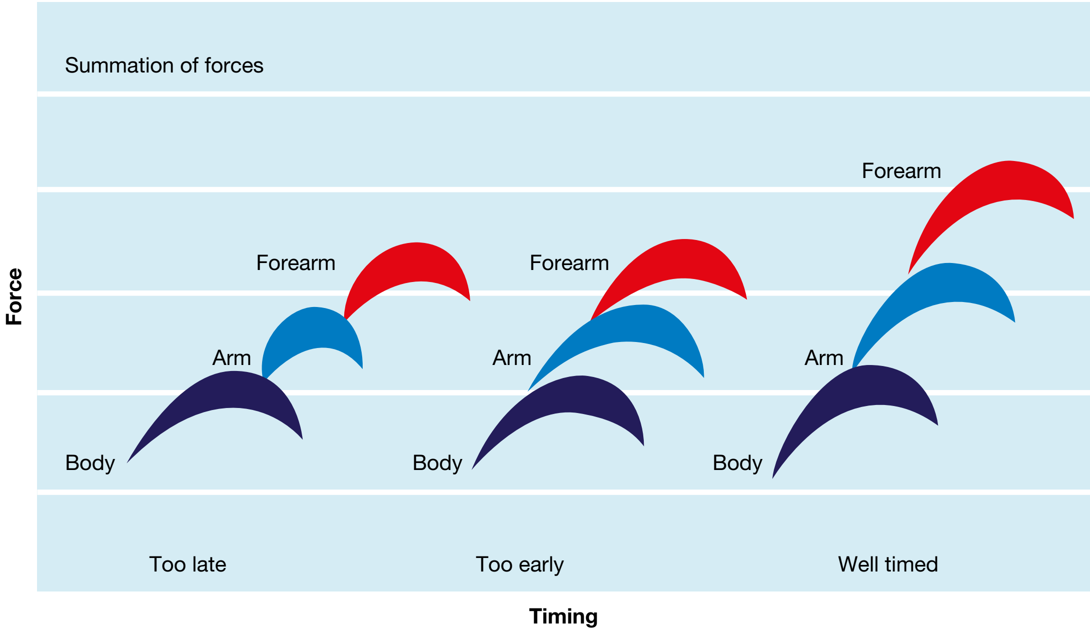


FIGURE 2.11 The best-timed actions will ensure that momentum is transferred from one part of the body to another when the force is maximal.

A stable base must be present for maximal acceleration of body parts to occur so that momentum can be transferred successfully from one body part to another

Technique is a vital aspect of a successful motor skill. A stable base must be in place for the development of efficient acceleration of body parts. Think of a golfer who needs to have a strong trunk and torso to enable successful sequencing and timing of the transfer of momentum from one body part to another and then onto the ball. A stable base in this example refers to the player's lower body. Another example is a 100-metre sprinter who has a strong and stable core, where the arms and legs rotate around this base.

Moment of inertia is a measure of an object's resistance to change in its rate of rotation.

Newton's first law of motion states that an object will stay at rest or continue to travel in the same direction at a constant velocity unless acted on by an unbalanced force.

Ensure an appropriate follow-through is used to prevent unnecessary deceleration of body parts

Many younger and inexperienced athletes fail to generate full power during activities that require a transfer of momentum to a projectile. A common reason is the inability to maintain acceleration during a movement. Many slow their movements down either prior to or at the time of impact, resulting in a drop in performance (due to inefficient movement patterns and subsequent drop in the execution of the skill). Athletes in all sports that require successful transfer of momentum are encouraged to 'follow through' with their action. This enables the performer to maximise the force generated.

Angular momentum

Like linear momentum, there are some principles that guide our understanding of how momentum is both conserved and transferred when angular motion is involved. Angular momentum is a product of **moment of inertia** and angular velocity. This can be expressed as:

$$H = I\omega$$

Moment of inertia is a measure of an object's resistance to change in its rate of rotation. It is based on **Newton's first law of motion**, which describes a rotating body or object's reluctance to change. The moment of inertia is dependent on both:

- the mass of the rotating object or body
- the distance the weight is distributed from the axis of rotation.

Angular momentum is greater if the mass is larger and the further that mass is distributed from the axis. When rotating a baseball bat, for example, angular momentum can be increased by increasing the mass of the bat, as well as the length of the bat (that increases the distance the weight is distributed away from the axis). The greater the angular momentum, the greater the transfer of momentum to the ball. What each athlete needs to do, however, is to select an appropriate bat to meet the demands of the situation. Generating angular momentum is useless if the speed of the baseball pitch, for example, is too quick for the batter to react. The batter may elect to reduce the weight of the bat to enable it to be swung more quickly, sacrificing overall momentum for increased angular velocity.

Instead of changing bats, there are other ways to alter an object's moment of inertia. This includes

FIGURE 2.12 In this example, angular momentum is a product of the angular velocity multiplied by the bat's moment of inertia (product of the mass of the bat and the distance the weight is distributed away from the axis).

FIGURE 2.13 If the bat is turned around, the mass is closer to the axis (point of rotation; in this example, the wrists). This would reduce the moment of inertia and, in turn, angular momentum.

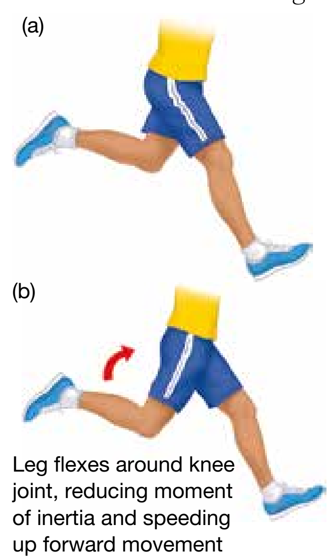


FIGURE 2.14 When running, the angular momentum in each leg is conserved throughout the action. When the leg is bent, the moment of inertia drops but angular velocity in that leg increases to conserve momentum.

altering how the striking implement is held. By holding the striking implement higher up (using the above example, the baseball bat), the moment of inertia is decreased as the distance between the centre of the bat's mass and axis of rotation is decreased. This is sometimes referred to as 'choking' the grip. This technique increases the ability to swing the bat more quickly, due to the drop in inertia. Children will often do this to gain greater control.

Modified equipment is another way of reducing the moment of inertia, promoting the ability to move the equipment with more ease. However, this also reduces the overall angular momentum. Cricket and tennis are two of many examples in which modified equipment is encouraged for ease of use.

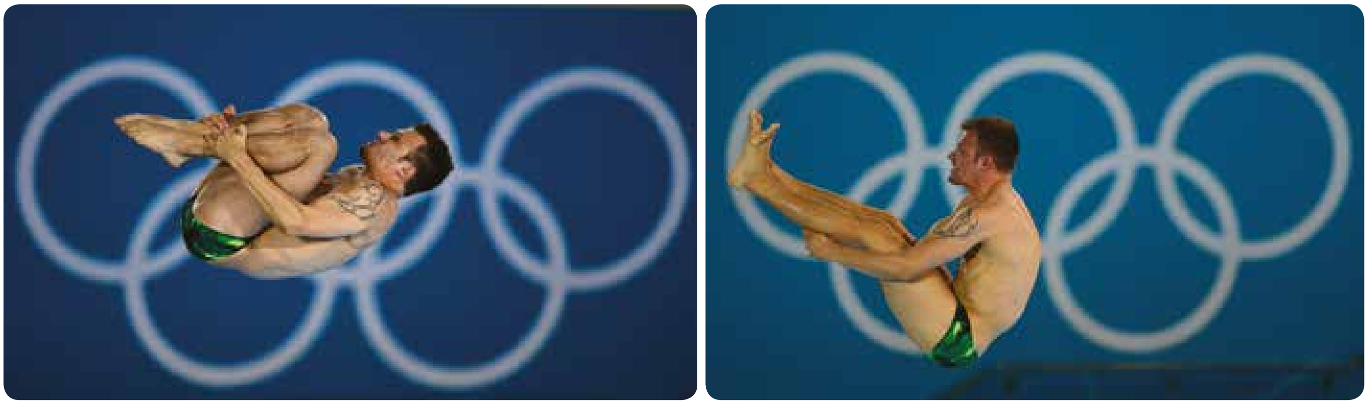


FIGURE 2.15 Once the diver leaves the diving board, angular momentum will be conserved. However, the diver can alter the moment of inertia and angular velocity by moving body parts into different positions. During the tuck, the moment of inertia is reduced significantly, which, in turn, increases angular velocity (degree of rotation) that conserves the momentum. The opposite occurs coming out of a tuck, where velocity decreases due to an increase in the moment of inertia.

FIGURE 2.16 The baseballer pictured here is maximising the potential to generate angular momentum by ensuring that the bat is held at a point that maximises the moment of inertia.

eBook*plus*

Digital document
Moment of inertia
Searchlight ID: doc-3562

studyon

Unit 3 **AOS 1** **Topic 2** **Concept 3** — **Momentum and impulse**

TEST your understanding

1 Explain what the term *inertia* means. Provide one example of static inertia and one example of dynamic inertia in a sporting context.
2 Describe the difference between animate and inanimate objects.
3 List four sequential force summation principles that should be adhered to so that maximum force production can occur.
4 Write the formula for angular momentum.

APPLY your understanding

5 For the following biomechanical terms, provide the symbols used for each: momentum, force, velocity and acceleration.
6 An athlete who has a mass of 75 kg reaches a peak velocity of 4 m/s during a 400-metre run. What is their peak momentum?
7 The table below shows some data relating to the mass and velocity of two athletes in a sprint.

Lane	Athlete's mass (m)	Athlete's peak velocity (v)
1	50 kg	8 m/s
2	60 kg	7 m/s

Calculate each athlete's peak momentum during the sprint, highlighting whether the athlete in lane 1 or lane 2 generates the most.

8 A rugby player receives a pass from a team mate while stationary. Immediately after receiving the ball, he is tackled by an opposition player. Explain, using the principle of transfer of momentum, what would happen next.
9 **Practical activity: tennis ball throw**
For this activity you will need a tennis ball, cones and a measuring tape. Each student will be asked to throw the tennis ball four times. Collate the results of the throws to get a class average for each one.
Throw 1 — Lie on the ground and throw the ball as far forward as possible while keeping all body parts flat on the ground except the throwing arm. Measure the distance.
Throw 2 — In a sitting position with your feet and bottom flat on the ground, throw the ball as far forward as possible. Measure the distance.
Throw 3 — With feet firmly planted on the ground (both facing forwards), throw the ball as far as possible. Measure this.
Throw 4 — With a five-metre run up, throw the ball as far forward as possible. Measure the distance.
After the results are provided back to you, discuss why the ball travelled different distances for each throw, using the principles of force summation to assist in your response.

EXAM practice

10 Draw on a graph the flight path (trajectory) of an optimal throw for distance, where the release height and landing height are the same. You need to:
- draw and label both the x- and y-axis **2 marks**
- draw the shape of the flight path **1 mark**
- label the angle of release as 45 degrees. **1 mark**

2.3 Newton's laws of motion

KEY CONCEPT Sir Isaac Newton devised three laws of motion that help describe the relationship between forces and objects.

Isaac Newton first compiled his three laws of motion in 1687. These laws describe the relationship between a body and the forces acting upon it. They also explain how these forces affect the motion of a body as a consequence.

Newton's first law of motion

Newton's first law of motion is commonly referred to as the law of inertia. This law states that:

'An object will stay at rest or continue to travel in the same direction at a constant velocity unless acted on by an unbalanced force.'

In other words, objects will not move from their state of being unless forces acting on them become unbalanced. This can be referred to as a body having uniform motion. To shift from a state of uniform motion, a force must be applied to disrupt the balance and hence accelerate an object. The higher the mass of a body, the greater the inertia and therefore more force is required to overcome this inertia. This is true both for objects that are static and those that are moving.

FIGURE 2.17 This bike rider is experiencing inertia as his body continues to travel in the same direction at a constant velocity after the bike hits the rails. The bike has been met by an external force that has slowed it down considerably but the rider's inertia has propelled him forward and will only be slowed by air resistance, gravity and whatever he actually lands on.

Newton's second law of motion

Newton's second law of motion states that:

'The rate of acceleration of a body is proportional to the force applied to it and in the direction in which the force is applied.'

Newton's second law of motion states that the rate of acceleration of a body is proportional to the force applied to it and in the direction in which the force is applied.

From a mathematical point of view, this presents as force = mass × acceleration or

$$F = ma$$

Force therefore is a product of mass and acceleration. To produce maximal force, mass and acceleration should be at their highest. Think of a baseball bat. The higher the mass and the more it is accelerated, the higher the overall force that can be transferred to the baseball. However, from a practical perspective, athletes need to find a balance between mass and acceleration. Using the same example, it is counterproductive to select a very heavy baseball bat if the person swinging it cannot accelerate it quickly enough to hit the ball. There is an inverse relationship between the mass of an object and its acceleration, using the formula $F = ma$. This means that as mass is doubled, the acceleration is halved with the same amount of force generated, and conversely, when the mass is halved, the acceleration is doubled.

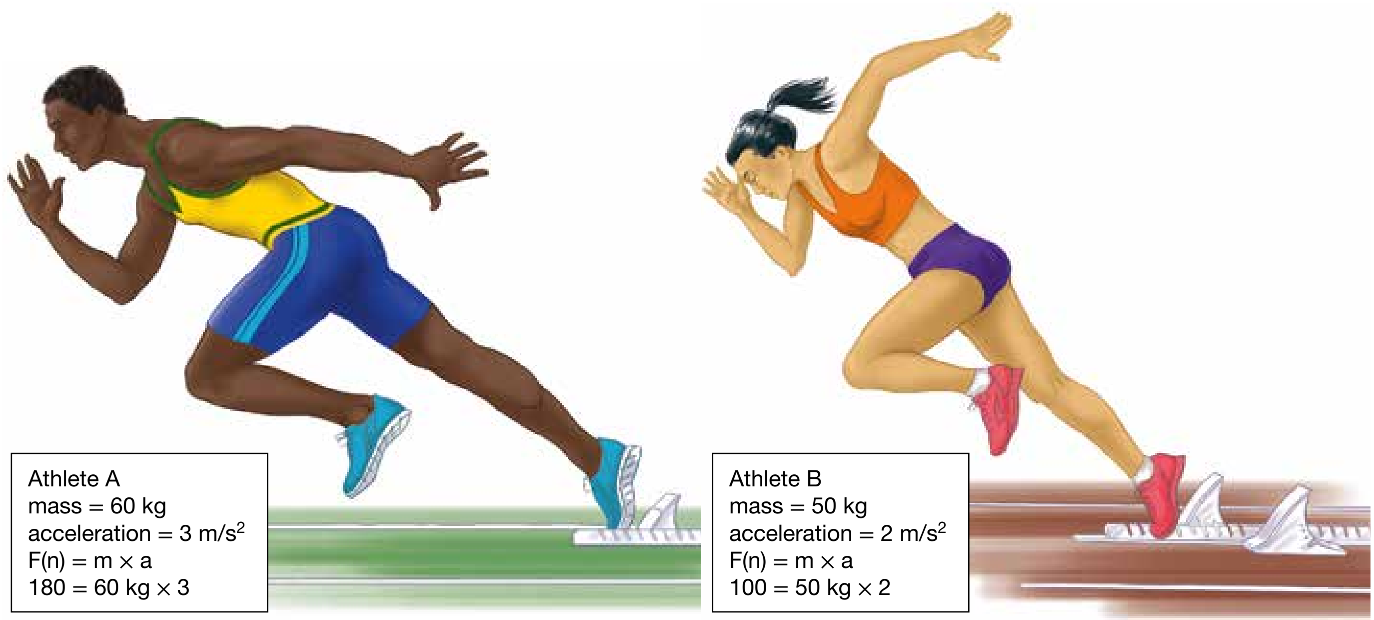


FIGURE 2.18 Compare the force generated by the two athletes shown here.

Newton's third law of motion

Newton's third law of motion states that for every action, there is an equal and opposite reaction.

Newton's third law of motion states that:

'For every action, there is an equal and opposite reaction.'

To elaborate on this point, this law means that when one body applies a force against a second body, the second body applies an equal force in the opposite direction on the first. Consider the same individual jumping three different times. If the individual aims to jump directly in the air and land on the same spot, then in order to go directly up, the force must be applied directly down. In the second jump, the athlete aims to propel themselves up and forward. To do this, the force must be applied down and back. In the last jump, the person wants to jump up but backwards. The force to enable this jump to succeed is to push down and forward. In all three jumps, the magnitude (size) of the force dictates the force applied back to the person jumping. The greater the force, the greater the propulsion.

Consider other examples in sport. A basketball hitting the backboard at an angle bounces off on an angle with similar force to that with which it was thrown. A soccer player aiming to move sideways to their left to change direction must apply a sideways force to their right. Again, the greater the force applied to the ground (action), the greater the force that the ground applies back to the soccer player (reaction).

Looking at Newton's third law in isolation tends to be confusing. This is because the effects of these equal and opposite forces are visibly very different. The ground clearly doesn't move but the person jumping does. The basketball clearly rebounds off the backboard but the backboard doesn't visibly shift. Newton's second law helps explain this phenomenon. In the case of the individual jumping, the force applied (in accordance with Newton's second law) by the individual is their mass multiplied by their acceleration ($F = ma$). The earth responds with the same force. Considering the enormous mass of the earth, its acceleration is miniscule (so tiny it is not detected by the human eye).

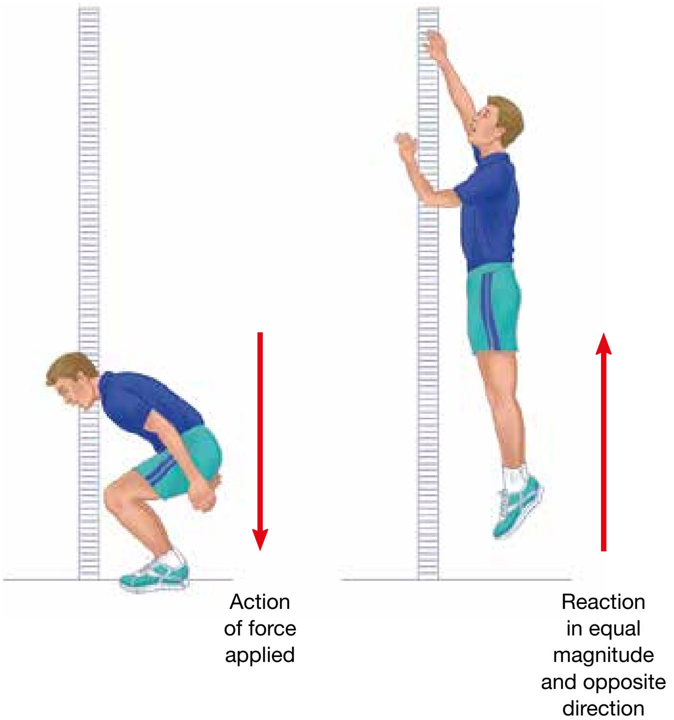


FIGURE 2.19 The direction and magnitude of the force applied will determine the direction and magnitude of the movement.

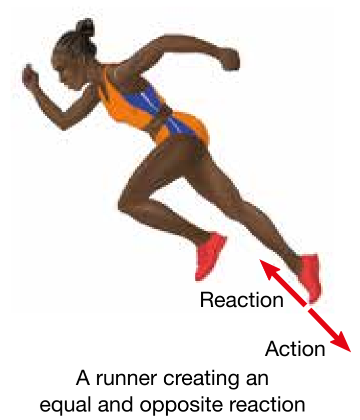


FIGURE 2.20 The runner who aims to move forward and up must apply a force back and down according to Newton's third law.

In the other example, where the basketball hits the backboard and bounces off, the backboard can be shifted if the force of the ball is strong enough. In this case, you may see or hear the backboard move (accelerate from a stationary position). Due to its higher mass than the basketball, its acceleration will be much smaller than that observed in the basketball.

Impulse

There is an **impulse**-momentum relationship that can be described by the formula:

Impulse is the product of force and time.

$$\text{Impulse} = \text{force} \times \text{time or } Impulse = F \times t$$

The greater the impulse, the greater the momentum generated. For this to occur, the force (via a combination of mass and acceleration) should be applied over the longest period of time. The term 'time' in this formula refers to the length of time force is applied to an object. An example of the impulse-momentum relationship includes when a tennis player uses a racquet with loose strings instead of very tight strings. When a tennis ball hits a racquet with tight strings, the amount of time the ball is in contact with the racquet is quite small. However, when hitting looser strings, the ball stays in contact for a longer period of time, resulting in greater impulse and subsequent momentum. Other sports such as throwing and racquet activities utilise techniques and equipment that increase the impulse.

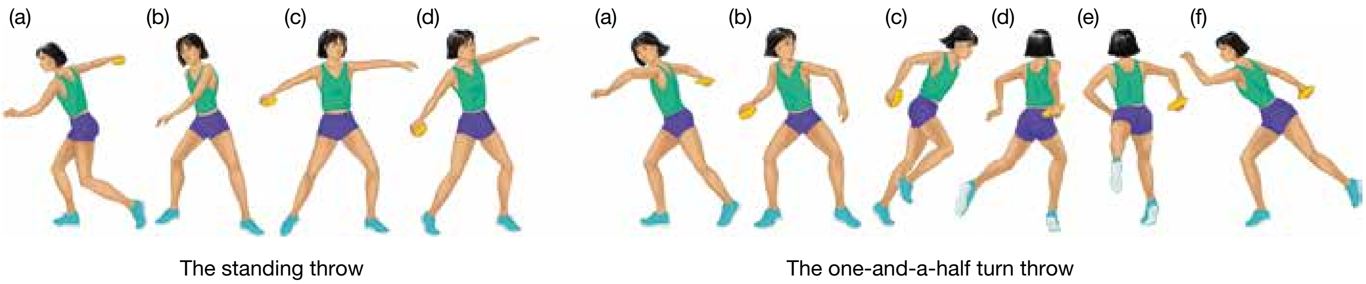


FIGURE 2.21 This diagram depicts the same discus thrower with two different techniques prior to releasing the discus. When using the standing throw, the athlete uses a quick half-spin prior to releasing the discus, meaning that force is applied over a small period of time and therefore has a small impulse. When applying force over a longer period of time during the one-and-a-half turn throw, greater impulse and subsequent momentum is generated.

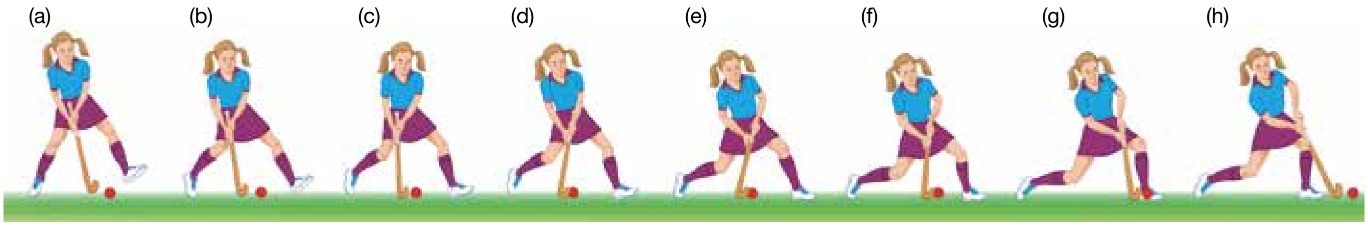


FIGURE 2.22 The hockey player applies greater momentum when making contact with the ball over a longer time frame (c to h).

Impulse can also be used to absorb force over a longer period of time to reduce the impact. Examples of equipment being used for this purpose include high jump mats and cricket pads. Techniques can also be adopted to use the principle of impulse to absorb force over time. If a person receives a catch over a period of time, the force is absorbed over a longer distance, over a longer time. This is generally done by bending the elbows and moving the arms in the direction that the ball is travelling rather than keeping the arms straight.

FIGURE 2.23 Large mats are used in high jumping to absorb impact and prevent injury to the athlete.

TEST your understanding

1 Identify which of Newton's laws is often referred to as the Law of Action and Reaction.

2 According to Newton's second law, the force produced is a product of what two variables?

3 A bike rider quickly puts on their front brake to avoid a collision but, as the bike slows down, the cyclist is thrown over the handlebars and becomes airborne. Explain, using Newton's first law, why this occurs.

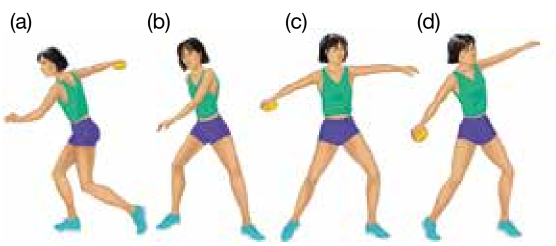
APPLY your understanding

4 There are two wrestlers, one with a larger mass than the other. Explain, using Newton's first law of motion, why the wrestler with the larger mass would be harder to move than the wrestler with smaller mass, all other factors being equal.

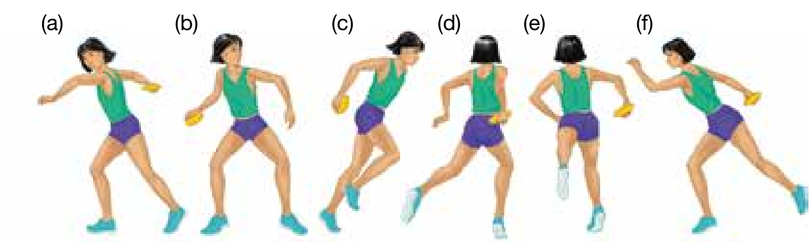
5 Explain how impulse can be used for success in sport.

6 **Practical activity: discus throw**

As a class, each complete six discus throws, three using the standing throw and another three using the one-and-a-half turn technique. Measure each throw and come up with a class average for each type depicted.



The standing throw



The one-and-a-half turn throw

Discuss the results in relation to the impulse-momentum relationship.

EXAM practice

7 (a) Explain what is meant by the term *Newton's third law of motion*. **1 mark**

(b) Using Newton's third law, explain how a runner can propel themselves forward and up during a race. **1 mark**

studyon

Unit 3 | AOS 1 | Topic 2 | Concept 1 — **Newton's laws**

2.4 Using kinematic concepts studied in biomechanics for analysis of human movement

KEY CONCEPT Kinematic biomechanical concepts can help analyse human movement.

Displacement is the difference between the initial position and final position of an object.

Kinematics is the study of movement with reference to time, distance, **displacement** and velocity. It studies things such as how fast or how far bodies move, without being interested in what causes these objects to move the way they do (covered by kinetics). By using kinematic concepts, coaches and athletes can better understand human movement and develop techniques to maximise performance.

Linear distance and displacement

Although distance and displacement measure the extent of motion of a body, there are significant differences between these two terms in biomechanics. Distance refers to how much ground an object covers throughout its motion, while displacement refers to an object's overall change of position from one point in time to another. An example outlining the difference between distance and displacement is the difference in distance and displacement in the following swimming events: a 50-metre swim where a swimmer starts at one end of the pool and finishes at the other end, and a 100-metre swim where a swimmer starts at one end of the pool, swims to the other end, turns around and swims back to the starting position.

Event	Description	Total distance travelled	Total displacement
50-metre swim	Swim from one end of a 50-metre pool to the other	50 metres	50 metres
100-metre swim	Swim from one end of a 50-metre pool to the other, turn around and swim 50 metres back to starting position	100 metres	0 metres

Even though the second swimmer covered 100 metres in total, the displacement was 0. Another way to understand displacement is to ask 'how far out of place' an object is from one point in time to another. Seeing that the swimmer was in the same position between start and finish of the 100-metre swim then they were 'not out of place'.

Consider another example. The same swimmer completes the first 50 metres, turns around and can only complete 30 metres before having to stop. The accumulated distance travelled is 80 metres. What is the displacement? To calculate this, you need to consider how far the person is away from the original starting position. In this instance, they are 20 metres away from the starting position, therefore they are 20 metres out of place between start and finish. Hence the displacement is 20 metres.

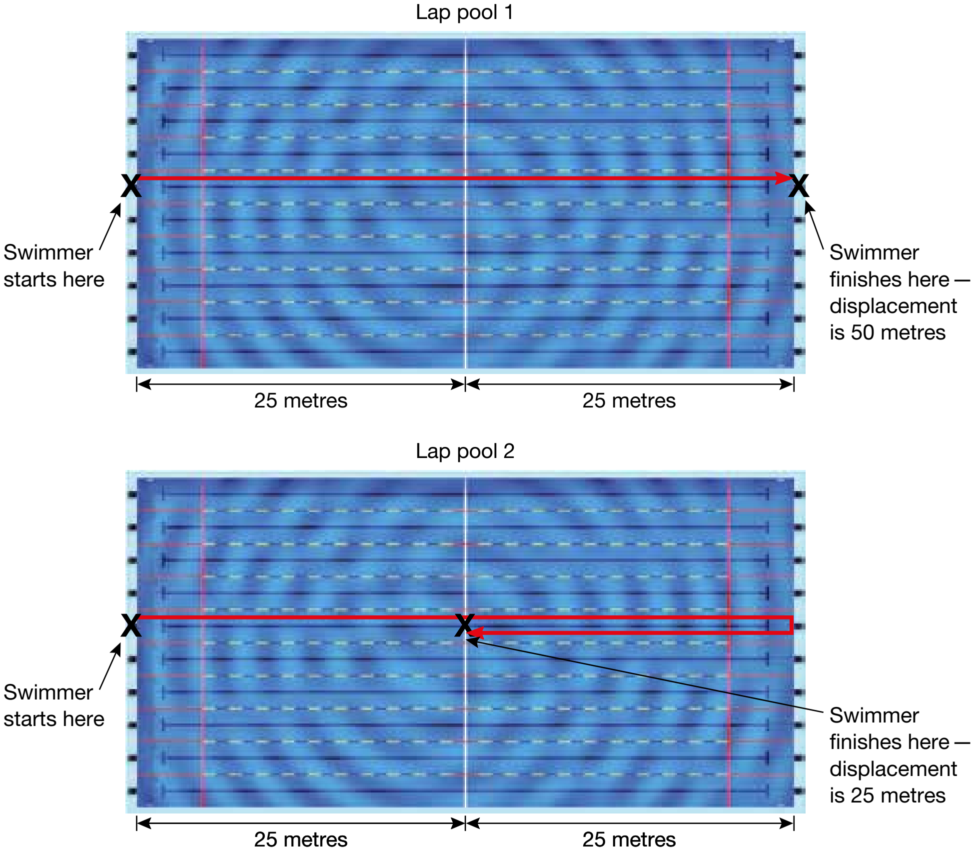


FIGURE 2.24 In this example, the displacement of the swimmer in lap pool 1 is 50 metres (distance between starting and finishing points) while the displacement of the swimmer in lap pool 2 is 25 metres (distance between starting and finishing points).

Angular distance and displacement

The concepts covered in the section on linear distance and displacement can be transferred to angular motion. When a body rotates from one position to another, it experiences angular motion. The angular distance is the total of all angular changes that result from an object or body part angle between the starting and finishing position. Consider the example of a ten-pin bowler swinging their arm during the bowling action. If the bowler moves their arm two-thirds of a full rotation (a full rotation is 360 degrees), the angular distance covered would measure 240 degrees. The angular displacement, however, is the difference in degrees between the object or body part's initial and final positions. It is measured by the smaller of the two angles. In this particular example, the angular displacement would be 120 degrees. Angular displacement has both size (magnitude) and direction. Typically, clockwise movements are referred to as positive and anti-clockwise as negative.

Note there are typically three units used to measure angular motion. These include revolutions (one revolution is a full circle), degrees (where 360 degrees is a full circle) and radians. Although commonly used in engineering and physics, the degree is a more common way it is measured in sports coaching and biomechanics.

studyon
Unit 3
AOS 1
Topic 1
Concept 4
Distance and displacement

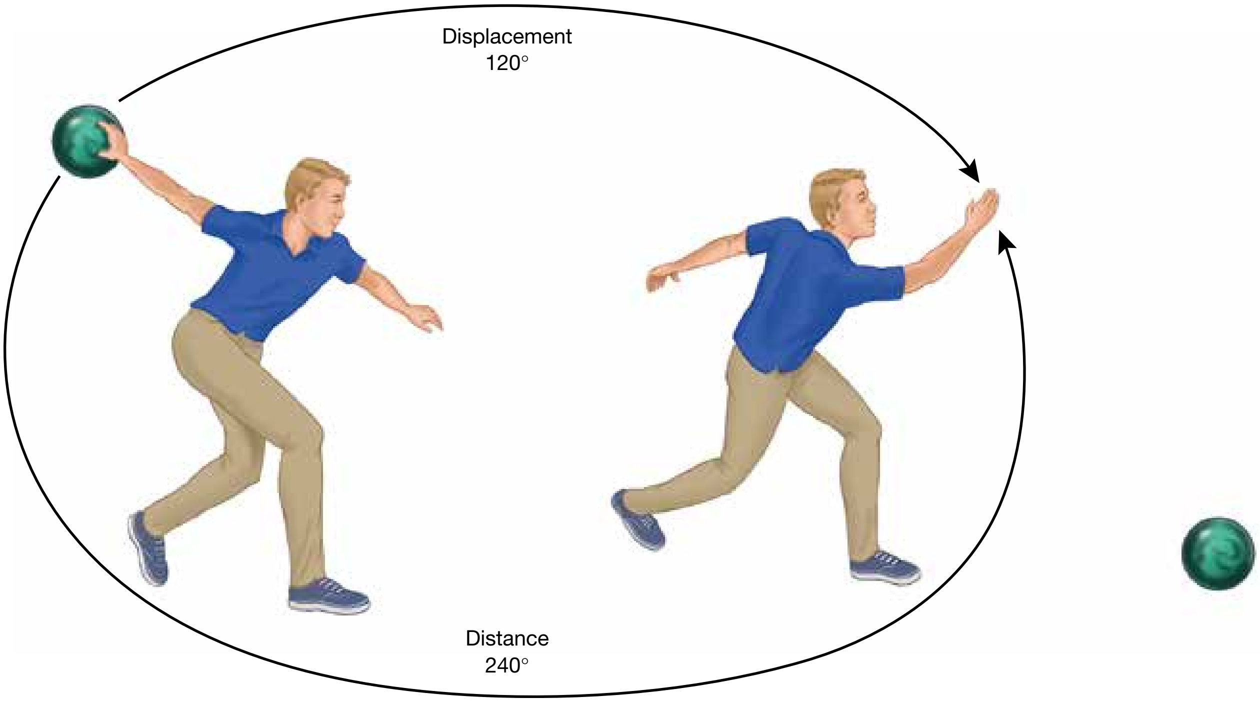


FIGURE 2.25 In this example, the angular displacement of the ten-pin bowler's arm between these two positions (start of forward swing of the ball and end position of arm after release) is 120 degrees, while the total angular distance the arm travels is 240 degrees.

Speed is the rate of motion (distance/time).

Linear speed and velocity

Similar to distance and displacement, **speed** and velocity are common terms used interchangeably to describe the rate with which an object moves from one location to another, but are in fact not the same.

The average speed of a body refers to the distance covered divided by the time taken. The velocity formula for this is represented by:

$$S = l/t$$

S = speed
l = length of path (distance)
t = time

Velocity, however, measures the displacement an object experiences over time. The formula for this is represented by:

$$V = d/t$$

V = velocity
d = displacement
t = time

Using the example of the distance and displacement of the 50-metre and 100-metre swimmers, we can see the differences in speed and velocity of the swimmers in these two events.

Swim event metres (m)	Description	Total distance travelled (l)	Total displacement (d)	Time of swim (t)	Average speed $S = l/t$	Average velocity $V = d/t$
50	Swim from one end of a 50 metre pool to the other	50 metres	50 metres	25.00 seconds	2 m/s	2 m/s
100	Swim from one end of a 50 metre pool to the other, turn around and swim 50 metres back to starting position	100 metres	0 metres	50.00 seconds	2 m/s	0 m/s

Angular speed and velocity

The term angular speed refers to the angular distance covered divided by the time taken. For example, a rotating object that completes two full revolutions (full circles) per second would have an angular speed of 720 degrees per second (360 degrees × 2).

The angular velocity is measured by dividing the angular displacement by the time taken.

Written as a formula:

$$\omega = \theta/t$$

ω = angular velocity = initial angle – final angle / time (and specifying the direction)
θ = angular displacement
t = time

Linear acceleration

Another key kinematic concept is that of acceleration. Acceleration refers to the rate of velocity change experienced by an object over time. This is represented by the following formula:

$$a = vf - vi/t$$

a = acceleration
vf = final velocity
vi = initial velocity
t = time

If the velocity increases over the period of time measured, then the object will experience acceleration that is positive; that is, it speeds up. If the velocity doesn't change over time, then the body will be travelling at the same velocity and therefore zero acceleration occurs. If the final velocity is slower than the initial velocity, the object is said to have negative acceleration. It is normal for the term 'deceleration' to be used to describe this.

An example of an athlete experiencing positive, zero and negative acceleration during an event is a 100-metre runner. When watching a 100-metre sprint, the observer sees the athletes explode from the blocks and accelerate to maximum velocity to compete for the win. The reality, however, is that the athlete does indeed accelerate but typically reaches maximum velocity at approximately the 40- to 50-metre point in the race, where the same velocity is held (zero acceleration), but will decrease their velocity to varying degrees over the last half of the race, experiencing negative acceleration (deceleration) during this time.

FIGURE 2.26 Paralympic athletes competing in the 100-metre sprint in the Rio 2016 Olympics

studyon

Unit 3 | AOS 1 | Topic 2 | Concept 5

Speed, acceleration and velocity

Gravity exerts downward forces and therefore can influence an object's acceleration as it moves through the air. The size of the acceleration due to gravity is about 9.81 m/s^2.

Angular acceleration

The angular acceleration is the rate of change of angular velocity (final velocity – initial velocity) over time.

$$\alpha = \omega f - \omega i/t$$

α = angular acceleration
ωf = final velocity
ωi = initial velocity
t = time

A gymnast rotating around a high bar who speeds up from 100 degrees/s to 300 degrees/s in 0.5 seconds has an angular acceleration of 400 degrees per second. This is written as:

α = 300 degrees/s – 100 degrees/s / 0.5 s
= 400 $degrees/s^2$

Projectile motion

As soon as an object or body is released into the air, it becomes a projectile and is automatically under the influence of two external forces, gravity and air resistance.

Air resistance is a force working against motion. It acts horizontally on a projectile as it moves through the air. Drag forces are created which then cause the projectile to slow down and reduce its flight time and the resultant distance it travels. There are many factors that impact on the amount of air resistance a projectile experiences. (Note that air resistance also acts on other bodies that are not airborne, such as bike riders and skaters.)

The following factors influence a projectile's motion:

- velocity; the higher the velocity, the greater the air resistance
- mass; the lower the mass, the greater the air resistance
- shape; objects considered streamlined will experience less air resistance than those that are not. Streamlined shapes allow air to flow over them with less drag.
- surface area; the greater the surface area, the greater the air resistance. The surface area refers to the area of an object which is exposed to the air. A good example of an object that has significant surface area exposed to the air is a badminton shuttlecock.
- nature of the surface area; smooth surfaces decrease drag and are therefore less affected by air resistance, while rough surfaces are slowed more readily.

FIGURE 2.27 A badminton shuttlecock has many openings and gaps to help create a large surface area that air can act against.

FIGURE 2.28 A heavy object such as a shot has a smaller air resistance than a lighter object.

FIGURE 2.29 Australian cyclist Anna Meares competing in the Rio 2016 Olympics. Cyclists are affected by air resistance, but the development of more aerodynamic bikes and helmets counteracts this.

Gravity acts against motion by pulling the object back towards the ground, acting as a vertical force on a projectile. In addition to the external forces that determine the flight path (trajectory) of a projectile, so do a number of other factors such as speed of release, angle of release and height of release.

Speed of release

The force applied to the projectile will have a large impact on its motion. The force can vary in amount as well as direction of application. The greater the force applied to the projectile, the greater the speed and the further it will travel, all other factors being equal. A technique to increase force is to use as many body parts as possible; for example, a bowler in cricket (as discussed in the section on summation of forces).

studyon

Unit 3	Projectile motion (height, angle and speed of release)
AOS 1	
Topic 2	
Concept 6	

eBookplus

Interactivity
Throwing a cricket ball
Searchlight ID: int-1831

Angle of release

In most sporting situations where maximal distance of a projectile is desired, there needs to be an optimal angle of release, to minimise the effects of both gravity and air resistance. In these instances, the desired angle of release is 45 degrees. Any deviation from this optimal angle (above or below) will result in reduced distance.

Some sporting situations require that the angle of release will be higher or lower than 45 degrees. For instance, in events where the ideal trajectory (flight path of the projectile) is low, then the angle of release will be well below 45 degrees. An example would be a tennis forehand from the baseline where the ball should be kept as low as possible when going over the net. The opposite would occur in a volleyball dig, where the aim is to achieve height so the ball reaches a player's teammate with height. The angle of release therefore should be higher than 45 degrees.

A person can easily alter the angle of release by moving body parts in different ways. In a sport such as golf, there are special clubs designed for different purposes. A putter, designed to release the ball to travel along the ground, is flat and therefore the ball comes off the face of the club at 0 degrees. Other clubs such as a 3-iron release the ball at about 23 degrees, while a sand wedge is closer to 55 degrees.

The human body can be manipulated to change the angle of release. Consider an Australian Rules footballer kicking the ball as far as they can. Their leg will be positioned at such an angle to maximise distance, aiming for a release height of approximately 45 degrees. Compare this to a player kicking a short pass where the aim is to get the ball to a team mate with a flatter trajectory. The leg will be positioned so the release angle is much lower than 45 degrees.

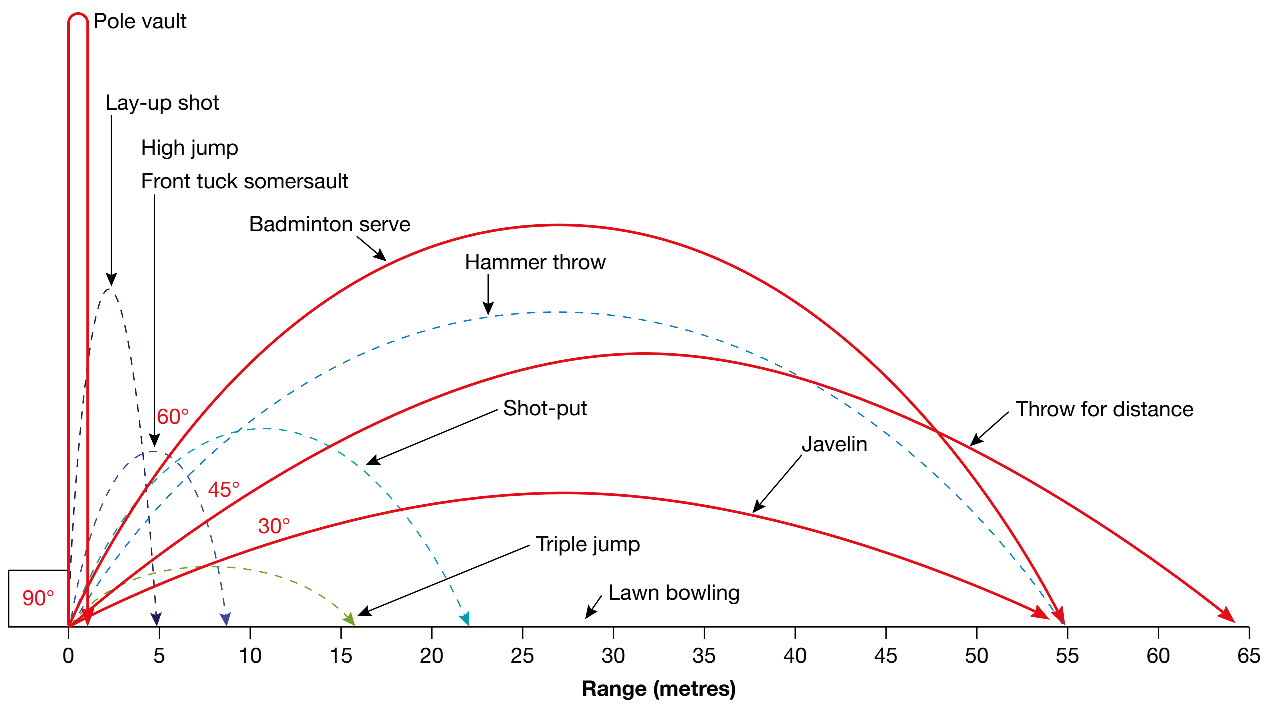


FIGURE 2.30 The optimal angle of release is determined by the needs at any given time. This graph shows some examples of typical angles of release that would be deemed ideal in a variety of contexts.

Height of release

Another factor which may affect the distance a projectile will travel is the height of release. If the angle and speed of release are constant, an object released from a higher point will travel further than one released from a lower level. A taller athlete who naturally releases a ball when throwing would therefore have an advantage over a shorter athlete.

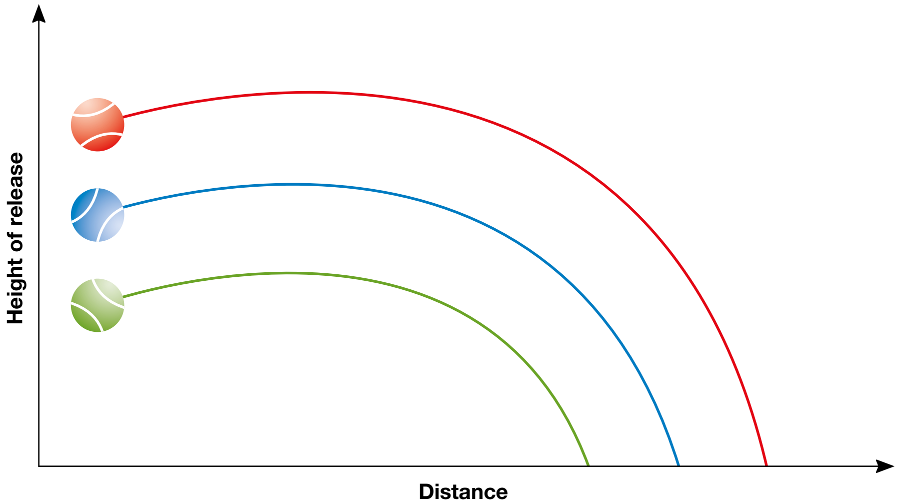


FIGURE 2.31 All other factors being equal, the higher the release, the further the projectile will travel due to having greater time in the air.

TEST your understanding

1. Explain what the term *projectile* means when discussing biomechanical principles.
2. What is the difference between the terms *distance* and *displacement* when discussing movement?
3. An athlete who is neither accelerating nor decelerating is said to have a constant what?
4. There are three units used to measure angular motion. List the three different units and highlight the one commonly used in sports coaching and biomechanics.

APPLY your understanding

5. You are a coach of two junior athletes. One of your athletes, Fiona, is positioned 1 km away in a straight line from where you are, while another, Sally, is next to you. Fiona runs to you, taking five minutes to get there. You instruct Sally to run two full laps of an oval with a distance of 500 metres per lap, finishing where she started.
   Using the information above, calculate the average speed and average velocity of Fiona and Sally. Compare the results.
6. **Practical activity: soccer ball kick**
   You kick a soccer ball from the ground into the air at an angle of 30 degrees. It lands 20 metres away.
   (a) Describe how the ball is impacted on by external forces once in the air.
   (b) For the next kick, your objective is to kick the soccer ball further. Describe three things that you could do to achieve this.
7. The table below indicates the velocity experienced by a 100-metre sprinter at different stages, including prior to the start at the starting line and at each 20-metre interval of the race thereafter.

Sprinter's position	Velocity
Starting line	0
20-metre point	7
40-metre point	11
60-metre point	10
80-metre point	8
100-metre point	7

   (a) At what point of the race did the sprinter experience the greatest velocity?
   (b) What is the unit that velocity is measured in?
   (c) The sprinter finished the race in 11 seconds. Using the correct formula, what was the average velocity from start to finish?
8. The optimal angles of release for the three different sports are as follows: high jump — 60 degrees; a throw for distance — 45 degrees; a javelin throw — 30 degrees. Draw a graph to visually represent this information. You must label both axes and include all necessary information.

EXAM practice

9 The results of a video analysis of a gymnast performing a full somersault from a static position, landing one metre ahead of the take-off position are given in the following table. Use the data to answer questions that follow.

Angular displacement	Angular distance	Angular speed	Linear displacement	Linear distance
0 degrees	360 degrees	720 degrees per second	x	y

(a) What is meant by the term *angular distance*? **1 mark**

(b) Analyse the data in the table to calculate the time it took the gymnast to perform this somersault. Explain how you worked out the answer. **2 marks**

(c) Using the information in the stem at the start of this question, what was the gymnast's linear displacement (x) and linear distance (y)? **2 marks**

x = ______________________________

y = ______________________________

2.5 Using principles of equilibrium, levers, stability and balance for analysis of human movement

KEY CONCEPT The principles of equilibrium, levers, stability and balance can help analyse human movement.

Levers

The term **lever** refers to a beam or rigid structure that rotates around a fixed point, commonly referred to as an axis (some sources use the terms 'fulcrum' or 'pivot point'). The term 'leverage' describes the action or advantage of using a lever. From a sporting perspective, levers are used to improve performance, via the use of equipment in addition to body parts that can be moved to create anatomical levers. Anatomical levers can provide a mechanical advantage where a small amount of force can be used to move a larger force.

A **lever** is a rigid structure that rotates around an axis.

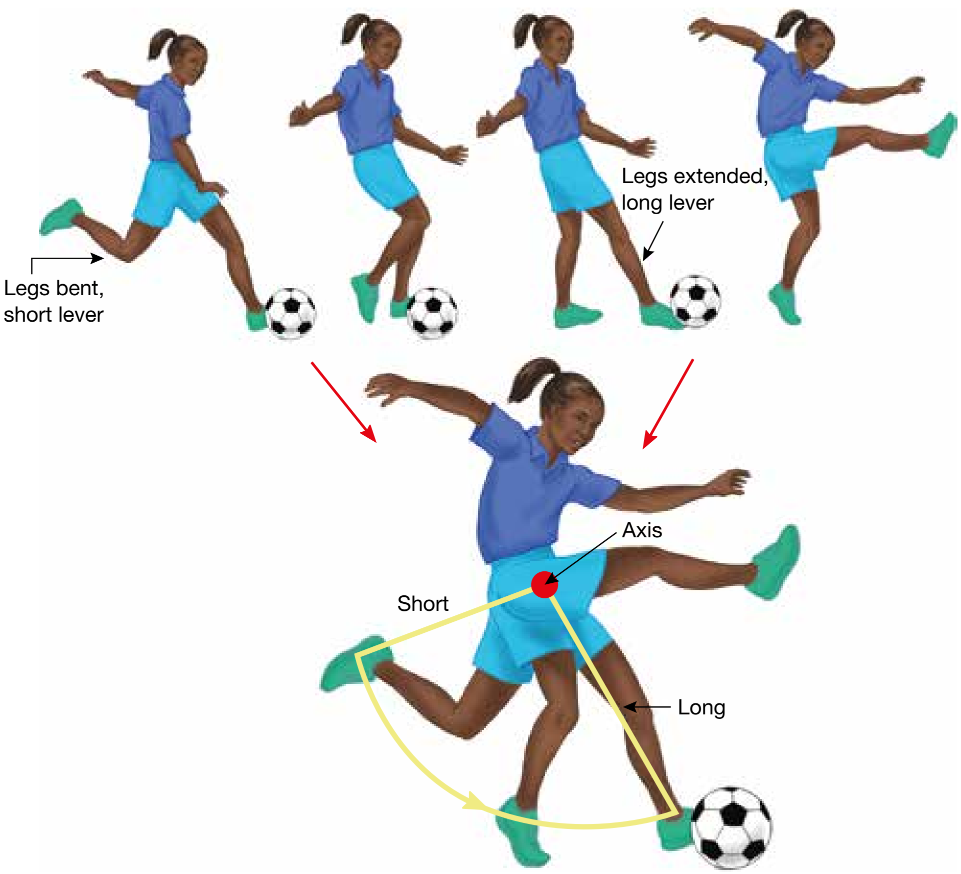


FIGURE 2.32 People can create short and long anatomical levers by moving their body parts to different positions, as shown here by the young soccer player.

FIGURE 2.33 This tennis serve shows the three components of a lever system: the axis, force and resistance.

There are many examples in and out of sport where equipment is used to enable human beings to generate force or speed more easily. Crowbars, wheelbarrows and scissors are examples of such equipment. There are three common components of levers.

- The **axis** is the turning point of the lever.
- The **force** is the point where force is applied.
- The **resistance** is the weight of whatever a person is trying to move (either the force of objects or the weight of body parts).

eBook*plus*

Digital document
Levers in sport
Searchlight ID: doc-3559

eBook*plus*

eLesson
Leverage
Searchlight ID: eles-2753

FIGURE 2.34 If you remember the acronym ARF, you will remember the central component of the three classes of lever in order.

Lever types

Levers are classified depending on the location of the axis, force and resistance in relation to each other. They are categorised as either a first class, second class or third class lever.

- First class levers have the axis as the central component that separates the force and resistance.
- Second class levers have the resistance as the central component that separates the axis and force.
- Third class levers have the force as the central component that separates the axis and resistance.

First class levers

An often used example of a first class lever is a simple see-saw. At either end of the see-saw are the force and the resistance, with the axis in the middle. The force comes from the person attempting to apply force to move the position of the person at the other end. The resistance is the weight of the person being moved.

There are limited instances of the human body acting as a first class lever. One example is your head and neck. To prevent the weight of your head bringing it forward, your neck muscles that sit posteriorly apply a force against the head (resistance). This enables the head to rotate back to an upright position.

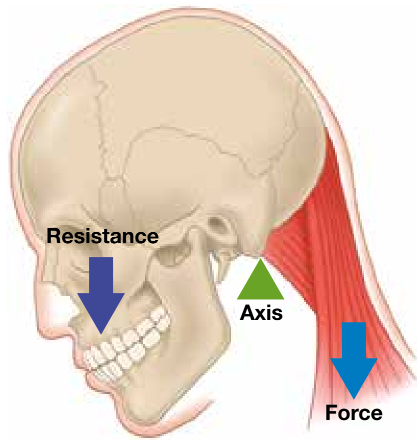


FIGURE 2.35 An example of a first class lever in the human body where the central point is the axis

FIGURE 2.36 An example of a second class lever in the human body where the central point is the resistance

Second class levers

Similar to first class levers, there are a few examples of the body acting as a second class lever. Second class levers have the resistance situated between the axis and force. A wheelbarrow is a second class lever, where the wheel acts as the axis, the load within the wheelbarrow is the resistance and the force is the pressure applied to the handles by the person moving the wheelbarrow.

An example of a human second class lever is when a person shifts their weight from having feet flat on the ground to standing on the balls of their feet (combination of the metatarsals and phalanges at the metatarsophalangeal joint). The metatarsophalangeal joint acts as the axis at one end of the lever. The resistance is the weight between the axis and the force applied to the heel bone by the two muscles at the back of the lower leg, the gastrocnemius and the soleus.

Third class levers

Third class levers are the most regularly used type of lever in the human body and when executing skills in sport. Whenever we kick a ball or strike an object with the hand or a racquet, the resistance is the weight of the object being struck and therefore is at one end of the lever system. To move a body part, a force needs to be applied by the muscles to change the angle of a joint (that acts as the axis). To enable this movement to occur, the muscles exert force to the bone via attachment to a tendon, which crosses the joint and applies force between the axis and resistance, hence becoming a third class lever.

Another example of a third class lever is the use of a fishing road. The resistance is the weight of the fish (or anything caught instead of the desired fish!), where the force is applied to the rod itself and the axis is the end of the fishing rod that will rotate when trying to move the load.

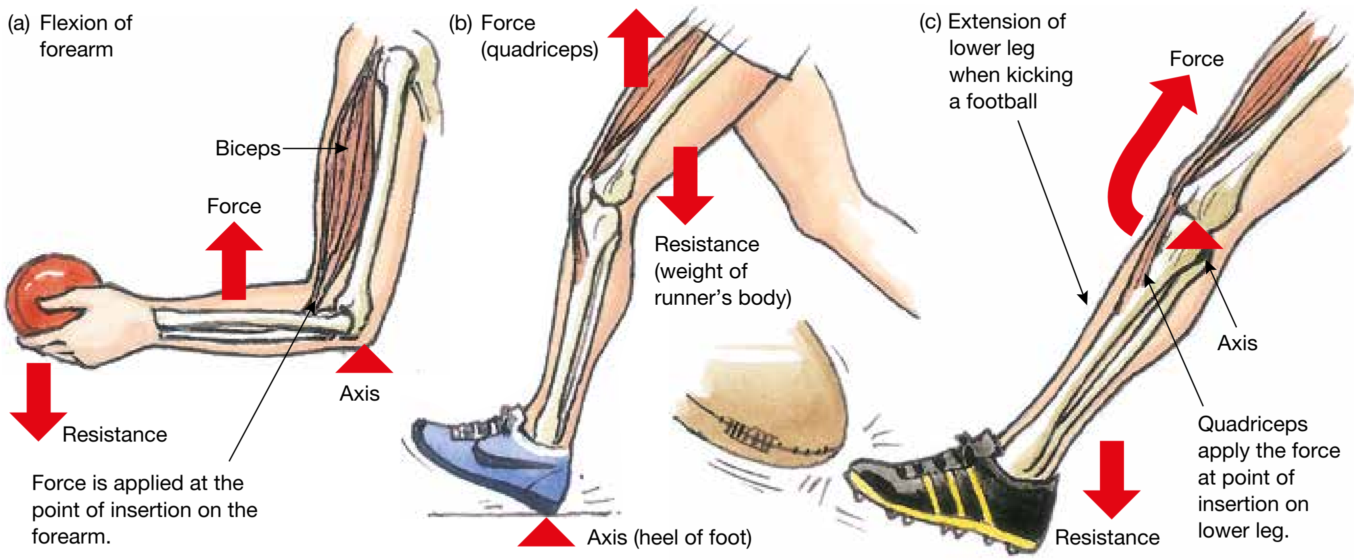


FIGURE 2.37 Examples of third class levers in the human body where the central point is the force

Using lever systems

Levers can have a significant mechanical advantage when used correctly. The actual advantages are often dependant not only on the type of lever used but on other factors, including the length of the force arm and the length of the resistance arm. The force arm refers to the distance between the force and the axis. The resistance arm is the distance between the axis and the resistance.

To determine the mechanical advantage over the use of the lever, the force arm is divided by the resistance arm.

Mechanical advantage = force arm/resistance arm

If the force arm is longer than the resistance arm, then the mechanical advantage is deemed to be greater than 1, where the force that is needed to move the load is less than the force of the resistance. In other words, less effort is required to move the resistance.

studyon

Unit 3 — AOS 1 — Topic 2 — Concept 7 — **Levers**

Equilibrium

Equilibrium is a term commonly used in sport. It refers to a state in which there is a balance of forces or influences in opposition to each other. Equilibrium is seen when all parts of a body are at rest, such as a ball stationary on the ground or a gymnast holding a handstand. This is an example of a body experiencing **static equilibrium**. Equilibrium can also be seen when all parts of a body are moving with the same constant velocity created by balanced forces. This refers to **dynamic equilibrium**.

Static equilibrium is the state in which a body has zero velocity and zero acceleration. A body is in equilibrium when the sum of all forces and the sum of all moments acting on the body are zero.

Dynamic equilibrium is the state in which a body is in motion with a constant velocity.

FIGURE 2.38 Static equilibrium

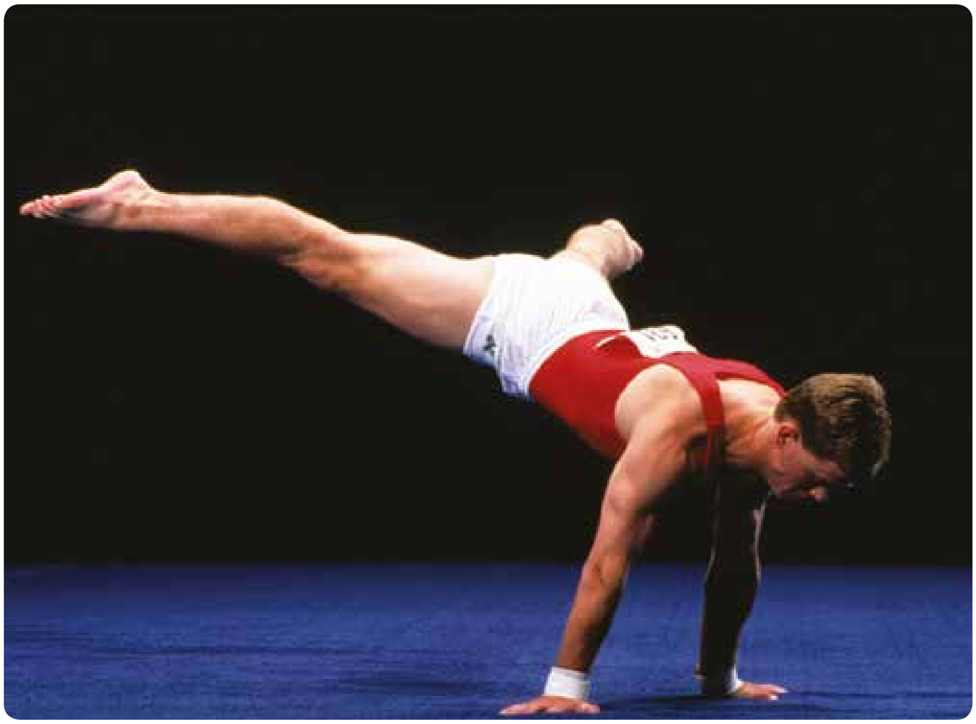


FIGURE 2.39 Dynamic equilibrium is required to move throughout a floor routine such as this with stability and strength.

Stability refers to the degree to which a body resists changing its equilibrium.

Balance is the ability to control the state of equilibrium.

Stability and balance

Stability and **balance** are important in many sports, particularly where force is required to move another human body, such as in a rugby scrum (or force is required to resist movement, such as the rugby player not wanting to be shifted).

The term 'stability' refers to the degree to which a body resists changing its equilibrium. Balance is the ability to control the state of equilibrium. This balance can refer to a person being in control of their body position while stationary, such as a gymnast holding a steady handstand. This is an example of static balance. Dynamic balance, on the other hand, relates to a person in control of their body position while moving. An example would be a squash player or netballer moving with speed and control on the court.

studyon

Unit 3
AOS 1
Topic 2
Concept 8

Stability and balance

FIGURE 2.40 Netballers use both static and dynamic balance on court: they need to be in control of their bodies while still and moving.

Some important stability definitions

The centre of gravity (COG) is the central point of an object, about which all of its weight is evenly distributed and balanced. This point shifts with every movement of the body.

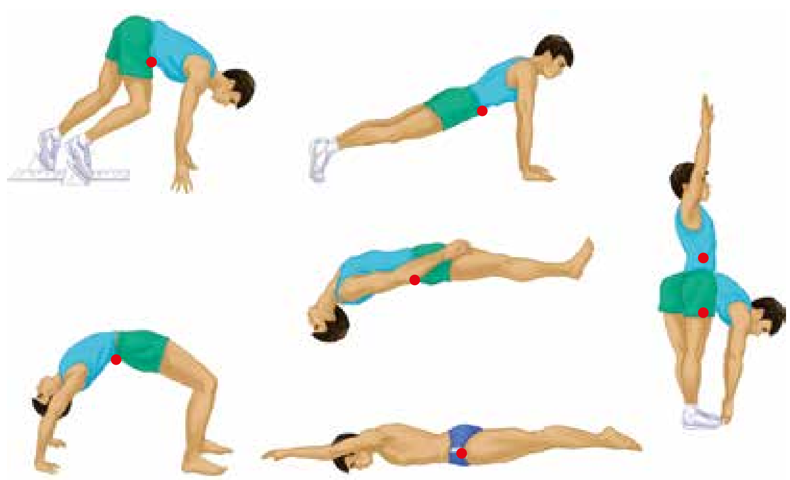


FIGURE 2.41 A person's centre of gravity moves when body parts are shifted from one position to another.

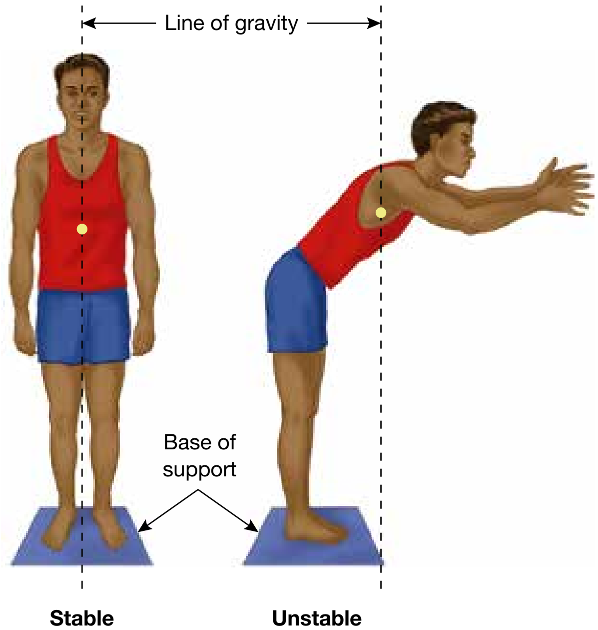


FIGURE 2.42 The further an object's line of gravity is from its base of support, the greater the instability and rotation.

The line of gravity is an imaginary line which passes through the centre of gravity and continues down into the centre of an object's base of support.

The base of support refers to the area of an object that is in contact with the surface supporting it.

Tips for increasing stability and balance

- Lowering an object's centre of gravity
- Ensuring the line of gravity is over the base of support
- Increasing the size of the base of support
- Increasing the friction between two or more bodies
- Increasing the mass of an object
- Extending the base of support in the direction from which a force is coming

There is a performance issue with being stable: the more stable an object or person is, the harder it is to shift. Think of a cricketer (a person batting) facing a fast bowler, or a 100-metre sprinter. In both of these instances, the person's ability to move quickly is diminished if their body is in a stable position. Instead, people adopt body positions where there is a degree of stability but from which they can can easily shift their body to an unstable (but controlled) position, allowing for quick movement. The cricketer, for example, will reduce their base of support by removing their heels from the ground. This also raises their COG and shifts their line of gravity closer to being outside their base of support.

FIGURE 2.43 By removing the front leg from the ground, the sprinter creates quick angular motion that enables him to accelerate out of the blocks. This is due to the line of gravity moving to well outside the base of support (back foot on the blocks) when the front leg is lifted.

studyon
Unit 3
AOS 1
Topic 2
Concept 9
Centre and line of gravity

studyon
Unit 3
AOS 1
Topic 2
Concept 10
Base of support

Tips for reducing stability and balance to promote agility

- Raising an object's COG
- Shifting the line of gravity outside the base of support
- Narrowing the base of support
- Decreasing the friction between two or more bodies
- Decreasing the mass of an object

FIGURE 2.44 Consider the two tennis players in this picture. The player in the red shirt has a wide base of support, which increases stability but negates agility. The player in the white shirt, on the other hand, has positioned his legs closer together, which promotes agility but reduces stability.

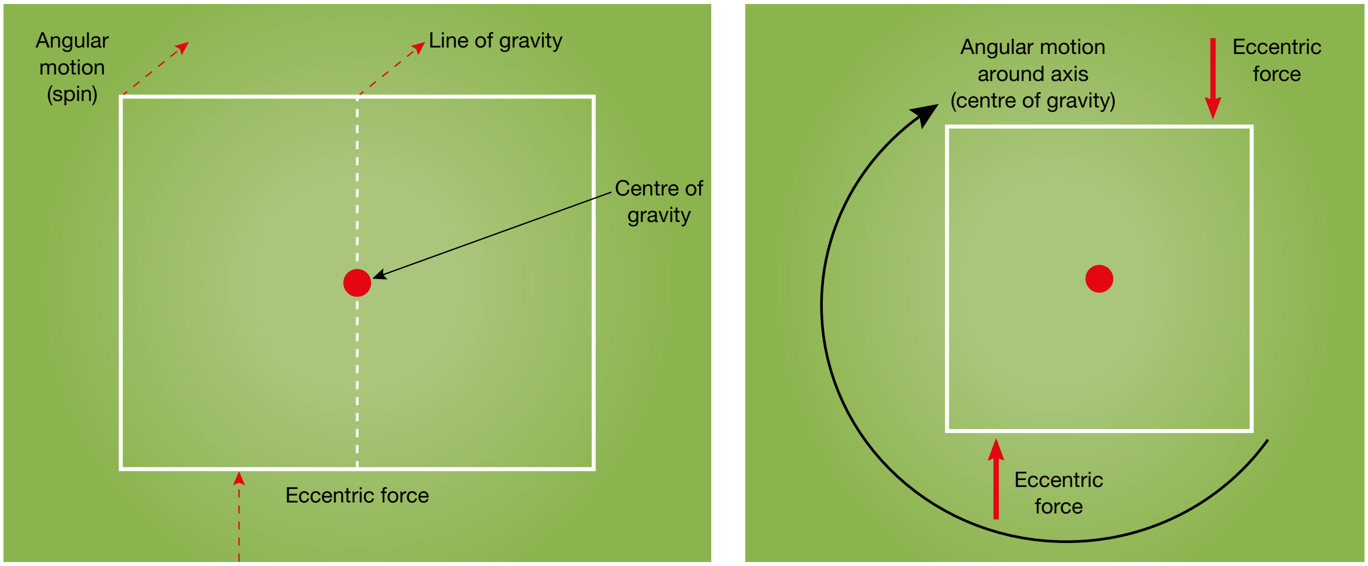
In many sporting instances, there is a need to promote angular motion. This is produced by a force that does not act throughout a body's COG. This is applied via an eccentric force that results in an object rotating, which in many sports is referred to as spin. This rotation is caused by torque, often referred to as the 'moment of force'.

Torque is dependent on two different factors:

- size of the applied force
- length of lever/moment arm (the distance that the force is applied away from the axis of rotation).

If two equal eccentric forces are applied in two opposing directions, then the object will rotate without moving from its position in space.

FIGURE 2.45 An eccentric force causes an object to undergo angular motion.



TEST your understanding

1 There are three classes of lever. Explain the difference between these.
2 Dividing the force arm by the resistance arm gives you what measurement?
3 Explain what is meant by the terms *static balance* and *dynamic balance*. Give an example of each in gymnastics.

APPLY your understanding

4 You are a sumo wrestling coach. Your task is to explain to your sumo wrestler how he can increase his stability and balance using the terms *centre of gravity*, *line of gravity* and *base of support*.
5 A tennis player serves with great velocity, using a racquet as a lever. At the point of impact, describe where the axis, resistance and force are. Use this information to identify the class of lever.

EXAM practice

6 Anatomical levers are used by athletes to promote performance.
(a) Define the term 'lever'. **1 mark**
(b) There are three classes of lever. Name the type of lever that is most common in the human body. What is the central component of this type of lever? **2 marks**
(c) Describe the difference between an anatomical lever and a non-anatomical lever. Use an example of each to help in your explanation. **3 marks**

KEY SKILLS

- Analyse, interpret and apply graphical, visual and physical representations of biomechanical principles to improve movement skills in a coaching context

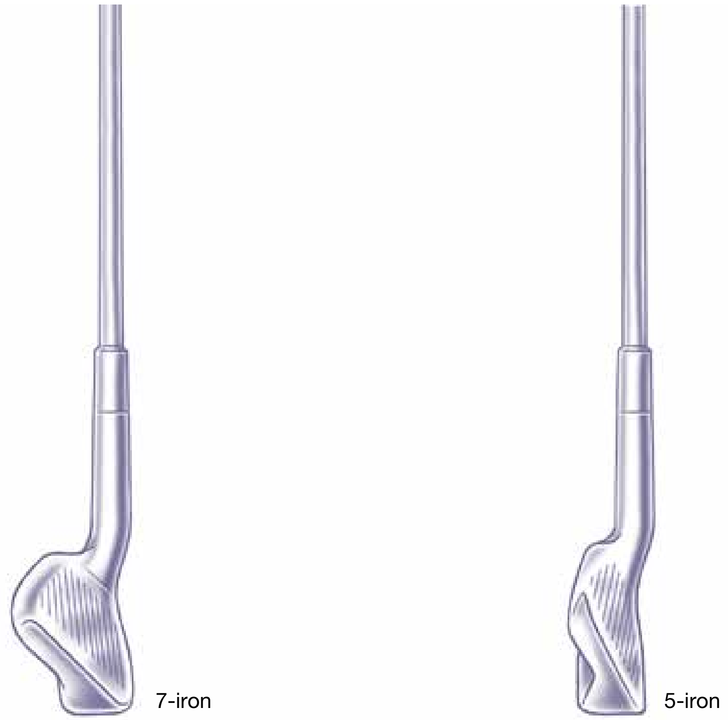
UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- Analyse and interpret information provided in a variety of formats that includes graphs, visuals (such as pictures) and digital media
- Apply knowledge acquired in a graphical or visual manner
- Answer structured questions that draw on primary data or secondary data that analyses a movement skill using biomechanical principles

PRACTICE QUESTION

1 A golfer chooses to hit with a 7-iron using maximal force off a tee, but the ball falls well short of the desired target. The golfer's playing partner suggested using a longer club, such as a 5-iron, which strikes the ball closer to its centre and therefore creates a reduced angle from the ground. The weight of the two golf clubs and their angular velocity at the time of impact are the same.



a. **Explain** why, using correct biomechanical terms, a longer golf club such as a 5-iron compared to a 7-iron would result in the golf ball travelling a longer distance. *5 marks*

b. **Draw** the likely differences in vertical and horizontal displacement between two golf shots, one using a 5-iron and one using a 7-iron struck, both struck with maximal force. *2 marks*

c. **Name** the predominant external force that impacts on the vertical displacement of the ball. *1 mark*

d. **Name** the predominant external force that impacts on the horizontal displacement of the ball. *1 mark*

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Explain — to make the meaning of something clear and understandable
  Draw — illustrate
  Name — identify or state
- **Key terminology:**
  Gravity — the predominant external force that acts on the vertical displacement of projectiles
  Air resistance — the predominant external force that acts on the horizontal displacement of objects
- **Key concepts:**
  Angular momentum — the product of angular velocity and moment of inertia
  Greater momentum — generated the further away the mass is distributed from the axis
- **Marking scheme:** a. *5 marks* b. *2 marks* c. *1 mark* d. *1 mark* — always check the marking scheme for depth of response required, linking to key information highlighted in the question.
- Please note that when asked to draw a graph, like that in b, make sure that both the x and y axis are labelled correctly.

HOW THE MARKS ARE AWARDED

a. **1 mark** for using the term *angular momentum*

1 mark for identifying that angular velocity is one of the components of angular momentum

1 mark for identifying that moment of inertia is one of the components of angular momentum

1 mark for identifying that the 5-iron's weight is distributed further from the axis so therefore greater momentum can be generated

1 mark for linking greater momentum generated by the 5-iron is transferred to the ball

b. **1 mark** for drawing a higher vertical displacement mapped to use of the 7-iron

1 mark for drawing a greater horizontal displacement mapped to use of the 5-iron

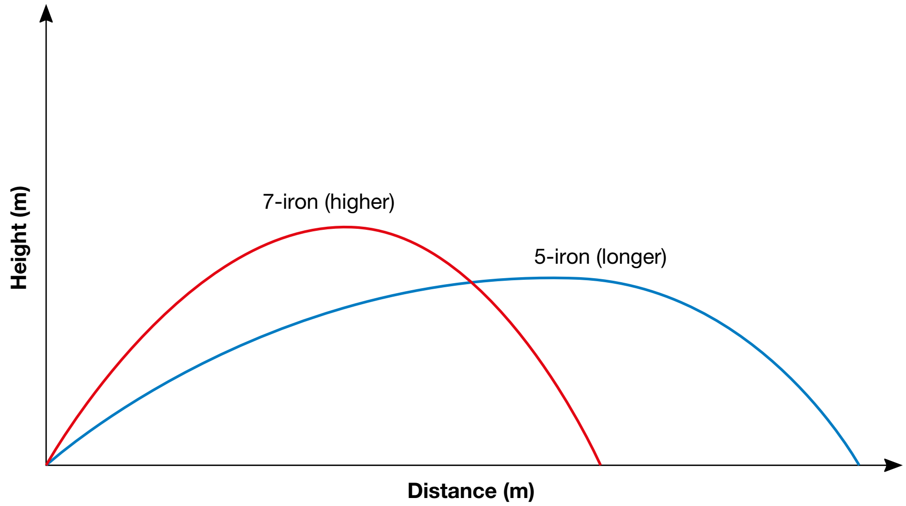
c. **1 mark** for identifying that the predominant external force which impacts on the vertical displacement of the ball is gravity

d. **1 mark** for identifying that the predominant external force which impacts on the horizontal displacement of the ball is air resistance

SAMPLE RESPONSE

a. The main reason why the 5-iron would make the golf ball travel further than the 7-iron would is due to the increased angular momentum that can be generated by using a longer club. Angular momentum is a product of angular velocity multiplied by the moment of inertia (mass of the object x distance the weight is distributed from the axis of rotation). In this case, the angular velocity and the mass were the same but the weight of the longer 5-iron would be distributed further away from the axis of rotation (shoulders) so therefore greater momentum could be generated and transferred to the ball.

b. In the following picture the vertical displacement should be drawn higher for the 7-iron.
In the following picture the horizontal displacement should be drawn further for the 5-iron.



c. The predominant external force that impacts on the vertical displacement of the ball is gravity.

d. The predominant external force that impacts on the horizontal displacement of the ball is air resistance.

CHAPTER REVIEW BIOMECHANICAL PRINCIPLES

CHAPTER SUMMARY

- Application of biomechanical principles can assist coaches and athletes to improve performance.
- Kinetics is a branch of biomechanics that studies the forces that cause motion.
- Kinematics is a branch of biomechanics that describes motion.
- Motion is typically described as angular, linear or a combination of these.
- Inertia is the resistance of a body to a change in its state of motion.
- Sufficient force must be applied to overcome inertia, having either a pushing or pulling effect on an object.
- Forces include those generated by the contraction of skeletal muscles, air resistance, gravity and friction.
- Momentum is the product of mass and velocity.
- Conservation of momentum occurs when two bodies collide or when momentum is transferred from one body part to another.
- Angular momentum is the product of angular velocity x moment of inertia (a measure of an object's resistance to changing its rate of rotation).
- Force summation involves the correct timing and sequencing of body segments and muscles through a range of motion.
- Newton's three laws of motion are used to describe the relationship between a body and the forces acting upon it.
- There is an impulse-momentum relationship where the greater the impulse, the greater the momentum.
- There is a distinct difference between the terms *distance* and *displacement* in biomechanics.
- Displacement is the difference between the initial position and the final position of an object.
- Speed is the rate of motion (distance/time), while velocity is displacement/time.
- Acceleration refers to the rate of change of velocity over time.
- As soon as an object or body is released into the air, it becomes a projectile and is automatically under the influence of two external forces: gravity and air resistance.
- Other factors that influence the trajectory of a projectile include: height of release, angle of release and speed of release.
- The term *lever* refers to a beam or rigid structure that rotates around a fixed point, commonly referred to as an axis.
- Levers are classified depending on the location of the axis, force and resistance in relation to each other. They are categorised as either a first class, second class or third class lever.
- Levers aim to provide a mechanical advantage to improve performance.
- Stability and balance are important in many sports, particularly where force is required to move others.
- There is a range of ways in which stability and balance can be altered to benefit performance.

eBook*plus*

Interactivity
Biomechanical principles quiz
Searchlight ID: int-6844

studyon

Sit VCAA exam

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 The study of the mechanical principles that govern motion is called
(A) kinetics.
(B) kinematics.
(C) biomechanics.
(D) dynamics.

2 Spin and rotation are common terms for which of the following types of motion?
(A) Curvilinear
(B) Angular
(C) Linear
(D) General

3 The correct unit of force is
(A) Newton.
(B) kilogram.
(C) metres per second.
(D) metres per second squared.

4 The correct formula for impulse is
(A) Force × Momentum.
(B) Force × Velocity.
(C) Force × Inertia.
(D) Force × Time.

5 A gymnast on a high bar spins one and a half full rotations. Her displacement is
(A) 180 metres.
(B) 180 degrees.
(C) 1.5 revolutions.
(D) 540 degrees.

6 In a 400-metre run, an athlete covers the first 50 metres in five seconds. The average acceleration would be
(A) 10 m/s.
(B) 10 m/s^2.
(C) 50 m/s.
(D) 50 m/s^2.

7 A badminton shuttle experiences greater air resistance than a tennis ball, primarily due to its
(A) mass.
(B) surface area.
(C) inertia.
(D) momentum.

8 Which of the following is an example of an anatomical lever?
(A) Throwing a shot
(B) A smash in tennis
(C) A badminton volley
(D) A table tennis serve

9 When a person is running, the prime resistance in a lever system is
(A) air resistance.
(B) gravity.
(C) friction.
(D) mass of body part being moved.

10 The most stable body position would be
(A) running.
(B) lying down.
(C) standing with legs spread.
(D) sitting.

TRIAL EXAM QUESTIONS

Question 1

Brooke Stratton set a new Australian women's long jump record in Perth during 2016 with a jump of 7.05 metres. Describing this achievement, a sports scientist said Brooke's jump was outstanding as she first had to overcome inertia and develop enough force during the run up to propel herself into the air for this performance. **9 marks**

a. Describe what the term *inertia* means. **1 mark**

b. Prior to Brooke moving, she has to overcome her static inertia. What is this static inertia directly proportional to? **2 marks**

c. After Brooke propelled herself into the air, she was confronted by two external forces that prevented her from jumping even further. Name these two forces. **2 marks**

For each of these forces explain how they acted on Brooke. **2 marks**

d. Describe what Newton's third law of motion states. **1 mark**

Use Newton's third law to describe how Brooke was able to run down the long jump track prior to her jump, explaining what the terms *equal* and *opposite* mean in this context. **1 mark**

Question 2

Two 13-year-old students competed in a 100-metre race during an athletics competition. The details of the two runners are provided below.

Runner 1
Rachael, who weighs 40 kg

Runner 2
Kylie, who weighs 60 kg

a. If Rachael and Kylie produce the same amount of force at the beginning of the race, explain, using Newton's second law of motion, who would be leading in the 100-metre race. **3 marks**

b. Use Newton's first law of motion to explain why Kylie would find it harder to slow down after the conclusion of the race. Use the key words *mass* and *inertia* in your response. **2 marks**

c. At the start of the race, both girls push back and down against the starting blocks with great force. Using Newton's third law, explain what occurs next and why. Why do the girls use great force? **3 marks**

INQUIRY QUESTION
How should coaches alter their instruction to cater for individuals with varying skill levels? How should coaches alter their instruction to cater for different types of movement skills?

CHAPTER 3 Coaching and instruction

There are different approaches to coaching and instruction. These reflect different methods of teaching movement skills, as well as sociocultural factors and theories about how people learn.

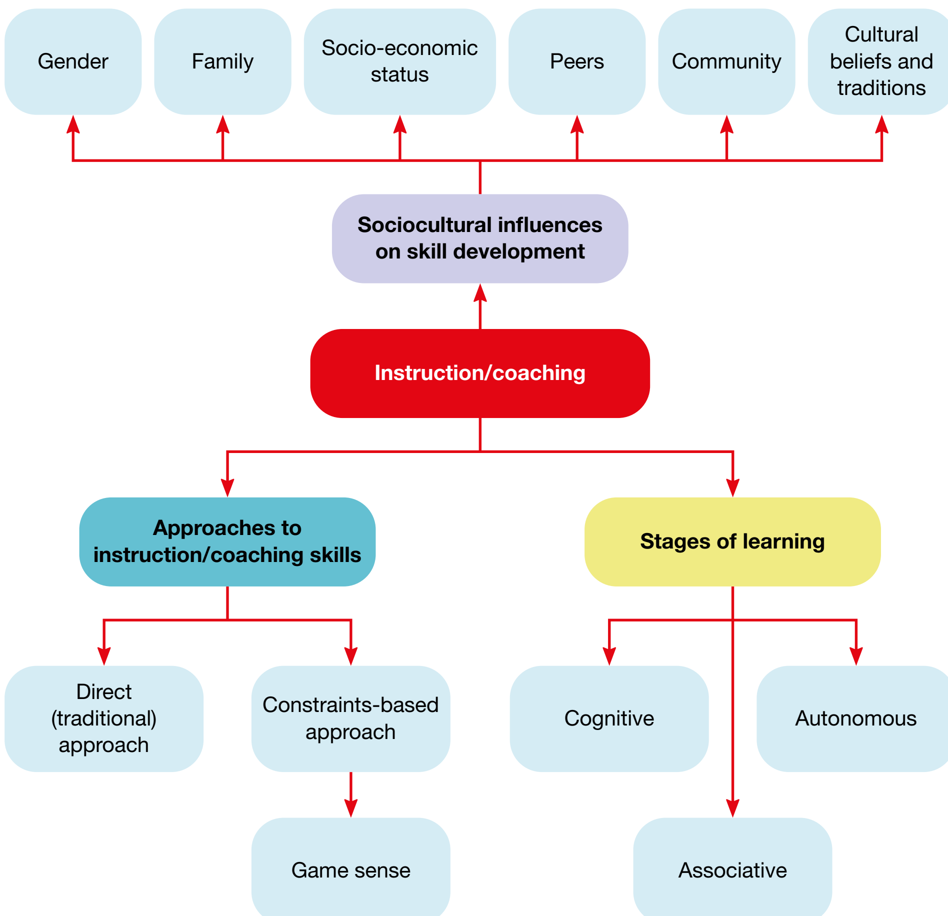
KEY KNOWLEDGE

- Direct and constraints-based approaches to coaching and instruction
- Sociocultural factors that have an affect on skill development, and the characteristics of the three stages of learning (cognitive, associative and autonomous)

KEY SKILLS

- Explain and apply theories of learning to practical coaching situations
- Explain sociocultural factors that influence movement skill development at different stages of learning

CHAPTER PREVIEW



3.1 The direct (traditional) approach to instruction

KEY CONCEPT The direct approach is an instructor-orientated approach to coaching movement skills, where the learner is told what to do and how to do it.

There are different methods of teaching movement skills. The direct approach to coaching is a 'skill and drill', instructor-driven method that is particularly effective at enhancing skill development in the early stages of learning. The constraints-based approach to coaching is a learner-driven method that develops both technical and tactical awareness through involvement in short-sided modified games.

studyon

Unit 3
AOS 1
Topic 3
Concept 1

The direct (traditional) approach to instruction Concept summary and practice questions

FIGURE 3.1 The direct approach is instructor-centred.

The direct approach, often referred to as the traditional approach, is a coach-orientated instruction model in which learners are given explicit instructions about skill execution and tactical awareness. In the direct approach, the instructor employs a more autocratic coaching style, organising highly structured drills and providing the bulk of feedback to the learner regarding their skill errors. In direct instruction, the learner is told what to do and when to do it.

The direct approach involves breaking sports down into technical skill components. For example, in tennis these skill components would consist of the ground strokes, both forehand and backhand, the volley, overhead shots and the serve. Often referred to as 'skill and drill' or the progressive part method, this approach dictates that athletes must learn and attempt to master these skill components in isolation, before applying them to a game situation.

FIGURE 3.2 Characteristics of direct instruction: breaking the skill down into simpler components, coach-orientated instruction and structured line drill

Skills are introduced to learners in their simplest form. As the learner becomes more competent through supervised drill practice, the coach introduces more complexity to the skill. For example, once the learner can perform the basic mechanics of a tennis serve, the coach may introduce the concepts of spin, speed and accurate placement. In time, the coach will move the learner from the predictable closed environment, practising the serve in isolation, to the less predictable open environment of serving to an opponent.

FIGURE 3.3 (left to right) Rafael Nadal and Gordon Reid executing complex skills in elite competition

The emphasis is on participants replicating the appropriate textbook technique. Once the learner is deemed suitably competent in these textbook techniques, they are considered ready for a competitive game.

'The traditional (direct) approach teaches the skills isolated from the game before putting the skills and game back together' (*Play with Purpose,* ACHPER 2009).

Explicit learning is learning that takes place as a result of direct instruction, where the performer is told what to do and when to do it.

The direct approach is based around coach-centred instruction, where the learner is a relatively passive receiver of information. The direct approach emphasises repeated supervised skill sessions in which the learning is **explicit** and the feedback comes from an external source; that is, a coach or teacher.

FIGURE 3.4 In direct instruction, the coach provides rules about how to interpret the competitive environment; for example, interpreting Alize Cornet's ball toss to anticipate the type of serve.

In a direct learning environment, participants receive explicit instructions about how to interpret visual cues in a game situation. The participants also receive implicit instructions about how to respond to these cues. In the sport of tennis, players are instructed to observe the service ball toss as a means of anticipating the type of serve they are about to receive. For example, a wide service ball toss is likely to suggest a wide swinging serve will be performed. For such a scenario, the receiver is explicitly instructed to adjust their court position to cover the swinging ball and look to strike the return down the sideline.

The direct approach is considered effective at facilitating skill development in the early stages of learning. This can be attributed to its emphasis on initially teaching simple skills in a relatively 'predictable' environment but also to a more regimented and instructor-driven approach that keeps the participants 'on task' and ensures the maximum use of practice time. In other words, prescribed learning goals are achieved through structured drills in an allotted period of time.

FIGURE 3.5 Line drills in junior soccer

Advantages of the direct approach

The direct approach has a number of advantages.

- The instructor-centred approach keeps the learners 'on task'.
- It provides a predictable/closed environment to assist the beginner skill learner.
- It facilitates early-stage skill learning.
- Improvements in practice performance are rapid compared with indirect instruction.
- There is an emphasis on mastering technique.
- The learner is provided with a set of rules to guide decision making.

Direct versus indirect instruction

Instruction or coaching can be classified on a direct/indirect continuum (see figure below). The indirect approach is more closely aligned with the constraints-based approach to coaching, which is discussed later in this chapter. While in the direct instructional approach the emphasis is on the learner following the coach's commands toward prescribed learning outcomes, the indirect approach allows the learner to discover effective skills and performance strategies for themselves.

eBook*plus*

Interactivity
Direct versus indirect instruction
Searchlight ID: int-6780

Direct ◄——►	Indirect
Coach-orientated	Learner-orientated
Explicit learning	Implicit learning
Autocratic	Democratic
Command	Cooperative
Prescribed learning outcome	Discovery-based learning

TEST your understanding

1. Explain what is meant by 'textbook' technique.
2. In the context of instructional approaches, what does it mean to be 'coach orientated'?
3. List two advantages and two disadvantages of the direct approach to instruction.
4. With the use of a coaching example, explain what is meant by *explicit learning*.

APPLY your understanding

5. **Practical activity: direct coaching of your peers**

The aim of this learning activity is to assess the effectiveness of the direct style of instruction.

Equipment: Relevant to chosen sport.

Method: Work in pairs or small groups. Each pair or group teaches the remainder of the class a sport of their choosing. The practicalities of the sport will have to be discussed with your teacher.

Direct coaching method
The aim is to put the class through an explicit learning experience; that is, the class is given detailed instructions regarding what to do and how to it.

Your session should include the following:

- a structured warm-up with moderate aerobic exercise and stretching
- individual and/or pair skill work
- line drills
- a gradual progression of skill complexity
- a gradual introduction of competition to the practice session.

Finish with a match.

Discussion

(a) How effective was your direct coaching session in facilitating skill learning within the practice drills?
(b) How effective was your direct coaching session at transferring learning from practice drills to the competitive game?
(c) If you were to repeat the exercise, what would you change about your coaching session to make it more effective?
(d) Did the direct method of instruction help you manage a relatively large class size? Explain.

3.2 The constraints-based approach to instruction

KEY CONCEPT The constraints-based approach to instruction encourages the learner to discover effective skill technique and develop tactical awareness through participation in short-sided modified games.

The direct approach encourages the learner to master skills in isolation, in a closed and predictable environment, before applying these skills in a less-predictable game situation. A potential weakness of this approach is that skills developed in isolation may lack the necessary complexity or adaptability to be effective in a game. Furthermore, the learner may not develop sufficient tactical awareness to be an effective competitor.

However, the constraints-based approach to instruction differs from the direct approach by seeking to develop effective movement skills within a game context. Rather than focusing on mastering 'textbook techniques' and then attempting to apply them within a game, the constraints-based approach places the learner in a game context as soon as it is practical to do so. There may be some initial rudimentary skill development; however, participants are placed in game situations at an early stage of learning, unlike the direct approach that delays game exposure to the latter stages of learning.

FIGURE 3.6 In constraints-based instruction, the learner is immediately involved in short-sided modified games.

In constraints-based instruction, the learner is immediately involved in short-sided, modified games, the purpose of which is to develop both technical and tactical awareness. Through the process of finding solutions to games-based challenges, the learner discovers and develops effective motor skills. Furthermore, the learner develops a sense of when and how to perform these skills within the context of a competitive environment. Hence the constraints-based approach improves the learner's decision-making as well as their movement skill execution.

The constraints-based approach is an *indirect instructional method* with an emphasis on learner-centred practice. The coach takes the role of a facilitator in a process of guided discovery where the learning is **implicit** rather than explicit.

Implicit learning is learning through doing. The participants learn through completing a task.

Constraints-based instruction facilitates what is known as **perception–action coupling**. Perception–action coupling describes the reciprocal relationship between what the performer sees (perception) and the actions they take; that is, the performer's perception influences their actions and, in turn, their actions influence what they see. This relationship between perception and action underlines the importance of using games in practice.

Perception–action coupling describes the reciprocal relationship between perception and action.

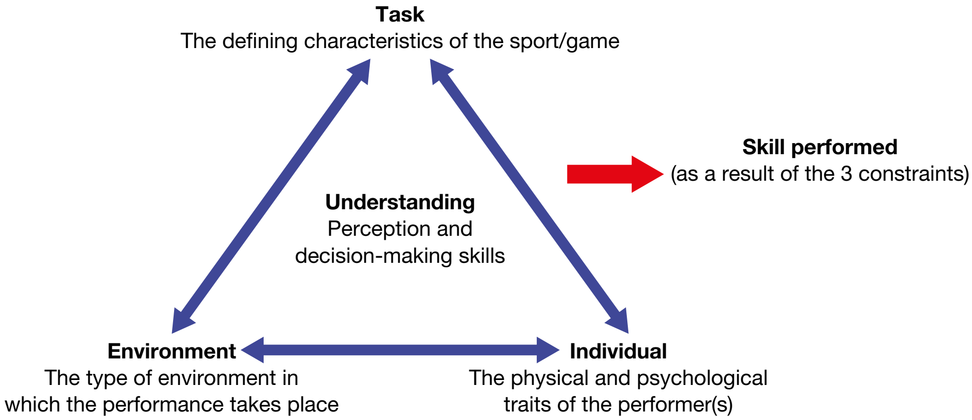
FIGURE 3.7 A batsman facing bowler Solomon Mire must interpret visual cues, e.g. action, body position and ball grip, and choose the appropriate skill to perform.

For example, a batsman in cricket learns to interpret (*perception*) a bowler's action and the bowler's grip on the cricket ball to predict the type of delivery before playing the appropriate shot (*action*). This may not happen if a batsman is only exposed to 'throw downs' — a coach throwing the ball to a predetermined length (spot on the cricket pitch) to replicate and perfect a prescribed technique, for example an 'off drive'.

Central to constraints-based learning is the understanding that all performance is influenced by three fundamental boundaries or constraints. These constraints are:

1. Individual
2. Environmental
3. Task

The coach manipulates these constraints during practice to achieve a desired learning outcome.



Source: Adapted from Renshaw, Chow, Davids & Hammond, 2010.

FIGURE 3.8 Skill as a product of three constraints: task, individual and environment

Individual constraints

These are the physical, psychological and behavioural characteristics of the individual performer. They include such things as height, weight, fitness, motivation, confidence, decision-making skills and learning styles.

For example, the decision-making skills an individual has developed by playing a particular team sport maybe transferrable to other team sports.

FIGURE 3.9 Individual constraints impact task performance

Environmental constraints

These are the characteristics of the environment in which the performance takes place. These include physical characteristics such as climate, the playing surface and stadium lighting. Environmental constraints can also include social factors such as the influence of peers and cultural norms. For example, different cultures and nationalities identify with particular sports. In India, cricket is extremely popular and this facilitates the development of skills such as throwing, catching, batting and bowling.

FIGURE 3.10 Environmental constraints include the influence of cultural norms; in India the popularity of cricket facilitates the development of specific skills.

Task constraints

Task describes the defining characteristics of the activity/sport. Task constraints explain the *goal* of the sport, for example kicking the soccer ball into the goal; task constraints describe the *rules* of the sport, for example soccer players may not use their hands (apart from the goalie); and task constraints describe the equipment and facilities used, for example the dimensions of a soccer field and the size of the soccer ball.

FIGURE 3.11 Task constraints explain the goal of the sport; for example, hitting the bulls-eye in archery.

studyon
Unit 3
AOS 1
Topic 3
Concept 2
The constraints-based approach to instruction
Concept summary and practice questions

Using constraints to teach a skill

The aim of constraints-based instruction is for the coach or teacher to manipulate the constraints, particularly the *task constraints*, to achieve a desired learning outcome.

For example, a coach wants his junior soccer players to pass more frequently and effectively. Using the constraints-based approach, the coach designs a short-sided game that helps the young soccer players to discover and understand the importance of passing. In this example, the coach manipulates constraints to encourage effective passing and deters the player's natural inclination (Individual) to show off their dribbling skills.

The goal of the game is for the team in possession to move the ball from one side of a defended area to the other. The coach designs/manipulates the game rules (Task) to limit the player's capacity to dribble by adopting a maximum three seconds possession rule. A team that successfully crosses the area also gains a bonus point if every member of their team possesses the ball (Task) — that is, they are encouraged to share the ball.

The young players discover their best chance of success (moving the ball the length of the field) is to employ quick passes, utilising all of their teammates.

The passing game style is further entrenched and encouraged by the coach engendering a team culture (Environment) that rewards selfless play and sharing the ball.

FIGURE 3.12 Short-sided modified game

Constraints-based instruction facilitates learning through manipulating boundaries or constraints to enable the learner to find a movement solution. The learning is discovery-based and guided by an experienced coach. (Renshaw, Chow, Davids & Hammond, 2010). In constraints-based instruction, such as the previous soccer example, the learning is implicit; that is, the players learn through participating in an activity. Through participation in games, the players discover what is required for successful skill execution and effective decision-making. Furthermore, a player who learns in this implicit manner, whose skills are forged within a competitive environment, is less inclined to compromise their skill execution or 'choke' (see explicit vs implicit instruction opposite) under the pressure of competition.

In constraints-based instruction, participants become autonomous or independent learners who are not overly reliant on a coach's instructions. Independent or autonomous learners are better equipped to solve the unexpected problems and challenges they encounter in competitions.

Another advantage of constraints-based instruction is that practice sessions are more varied and interesting, marking a departure from 'boring' repetitious drills associated with direct coach-centred instruction.

eBook*plus*

Interactivity
Constraints-based approach
Searchlight ID: int-6781

Modified junior sports

Task constraints such as equipment, court size and competition rules should be modified to enhance skill acquisition in children. Lighter racquets and bats, smaller court sizes and rules that encourage maximum participation and reduced physical contact are all examples of modifications necessary to ensure children enjoy their sporting experience. These modifications enable children to learn the applicable movement skills as well as begin to understand game tactics. If children use equipment designed for adults, they are less likely to experience performance success. Inappropriately heavy and/or oversized equipment can also lead

FIGURE 3.13 Children's capacity to learn is compromised if they are forced to use adult-sized sporting equipment.

to children developing skill techniques that compromise future development in their chosen sport. For example, a 7-year-old basketballer using an adult-sized basketball on a full-sized ring may be forced to shoot with two hands or adopt a throwing-like action in order to score. With a smaller ball and a lower ring, the young basketballer can experience success utilising a traditional shooting action — a technique he/she will rely upon to progress to more senior basketball competition.

Many sports have developed modified games, acknowledging the importance of changing task constraints to make the experience more fun for children and to facilitate skill development. Examples of these modified sports include 'Kanga Cricket', 'Netta Netball', 'Auskick' AFL football and 'Hot Shots' tennis.

In 'Hot Shots' tennis, children use a smaller court and larger, less-bouncy tennis balls. The modified tennis balls encourage the beginner to hit confidently and help to facilitate longer rallies. The smaller court size is more manageable and assists the young learner to start developing tactical awareness.

Explicit vs implicit instruction

Reinvestment — making mistakes under pressure

At times of stress, when the performer is highly invested in their relative success, when the 'stakes are high', there is a tendency for the explicit learner to direct too much attention to technical issues (how to perform the skill) at the expense of fluent skill execution.

That is, the learner suffers from what is known as reinvestment: the tendency to consciously attend to the rules and knowledge that underpin the skill in an attempt to control the quality of performance. Reinvestment can reduce the performance of an expert/autonomous performer to the standard of a relative beginner. However, implicit learners, whose skills are developed within the context of a games environment, tend to be less susceptible to the effects of reinvestment.

FIGURE 3.14 Use of metaphor (shape of an arrow) to simplify skill performance is an implicit coaching strategy.

Implicit instruction — use of metaphors

The use of a metaphoric analogy is an effective implicit coaching strategy as it gives the learner a simple focus and reduces the technical information they need to process. For example, a swim coach tells his young swimmers to make their bodies into the shape of an 'arrow' as they push off the end of the pool. Long-winded explicit technical instruction about arm, leg and body position is avoided as this is implicit in the roleplay or analogy of the arrow.

Advantages of the constraints-based approach to instruction

- Practice closely replicates the game environment, facilitating the development of more applicable skills.
- Practice is more varied ensuring the development of versatile skills, as well as providing the learner with a more interesting and engaging learning environment.
- The learning is implicit.
- Implicit learners make better problem solvers and are less likely to choke at times of stress.
- It develops both technical and tactical awareness.
- It engenders independent/autonomous learning.

Game sense approach — a constraints-based approach to instruction

Game sense is a method of teaching tactical awareness and effective skill performance through game constraints modification and the use of guiding, open-ended questions.

In Australia, the most commonly used constraints-based instruction model is **game sense**. Game sense is a means of coaching or teaching that uses small-sided modified games to develop tactical and strategic thinking, as well as movement skill performance. Game sense is an Australian adaptation of the Teaching Games for Understanding Model (TGFU) (Thorpe, 1996).

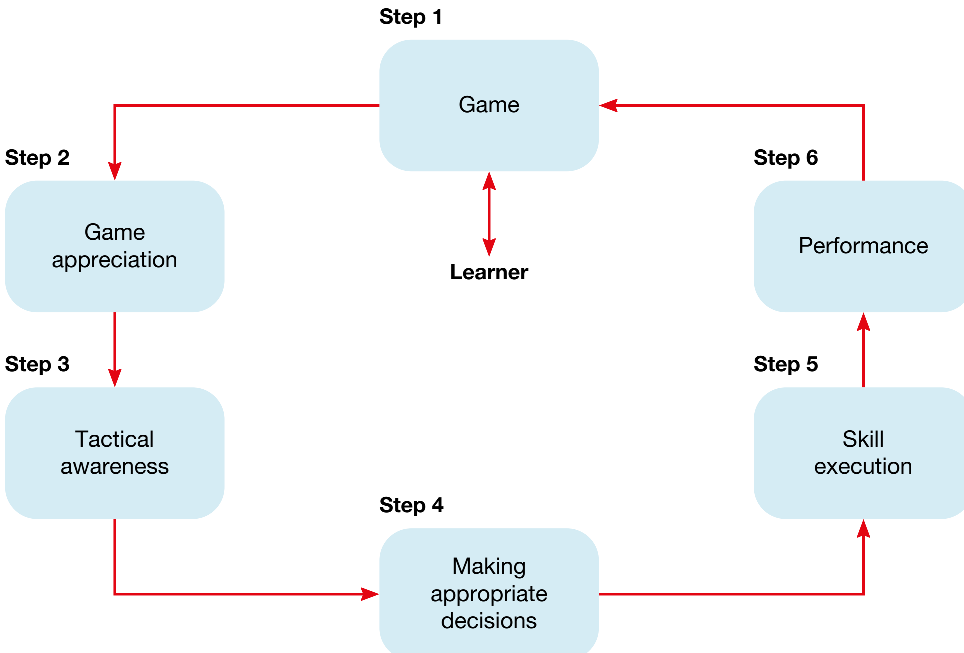


FIGURE 3.15 The game sense approach seeks to teach game appreciation and tactical awareness prior to teaching movement skills.

Source: Adapted from Werner, P, Thorpe, R & Bunker, D 1996, 'Teaching games for understanding: evolution of a model', *The Bulletin of Physical Education, Recreation and Dance*, vol. 67, no. 1, p. 29.

The core elements of game sense

A game sense approach to coaching consists of five core elements:

1. Designing modified short-sided games to simulate the decision-making and movement skill demands found in the relevant sport. These modified games improve a player's competitive performance by heightening their tactical awareness and improving their ability to apply the relevant movement skills.

FIGURE 3.16 Coaches use guiding questions to facilitate learning.

2. Coaches use questioning to guide the learning process. For example, in a 2-on-1 game the coach 'freezes' (stops) play and asks the participants: *How do you draw the defender before passing to your teammate?*
    - Questions should be open-ended to encourage the learner to think for themselves.
    - Questions should cover four fundamental concepts:
        1. TIME — when should you . . .?
        2. SPACE — where should you . . .?
        3. RISK — which option . . .?
        4. EXECUTION — how should you . . .?
3. Establishing an environment where learning occurs through problem solving. Learners tend to be more motivated in discovery-based instruction as they take ownership of the learning process.
4. Constraints are manipulated to emphasise a particular learning goal regarding tactical/strategic awareness and skill application.
5. Sports are classified into four game categories (see table 3.1):
    - Invasion games (for example, soccer and netball)
    - Striking field games (for example, cricket and basketball)
    - Net/court games (for example, tennis and badminton)
    - Target games (for example, archery and shooting).

    All sports have their unique characteristics however, sports grouped in the same games category share common principles of play. Hence the tactical knowledge and decision-making skills you develop in one sport are easily transferred and applied to other sports within the same category. For example, a modified game designed to encourage effective passing in soccer could easily be adapted for use in another invasion game such as netball.

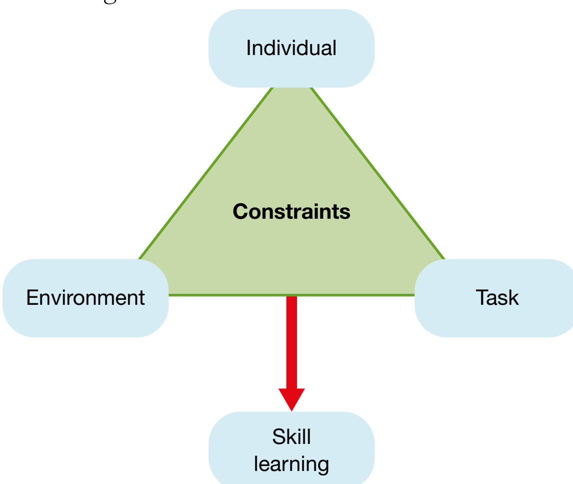


FIGURE 3.17 Performance constraints

TABLE 3.1 A brief overview of the fundamental concepts for each game category

Category	Team in possession	Team without possession
Invasion	• Use a safe pass • Move to create or receive a pass • Advance to score	• Pressure the ball/receiver • Track a player and the ball • Use a zone or one-on-one defence to cause a turnover of possession
Striking/fielding	• Maximise time batting • Maximise runs scored	• Minimise time in the field • Build pressure • Minimise unnecessary score (e.g. leg byes, no balls, four-ball walks)
Net/court	• Place object within boundaries where it cannot be returned	• Return object within boundaries
Target	• Place object as close as possible to intended target	• Prevent or protect object from being placed nearest to the target

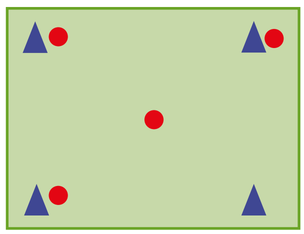
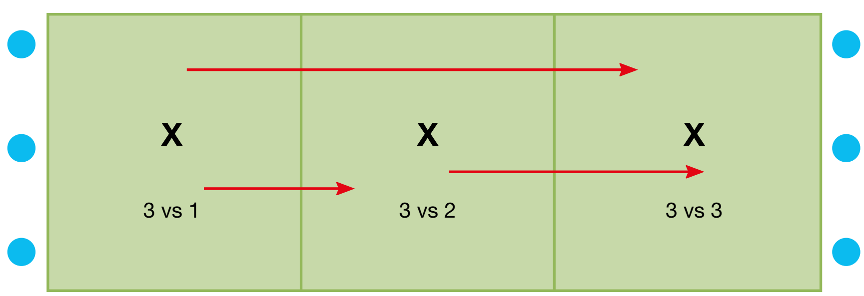
In a game sense approach, a coach still has an obligation to identify poor technique. However, while technical faults should be addressed, the fundamental difference to the direct approach is that skill correction and refinement occur within the context of the games environment, ensuring the development of applicable movement skills.

eBook*plus*
Interactivity
Fundamental concepts for each game category
Searchlight ID: int-6782

Comparing different instructional approaches to the same sport

In this example, the sport is junior basketball and the learning objective is effective passing.

TABLE 3.2 Comparison between the game sense approach and the direct approach to instruction

Direct approach	Game sense approach
Warm-up — 10 minutes jog and stretching — Passing in pairs	**Warm-up** — 3 vs 3 Short-sided games — keepings off. The aim is to maintain possession for as long as possible.
Instruction and demonstration Coach gives instruction about how to perform different passing techniques. The coach uses the most accomplished player to demonstrate different passing techniques: bounce pass, overhead 'soccer' pass, chest pass and lob pass. Players return to passing in pairs Coach provides feedback on players' passing technique, drawing attention to skill errors and encouraging the necessary modifications.	**Short-sided modified game 1 — 'Three Point Square'** The three players in possession of the ball pass along the length the of the square, not the diagonal. Players in possession run between cones to ensure the player with the ball always has two passing options. A single defender tries to intercept the passes.  **FIGURE 3.18** Three Point Square **Freeze play — play analysis**. Coach question: What have you learnt about making sure your pass hits its intended target? **Continue 'Three Point Square' with constraint modification to enhance learning objective:** Reduce the size of the square to make it easier for the defender to intercept the pass, placing more pressure on passing.
Line drills focusing on passing Players organised into opposing single file lines. Players dribble then pass between opposing lines. Coach modifies line drills to make them more challenging such as criss-crossing the lines or having the players pass the ball in pairs as they 'run the court'. Coach instructs players to pass the ball some distance 'in front' of the moving receiving player	**Short-sided modified game 2 — 'Build the Pressure'** See figure 3.19. Teams of three attempt to move the ball through three designated areas. With each new area, another defender is added and the task becomes increasingly difficult.  **FIGURE 3.19** Build the Pressure **Freeze play — play analysis** Coach question: What's the best way to 'draw' a defensive player before passing to a teammate? **Continue 'Build the Pressure' with constraint modification to enhance learning objective:** Add an extra defender to the first square to make the progression: 3 vs 2, 3 vs 3 then 3 vs 4 to make the game more challenging and to encourage fast, decisive passing. **Freeze play — play analysis** Coach question: What type of pass worked best in particular game situations?

Direct approach	Game sense approach
Coach organises the players into a 2 vs 1, introducing a competitive element to the practice. Coach instructs the players in possession to keep width and encourages the 'early' pass.	**End Game** — 3 vs 3 half court game. Team that scores keeps possession. Bonus point awarded for three or more passes before a successful shot or lay-up — an implicit coaching strategy to encourage passing.
End game — full court match	Coach and players discuss what they have learnt and where they can make future improvements.
Cool-down Coach provides feedback on performance and outlines strategies for future development.	Players cool down

TABLE 3.3 Direct versus indirect

Advantages and disadvantages of coaching approaches			
Instructional approach	**Emphasis**	**Advantages of the approach**	**Disadvantages of the approach**
Direct (traditional)	• Explicit learning • Coach/instructor centred • The learner is a passive receiver of information • Skill and drill • Skill learnt in 'isolation' prior to game participation • Learner aspires to textbook technique	• Time efficient • Maximises practice time • Keeps learner 'on task' • Effective in the early stages of learning • Learning is immediately evident • Emphasis on developing 'sound' technique	• Boring repetitious drills • Risk of learner being unable to apply skills in a game situation • Learners become overly dependent on coach's instructions for successful performance • Does not develop decision-making skills • Learner is more at risk of choking under pressure
Constraints-based (including game sense)	• Implicit learning • Learner centred • Discovery-based learning • Learner solves problems • Small-sided modified games • Perception–action coupling • Coach is a facilitator not an instructor • Game categories, e.g. invasion games	• Practice sessions mimic game performance • Skills developed are applicable to games environment • Development of tactical/strategic awareness and decision-making skills • Motivating — participants empowered to find solutions • Learning transferrable between sports in same categories • Greater variability in practice • Skill performance is resilient to competitive pressure • Cultivates the independent/autonomous learner	• Technical skills may lack refinement • Coaches often less familiar with game sense approach • A less regimented and structured approach may not suit coaching large groups or younger athletes • May take longer to achieve results

TEST your understanding

1 What is perception–action coupling?
2 Name and explain the three performance constraints.
3 Explain the difference between implicit learning and explicit learning.
4 Discuss two advantages and two disadvantages of the constraints-based approach to coaching movement skills.
5 Outline the five core elements of the game sense approach.
6 Explain how a coach uses questioning to guide the learning process.

APPLY your understanding

7 Watch footage of an elite team sport. Choose a position (for example, a striker in soccer) and identify the constraints and how these constraints impact on this player.
For example: *Soccer*. Position: *Striker*
Task: The striker must time their forward runs carefully so as not to be off-side and taking a 'shot' on goal.
Individual: The striker uses their agility to evade defenders.
Environment: The striker takes account of the conditions when choosing the type of shot on goal. For example, choosing a low 'skidding' shot at goal with a waterlogged ball rather than unsuccessfully attempting to 'bend' the ball by imparting spin.

8 Classify the following sports into one of the four games categories: Invasion, Striking/fielding, Net/court or Target.
- croquet, ultimate frisbee, Gaelic football, curling, golf, baseball, hurling

9 **Practical activity: designing and teaching a game sense practice session**
The aim of this learning activity is to design and run a game sense practice session with your classmates.
Equipment: relevant to chosen sport
Method
Work in pairs or small groups. Use the **Designing and teaching a game sense practice session** document in your eBookPLUS to design your session. Remember, game sense uses implicit learning. That is, your classmates should learn the relevant skills through involvement in your modified game rather than receiving direct coach's instruction.
For example:
Aim: improve basketball shooting
Modify game: team knockout competition
Guiding question from coach: Is your shooting percentage better or worse when you have a balanced stance?
Modification: Give each team two balls to increase the speed of the game.

Discussion
(a) Did the students' skill performance improve during the course of the session?
(b) Were the students actively engaged in this practice session? Outline the influences on the students' and how the modified games affected the students' motivation.
(c) Speculate as to whether transfer of learning would be more or less from this game sense practice in comparison with a direct coaching session. Discuss.

EXAM practice

10 **ACHPER Trial Exam Unit 2 2014**
Decision-making in sport
'Sports have traditionally been taught using the "skill and drill" or progressive part method. Sports are broken down into their component skills and these are then taught. This technical approach, developed after World War 2, taught the skills isolated from the game and then the skills and the game are put back together. This method assumes there is only one right way to perform a skill, but we know from observation of elite sportspeople that frequently they don't kick the ball or swing the racquet like the ideal model. Successful sport athletes often do not have perfect stylised technique, frequently having individual technique differences and successful unorthodoxies. The other problem with this technical approach is that the thinking and problem-solving aspects required for successful game performance are not central to the initial learning as the technical requirements are isolated from the game in skill drills.'
Source: *Sports Coaching Magazine*, Volume 29 Number 2.
(a) Clearly demonstrate the difference between the above model of teaching a sport and game sense by outlining a typical training session for each for the sport of basketball. **4 marks**
Traditional method:
Game sense method:
(b) Each model has a place in all sports. Briefly discuss an advantage and disadvantage of each of the above models, and in doing so suggest when each model is best used. **4 marks**

	Traditional	Game sense
Advantage		
Disadvantage		

(c) Identify and justify which sport category is appropriate for basketball. **2 marks**

eBook*plus*
Digital document
Designing and teaching a game sense practice session
Searchlight ID: doc-21026

3.3 Stages of learning

KEY CONCEPT The skill learner's pathway from complete beginner to expert performer is characterised by three distinct stages of learning. Each stage of learning requires different practice and instructional strategies to ensure further skill development.

To design an effective skills training session, a coach needs to take into account the skill level of the learner. That is, the coach must be able to successfully match the learning needs of the performers with the appropriate learning environment. For example, the structure of an effective practice session for a novice performer will be significantly different from a practice session designed for an expert/elite performer.

The stages of learning model classifies learners into three distinct learning stages:

1. Cognitive (*Beginner stage*)
2. Associative (*Practice stage*)
3. Autonomous (*Expert stage*)

Each of these stages describes the characteristics of the learner as they progress from novice performer (cognitive stage) to an intermediate level (associative) and finally to skill mastery (autonomous).

Understanding a performer's stage of learning helps the coach decide on the most appropriate type of instruction and the most effective way to structure the practice session (covered in more detail in topic 4).

FIGURE 3.20 A continuum from novice to skill mastery

While the model describes three distinct stages, it's best to think of the stages of learning as a continuum where learners transition gradually from one stage to the next.

How quickly a performer moves through these stages of learning will depend on the skill being taught, the characteristics of the learner and the type of instructional and practice environment. It should also be noted that not all performers will reach the autonomous stage. For example, the demands of the skill may surpass the relative ability of the learner and/or the learner is not exposed to appropriate practice or suitable instruction.

Cognitive stage

The **cognitive stage of learning** describes the novice performer. In the cognitive stage the learner must dedicate a substantial amount of **attention** to understanding the skill and how to perform it. The performer makes many skill errors and struggles to understand why the errors occur or how to correct them.

Learning in the cognitive stage takes place largely through 'trial and error'. The cognitive stage is usually the shortest of the three stages, as improvements in skill performance tend to be rapid early in the learning process.

The **cognitive stage of learning** is the initial phase of learning of a motor skill where the emphasis is on conscious understanding of the task requirements.

Attention refers to the amount of mental concentration or thought required to complete a task.

study on

Unit 3	**Stages of learning: Cognitive** Concept summary and practice questions
AOS 1	
Topic 3	
Concept 3	

Coaching the cognitive stage

- As the performer must dedicate a considerable amount of attention to understanding the skill, it is important the coach does not overload his or her learners with information. Coaches should keep feedback simple, only providing one or a maximum of two teaching points at any one time.
- Performers in the cognitive stage of learning benefit greatly from watching repeated demonstrations of effective technique.
- Verbal instruction should be clear and concise.
- The coach should provide feedback on the relative success of the performance, as well as provide the learner with strategies to correct faults.

FIGURE 3.21 Learning a new skill

The **associative stage of learning** is the second phase in the learning of a new skill, in which movement patterns become more refined and consistent through practice.

study on

Unit 3	**Stages of learning: Associative** Concept summary and practice questions
AOS 1	
Topic 3	
Concept 4	

Associative stage

Once a learner has progressed to consistently performing the basic mechanics of the skill with relatively few mistakes, they are said to be in the **associative stage of learning**. In the associative stage, the performer moves away from the 'trial and error' style of learning toward refining and replicating the required movement pattern. Hence the associative stage is often referred to as the practice stage; the learner can successfully perform the skill but needs regular practice to eliminate minor errors.

In the associative stage, the learner begins to understand why they make errors and starts to comprehend and adopt strategies to correct these errors. As the learner requires less attention to understand the skill, they are able to pay more attention to the game environment. The learner begins to interpret relevant cues in a game situation and selects the appropriate skill to perform. For example, an AFL footballer who has learnt to handball can use this technique to dispose of the ball quickly prior to being tackled.

FIGURE 3.22 Associative stage: refining a movement skill

Coaching the associative stage

- Coaches must provide regular practice opportunities.
- The learner should to be exposed to a more 'open' competition environment where they learn to recognise important cues and develop their decision-making capabilities.
- Coaches should continue to assist the learners to recognise why they have made an error and develop their ability to self-correct the error.

Autonomous stage

In the autonomous stage of learning, the learner can perform the skill almost 'automatically'. The skill is 'ingrained' and 'second-nature' to the performer, with very little attention required for skill execution. A performer in the autonomous stage is able to multi-task. For example, an elite hockey player is able to execute the skill of dribbling at high speed while simultaneously observing the whereabouts of opposition players.

Performers become further aware of their competitive environment, developing their tactical and strategic awareness and their decision-making capabilities.

studyon

Unit 3 | AOS 1 | Topic 3 | Concept 5

Stages of learning: Autonomous Concept summary and practice questions

eBookplus

Interactivity Characteristics of the stages of learning
Searchlight ID: int-6783

FIGURE 3.23 The autonomous performer can multi-task and concentrate on tactics and strategy.

Coaching the autonomous stage

- The coach should provide precise feedback to further improve skill execution. Small improvements can make a significant difference at an elite/high level of sport.
- Pay particular attention to keeping the performers motivated to further improve and refine skill level.
- Use match simulation to enhance tactical knowledge and decision-making skills.

TABLE 3.4 Coaching the stages of learning

Stages of learning	Cognitive	Associative	Autonomous
Characteristics of learner	• Complete beginner • Many errors in performance • Learner's attention is given to understanding the skill • Trial and error learning style • Unable to detect and correct performance errors	• Consistent performance of the basic mechanics of the skill • The learner concentrates on • skill refinement • Improved ability to detect and correct errors • Some perception of important cues/information in a game environment	• Performance almost automatic • Highly skilled • Very few errors • Multitasking evident • Able to adjust skills to games environment • Greater tactical and strategic awareness • Highly developed ability to detect and correct errors
Considerations for coaches	• 'Keep it Simple' • Don't overload learner with Information • Verbal instructions should be clear and concise • Learner benefits from skill demonstrations • Teach learner how to detect and correct errors • Skills may be simplified or broken into smaller skill components.	• Provide opportunity to practise • Learners continue to work on error detection and correction • Assist learner to recognise important cues/information in a game environment	• Precise feedback • Match practice • Ensure learner motivation is high through varied and engaging practice • Continue to challenge the learner

TEST your understanding

1 Name and discuss the characteristics of the three stages of learning.

2 Why is it important for the coach to understand their performer's stage of learning?

3 Explain the difference in learning styles between the cognitive stage and the associative stage.

4 (a) Define the term *attention*.

(b) Explain how the amount of attention given to executing a skill changes as the learner progresses through the three stages of learning: cognitive, associative and autonomous.

(c) What are the implications of your answer to part (b) regarding coaching an autonomous performer?

APPLY your understanding

5 Imagine you're a hockey coach. You've been asked to run two very different training sessions; one for a group of under-10 beginners and one for an elite senior State League club side.

(a) What's the most likely stage of learning for the players in the under-10 group?

(b) What's the most likely stage of learning for the players in the senior team?

(c) List some coaching strategies appropriate for the under-10's.

(d) List some coaching strategies appropriate for the senior team.

6 **Practical activity: learning a new skill**

The aim of this learning activity is to observe the characteristics of a novice performer and to gain an understanding of the most effective way to coach individuals in the cognitive stage of learning.

Equipment: Class set of footbags (hacky sacks)

Method

Use the **Footbag** weblink in your eBookPLUS and choose one or two skills you'd like to learn; for example, juggling the bag with consecutive inside kicks. Working in pairs, one student attempts to practise the skill while the other observes and provides instruction. Each student should spend approximately half the lesson time in each of the roles: coach and learner.

Discussion

(a) Use your observation of your partner's performance to describe the characteristics of the cognitive stage of learning.

(b) As the learner, discuss where the majority of your attention was focused.

(c) As a coach, reflect on the most effective and least effective means of teaching the new skill.

(d) From the learner's perspective, what was your partner's most effective coaching strategy? Discuss why.

EXAM practice

7 **ACHPER Trial Exam Unit 2 2016**

The local hockey coach has just taken on the task of coaching a junior side with a wide range of skills and experience. She has split the team into three groups based on the stage of learning they are at with trapping and passing.

(a) Outline one distinct characteristic you would expect to see from each of the groups listed above. **3 marks**

(b) Discuss the type of environment and method of practice that would best suit the least advanced group. **2 marks**

eBook*plus*

Weblink
Footbag

3.4 Sociocultural influences on skill development

KEY CONCEPT Sociocultural factors refer to the specific social and cultural practices, beliefs and traditions within a community or society that encourage or discourage involvement in sport.

We generally consider skill development to be the result of a combination of the learner's genetic traits, the amount of practice undertaken and the availability of expert coaching. However, it's also important to understand sociocultural factors and the impact they have on the skill learner.

Sociocultural factors influence the amount of opportunity to participate in sport, as well as the availability of practice facilities and expert instruction. **Sociocultural influences** also affect the degree to which the learner is motivated to practise and strive for further skill development. Examples of sociocultural factors that influence involvement in sport, physical activity and exercise and the extent to which movement skills are developed include: family, peers, gender, cultural norms, community and socioeconomic status.

Sociocultural influences are the combination of social and cultural factors that impact on an individual's opportunities to participate in particular sports or recreational activities and, in turn, develop the relevant movement skills.

FIGURE 3.24 Skill development is influenced by sports prevalent in the local community.

Sociocultural factors have a significant influence on determining future sporting success. For example, an athlete brought up in a 'sports-mad' family who receives expert adult guidance from a young age, as well as unrestricted access to training facilities is more likely to reach a higher level of performance than an athlete with more natural ability who grows up in an environment that does not develop and/or value these talents. In this example, the relevant sociocultural influence is the presence, or lack thereof, of a supportive family. A growing body of evidence suggests that athletes' transitions and progressions along the continuum from novices to experts are heavily influenced by their social environments,by the developmental experiences created for participation in play and practice, and by the support provided to assist athletes through key developmental periods (Weissensteiner, Abenethy and Farrow, 2008).

FIGURE 3.25 The environment and climatic conditions influence the type of sports available.

The section that follows outlines the impact of sociocultural factors on skill development. As illustrated in figure 3.26, the influences on the learner are multi-dimensional. The sociocultural factors combine to create an environment that influences the learner's behaviour and subsequent skill development. It's the combination of sociocultural influences and the learner's genetic traits (biological, physiological and psychological characteristics) that determines the type and extent of movement skill learning.

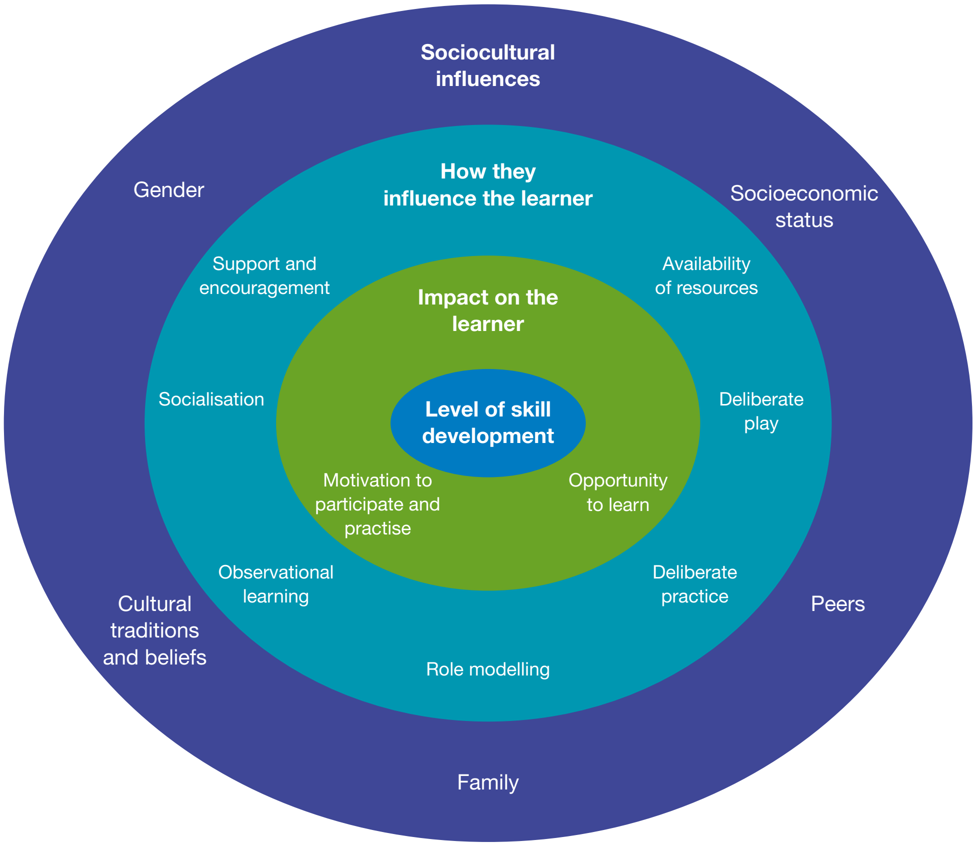


FIGURE 3.26 The impact of sociocultural influences on skill development

FIGURE 3.27 Families have a significant impact on children's sport and movement skill development.

Family

Parents facilitate their children's involvement in sport by driving them to practice, and buying uniforms and sports equipment, as well as funding registration fees. But more than meeting costs and providing logistical support, parents encourage their children to get involved and to apply themselves to practice. Parents have a significant impact on their children's values and their attitude towards learning.

FIGURE 3.28 Kids playing street baseball is an example of deliberate play.

Deliberate play describes an unsupervised learning environment where children devise their own interpretation of competition rules and experiment performing different types of skills.

Traditionally, the family backyard is a place where children hone their movement skills. The game of 'backyard cricket' is an excellent example of '**deliberate play**'.

Deliberate practice involves highly structured activities overseen by a coach/instructor aimed at improving designated movement skill(s).

Observational learning is the learning that takes place as a result of watching and imitating others.

Deliberate play, as opposed to **deliberate practice**, describes an unsupervised learning environment where children devise their own interpretation of competition rules and experiment performing different types of skills. Deliberate play allows the learner to take ownership of the learning experience and it provides the opportunity to trial different techniques free from the pressure of more formal sporting fixture.

The AIS recognised the important role family plays in developing young talent when, as part of their AIS Pathways Connect program, it released the document *Top Tips for parents to nurture and support your child's foundation sporting development* (author Dr Juanita Weissensteiner). The document is based largely on the Foundation Talent Elite Mastery (FTEM) Framework (figure 3.29), a framework to facilitate sports development in 'three worlds': active lifestyle, sport participation and sport excellence. The AIS recommendations regarding nurturing talent emphasise the need to establish fundamental movement skills in the young learner as these will form the foundation for lifelong involvement and development in sport. These fundamental movement skills are achieved by such things as:

- sampling many sports at a young age rather than specialising too early
- ensuring children participate in deliberate play as well as age-appropriate modified sports
- providing **observational learning** opportunities such as watching live or televised sport
- ensuring children work with a suitably qualified and experienced coach.

FTEM stage		
	F1	**Foundation** Learning and acquisition of basic movement
Active lifestyle	F2	**Foundation** Extension and refinement of movement
Sport	F3	**Foundation** Sport specific commitment and/or competition
Sport excellence	T1	**Talent** Demonstration of potential
	T2	**Talent** Verification
	T3	**Talent** Practising and achieving
	T4	**Talent** Breakthrough and reward
	E1	**Elite** Representation
	E2	**Elite** Success
	M1	**Mastery** Sustained success

FIGURE 3.29 Foundation Talent Elite Mastery (FTEM) Framework

Source: Adapted from www.ausport.gov.au.

Cultural norms, traditions and beliefs

Different nationalities identify with different sports. The prevalence of a particular sport in a community can have a significant impact on skill development. For example, swimming is a high-profile sport in Australia. Our national swimmers receive a great deal of attention in the media and are afforded celebrity status. These high-profile swimmers become idols to Australian children and this, in turn, leads to greater participation in the sport of competitive swimming. Combine this with the natural environmental advantages of a warm climate and an abundance of beaches and pools and it's not difficult to understand why the standard of swimming skills in Australia is comparatively high.

FIGURE 3.30 Different nationalities identify with different sports.

Other examples of sports we associate with particular nationalities include Kenya with distance running, Canada with ice hockey and Brazil with football. Furthermore, nationalities may influence the style of play. For example, compare the attacking and flamboyant style of a South American football team to the more systematic and disciplined approach of the German national team.

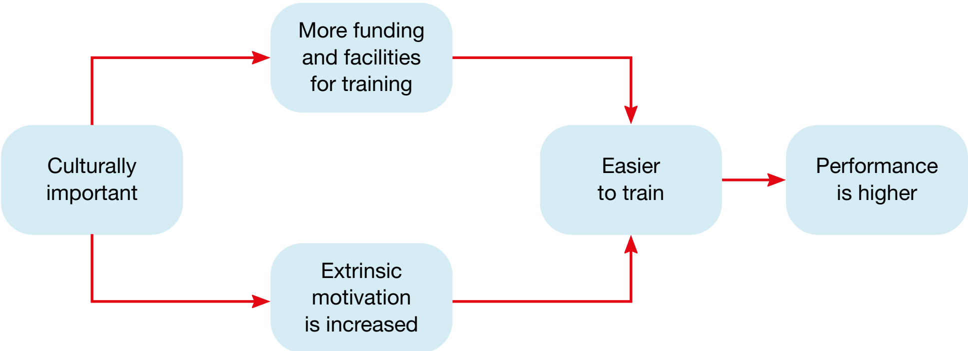


FIGURE 3.31 When a culture values a particular sport, it leads to an increase in the standard of performance in that sport.

Barriers to involvement in sport and physical activity

Cultural and religious beliefs can also be a barrier to sports participation and potential skill development. For example, some conservative societies may be opposed to women being involved in sport or particular types of sport. Likewise, opportunities to be involved in sport and recreational pursuits can be seriously compromised in countries that suffer from political instability and civil unrest.

FIGURE 3.32 Do some cultural and religious beliefs present a barrier to involvement in sport and physical activity?

Ethnic minorities in society and/or recent refugees may encounter many barriers to involvement in sport and the opportunity to develop fundamental movement skills. These include:

- language barriers in accessing important information regarding organised sport
- lack of culturally appropriate venues and facilities
- encountering discrimination and racism
- cultural and religious standards of modesty may be at odds with a sport's dress code/uniform expectations
- lack of appropriate role models.

Peers

Friends play an important role in influencing the type of sport children participate in and therefore the type of skills they develop. Younger athletes are generally motivated to play with their friends and will consequently choose and work on the sports popular with their social group. In peer groups, the concept of 'deliberate play', as explained previously, may also be an important factor in the learner's development; that is, backyard or playground sport is fertile ground for developing movement skills. However, if a peer group has a tendency toward sedentary behaviour, such as playing computer games, then this can present a barrier to physical activity and movement skill development.

FIGURE 3.33 The sporting experience is influenced by peers as well as socioeconomic factors.

Gender

Gender stereotypes

Girls and boys will be socialised into different sports. Some sports such as netball, softball and gymnastics can be seen as girls' sports, while sports such as AFL football, rugby and boxing can be considered more masculine and therefore more suitable for boys. In recent times, many gender stereotypes in regard to sporting participation have been challenged, with an increasing number of women playing traditionally male-orientated sports. However, differences in the types of sports played by girls and boys still exist and this, in turn, leads to differences in skill development. For example, girls are more likely to develop coordination, balance and flexibility associated with such sports as gymnastics and dance.

FIGURE 3.34 The eight marquee players for the Melbourne clubs in the women's AFL at Etihad Stadium

Barriers to involvement in sport and physical activity

Historically, women have experienced significantly more barriers to participation in sport, recreation and physical activity. The factors listed below help to explain the inequity regarding sporting opportunities for women and consequently the detrimental impact on potential skill development.

- Lack of appropriate, accessible, affordable and acceptable facilities; for example, sport gymnasiums that do not have adequate female change rooms.
- Lack of media coverage. Male sport enjoys far more media coverage, which helps to bolster participation rates as well as provide prominent role models.
- Lack of role models. Young female learners need senior mentors to facilitate skill learning and sports expertise.
- Social stereotyping. In society, there can be a perception that sport is unfeminine. This perception can prevent young girls from participating in sport.
- There are fewer opportunities for girls to participate in sport. In schools, local sports clubs and gymnasiums there are often fewer sporting programs and competitions afforded to females.
- Sporting organisations have fewer women sitting on managerial boards. Hence, there is a lack of advocacy for women's sporting issues.
- Negative peer pressure and a lack of confidence. Attitudes towards involvement in sport are heavily influenced by peers and family.

Socioeconomic status

Socioeconomic factors describe the social and economic status of a participant or their family based on income, occupation and education. Socioeconomic factors can have a strong influence on the type of sports people choose to play and consequently the skills they develop.

People considered socially disadvantaged or from a low socioeconomic background often record lower levels of physical activity and sporting participation. The cost of uniforms, transport and registration fees may be a deterrent to involvement in sport to those who are financially challenged.

Also, socially disadvantaged communities, for example remote outback communities, may lack adequate facilities such as indoor stadiums and heated pools required for some organised sport.

FIGURE 3.35 Socioeconomic status can influence the type of sport in which an individual chooses to participate.

Socioeconomic status can influence the type of sport in which an individual chooses to participate. For example, a sport such as rugby league has a working class background and, to an extent, this is still evident in the current demographic of participants. Those who pride themselves as coming from a working class background may also identify with the defining characteristics of a sport such as rugby league: tough, hard-working and no-frills.

Other sports are more closely aligned with middle-class participants or those from a more privileged background. For example, the sport of sailing has extremely high associated equipment and logistical costs. These costs are a potential barrier to those from relatively low socioeconomic backgrounds.

Other sports such as rowing are associated with privilege and entitlement. Rowing, along with being an expensive sport, is often associated with prestigious private schools and universities.

Local community

As with previously mentioned sociocultural factors, the local community facilitates sporting development via the prevalence of suitable positive role models, conducive climatic conditions and natural resources, ease of access to safe training facilities and readily available coaching.

An interesting phenomenon is the overrepresentation of elite sportspeople who grew up and developed their sporting prowess in small country towns. One explanation of this phenomenon is that sporting clubs are highly prominent in country towns. For example, a high proportion of young people in rural settings are involved in their local netball or football club. Furthermore, access to training facilities in rural communities may be better than in urban communities. Urban sporting facilities have to cater for larger populations, which potentially limits the time available for a team or an individual to partake in practice sessions. Also, country towns can struggle to find sufficient participants to fill their various sports teams. A young sportsperson in a rural community may find themselves playing in a number of different sports, as well as participating in various age groups. This kind of experience can create a highly stimulating learning environment conducive to developing fundamental movement skills and game sense.

Regardless of the reason behind the overrepresentation of elite sportspeople in rural areas, it is clearly evident the defining characteristics of local communities have a significant bearing on sporting prowess and the development of movement skill.

TEST your understanding

1 (a) Make a list of the sociocultural influences that can impact movement skill development.
(b) Draw up two columns, labelling one 'Barriers to skill development' and the other 'Enablers of skill development'. Based on your list for part (a), give examples of sociocultural influences and classify them as either barriers or enablers.

2 Explain the difference between *deliberate play* and *deliberate practice*.

3 What is meant by *observational learning*?

APPLY your understanding

4 Analyse your own sporting achievements. Name the sociocultural influences that apply to your involvement in sport and explain how they impacted on your skill development and performance.

5 **Analysis activity: female and male participation rates in sport**
Aim: Conduct a statistical analysis of male and female participation rates in sport and discuss the potential impact on skill development.
Resources
Australian Bureau of Statistics website: *Sports and Physical Recreation: A Statistical Overview, Australia, 2012*

studyon
Unit 3
AOS 1
Topic 3
Concept 6
Sociocultural influences on skill development
Concept summary and practice questions

eBook*plus*

Weblink
Australian Bureau of Statistics

Method
Using the **Australian Bureau of Statistics** weblink in your eBookPLUS, analyse the data on the website and answer the following questions.
Discussion
(a) What are the most popular sports for female children in Victoria?
(b) What are the most popular sports for male children in Victoria?
(c) Identify and discuss the potential sociocultural influences that may have led to the differences in sporting preferences between girls and boys.
(d) What impact do these sociocultural influences have on skill development in both girls and boys?
(e) Record the difference in overall sporting participation rates between girls and boys in Victoria. Identify and discuss the potential sociocultural influences that contributed to the disparity in participation rates between girls and boys.

FIGURE 3.36 An international game of Kabaddi

eBook*plus*

Weblink
Rules of Kabaddi

6 Physical activity: Kabaddi
Participate in a game of Kabaddi.
Method
Research the rules of the game Kabaddi using the **Rules of Kabaddi** weblink in your eBookPLUS.
(a) Play a game with your classmates using the school oval or the school gym (using protective mats).
(b) Spend some time researching the origins of the game and the history of Kabaddi.
Discussion
(c) Where did the game of Kabaddi originate?
(d) How has this country's culture and mythology help to shape/create the game of Kabaddi?
(e) How could you make the game of Kabaddi more available in your local community?

EXAM practice

7 Outline three measures a local council could put in place to encourage greater participation in sport and physical activity for ethnic minority groups. **6 marks**

KEY SKILLS

- Explain and apply theories of learning to practical coaching situations
- Explain sociocultural factors that influence movement skill development at different stages of learning

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- Recognise a skill learner's stage of learning and apply appropriate and effective instructional strategies
- The constraints-based approach and the direct approach both have their relative strengths and weaknesses. The coach should choose an instructional approach based on the participant's stage of learning (individual) and the nature of the movement skill (task).
- Understand how manipulating task constraints can assist in learning applicable movement skills
- There are a range of sociocultural factors that influence the type and extent of movement skill development
- Sociocultural factors influence the prevalence of learning opportunities and the learner's motivation to apply themselves to practice through a range of mechanisms including socialisation, role modelling, observational learning and structured play, as well as availability of resources and expert coaching

PRACTICE QUESTION

1 Ben is an under-12 AFL footballer who demonstrates effective technique when executing a drop-punt kick during uncontested line drills. His kicks generally hit their intended targets but lack consistency and fluid skill execution. However, when Ben is involved in match practice, his kicking skills deteriorate significantly.

a. **Name** the stage of learning most applicable to Ben's kicking skills and **provide** two instructional strategies applicable to this stage of learning. *(3 marks)*

b. **Name** the instructional approach that would most likely enhance Ben's kicking skills in a match. **Explain** how this instructional approach facilitates the execution of effective skills under match conditions. **Provide** an example to support your answer. *(4 marks)*

SAMPLE RESPONSE

a. Ben's kicking is in the associative stage of learning. Firstly, Ben needs regular supervised kicking practice and secondly, the coach should assist Ben to understand why he has made a kicking error, as well as develop strategies to correct skill errors.

b. A constraints-based approach to instruction. The constraints-based approach places the learner in a small-sided game modified to simulate match conditions and hence develop applicable movement skills; for example, a game of 'keepings off', in which Ben and three other teammates try to maintain possession by kicking the ball to each other within a defined space and avoid being intercepted by two designated defenders.

The game implicitly teaches important and applicable kicking skills that are generally not developed in line drills. For example:

- kicking the ball out 'in front' of the leading teammate
- being able to kick with either leg is an advantage
- attending to cues important to skill execution and blocking out distractions
- practising externally paced skills.

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  a. **Name** — identify or state
  Provide — give or state
  Explain — to make the meaning of something clear and understandable
- **Key terminology:**
  Applicable — most relevant or appropriate
  Instructional strategies — considerations for coaching or ways of coaching/teaching
  Enhance — improve
  Match — competitive game
  Execution of effective skills — performing skills that achieve intended outcomes
  Match conditions — performing skills in an open, less predictable environment
- **Key concepts:**
  Stage of learning — the learner's relative level of performance
  Instructional approach — constraints-based or direct-based approach to instruction
- **Marking scheme:** a. *3 marks*
  b. *4 marks* — always check marking scheme for the depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

a.
- **1 mark:** name associative stage of learning as being applicable to Ben's level of performance
- **2 marks:** name two instructional strategies — supervised practice, and skill error recognition and correction strategies

b.
- **1 mark:** name the constraints-based approach as the most effective way of developing skills resilient to competitive pressure
- **2 marks:** explain how the constraints-based approach simulates match conditions (1 mark) to produce applicable movement skills (1 mark)
- **1 mark:** for relevant example; in this case, 'keepings off' game

CHAPTER SUMMARY

Instructional models

- There are two prevalent instructional models: the direct approach to instruction and the constraints-based approach to instruction. The direct approach is a coach-orientated, autocratic style of instruction where the learning outcomes are prescribed and the learner is given explicit instruction as to how and when to perform movement skills. The constraints-based approach is a discovery-based, learner-orientated model in which coaches guide the learner to technical competence and tactical awareness via the use of short-sided modified games.
- The direct approach encourages skill mastery in isolation prior to taking part in a game. The direct approach dictates that skill learning should first take place in a predictable/closed environment before the learner is forced to endure the less predictable/open environment of a game.
- The constraints-based approach encourages early involvement in modified games. In the constraints-based approach the coach modifies the game constraints (task, individual and environment) to enable the learner to discover applicable movement skills and tactical awareness.
- Explicit learning is the result of direct verbal instruction from a teacher or coach, where the learner is told how and when to perform a movement skill. We associate explicit learning with the direct approach to instruction.
- Implicit learning is the learning that takes place as a result of completing a task or, in the case of skill development, taking part in a game. We associate implicit learning with the constraints-based approach to instruction.
- Game sense is a constraints-based approach to learning that is utilised in Australia. The game sense approach involves short-sided games where constraints are modified to facilitate learning. In game sense instruction, the coach uses guiding questions to engender a discovery-based learning environment and sports are classified into four game categories based on common principles of play.

Stages of learning

- There are three stages of learning. In order progressing from novice learner to expert performer, the stages of learning are: the cognitive stage, the associate stage and the autonomous stage.
- The cognitive stage of learning is characterised by the novice learner directing most of their attention to understanding the relevant movement skill and the prevalence of many skill execution errors. In the associative stage of learning, the learner successfully performs the fundamental components of the movement skill but requires regular practice to refine skill executions and eliminate minor errors. In the autonomous stage of learning, the learner has mastered the skill, directs very little attention to skill execution and is able to multi-task.
- Knowing the stage of learning enables the coach to tailor more effective instructional and practice strategies.

Sociocultural influences on skill development

- Sociocultural factors are social and cultural practices, beliefs and traditions that encourage or discourage involvement in sport and thereby influence the type and extent of movement skill development.
- Sociocultural factors include such things as the influence of peers and family, socioeconomic status, gender issues, nationality, cultural traditions and beliefs.
- Sociocultural factors impact the learner's opportunity to be involved in sport, as well as their motivation to learn movement skills through a range of influences such as: socialisation, role modelling, observational learning, deliberate play, support and encouragement, and the availability of practice facilities as well as expert coaching.
- For some groups in society, sociocultural factors can present a significant barrier to involvement in sport and the subsequent development of fundamental movement skills. Traditionally there has been an inequity toward women, socially disadvantaged and ethnic minority groups regarding opportunities to be involved in sporting programs, access to appropriate facilities and the presence of positive role models.

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 Which of the following is NOT an example of a sociocultural factor that presents a barrier to sports participation for ethnic minority groups?
(A) Lack of role models
(B) Racism
(C) Language barrier
(D) Talent identification

2 Deliberate play is best described as
(A) highly structured drill practice.
(B) explicit learning.
(C) coach-driven practice designed to develop relevant movement skills.
(D) an unstructured discovery-based learning environment.

3 Skill development results from a combination of
(A) genetics and coaching.
(B) psychological, biological and physiological traits, as well as the opportunity to learn.
(C) socioeconomic status and opportunities it affords to the novice learner.
(D) genetic traits, expert coaching and sociocultural factors that encourage and facilitate learning opportunities.

4 David performs his tennis serve successfully 60 per cent of the time. His service action looks technically sound but lacks rhythm and fluent execution. Identify David's stage of learning.
(A) Cognitive
(B) Associative
(C) Autonomous
(D) Elite

5 A consideration for coaching the autonomous performer is
(A) keep instruction simple.
(B) provide precise feedback and games practice.
(C) teach correctional strategies.
(D) overload the performer with information.

6 Which of the following instructional characteristics is NOT associated with the direct approach?
(A) Autocratic
(B) Prescribed
(C) Coach-orientated
(D) Discovery-based

7 Canada has a relatively high number of outdoor ice rinks that are used by children to play ice hockey. This is an example of which kind of skill learning constraint?
(A) Environment
(B) Task
(C) Individual
(D) Performance

8 An example of a task constraint modification specifically designed to enhance skill learning in children is
(A) lighter racquets.
(B) a tennis-specific fitness program.
(C) senior role models.
(D) video analysis of ground strokes.

9 The basketball coaching analogy comparing the action of 'shooting' to 'putting your hand in the cookie jar', is an example of
(A) psychological imagery.
(B) an implicit-based instructional strategy that reduces the amount of information required to process and execute the skill.
(C) a coaching strategy designed to provide detailed and precise instruction.
(D) an explicit-based instructional strategy.

10 An advantage that game sense has over a direct approach to instruction is that it
(A) is effective at quickly developing movement skills in the novice learner.
(B) doesn't put the learner in a game until individual skills are mastered.
(C) develops applicable movement skills, tactical awareness and decision-making skills.
(D) has prescribed learning outcomes.

eBook*plus*

Interactivity
Coaching and instruction quiz
Searchlight ID: int-6784

studyon

Sit VCAA exam

TRIAL EXAM QUESTIONS

Question 1 **(adapted from ACHPER Trial Exam Unit 2, 2015, question 7)**

a. **i.** State which stage of learning the players participating in the NBA would be in. **1 mark**

ii. Outline **two** characteristics that the players display to support your choice in **part a. i**. **2 marks**

b. **i.** State the stage of learning most 5–10 year olds would be in when they first begin the Aussie Hoops program. **1 mark**

ii. Outline **two** strategies a coach or teacher would utilise to cater for the children within the stage identified in **part b. i.** **2 marks**

Question 2

Two 9-year-old girls take up netball at the same time. Stephanie receives direct (traditional) instruction whereas her friend Molly is taught via a game sense approach.

In early practice sessions, Stephanie displays more rapid skill development than Molly in regard to passing and shooting. However, as the season goes on, Molly's technical competence steadily improves and she outperforms Stephanie on match days.

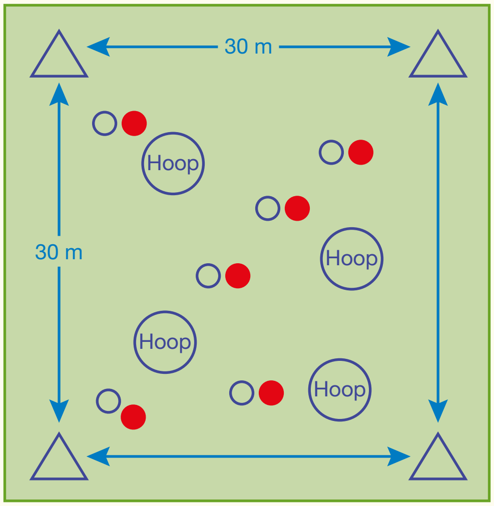
a. Explain the two girls' relative skill development and match day performances in the context of the instructional model they have received. **6 marks**

b. As coach of a large squad of junior novice netballers, discuss the most effective and pragmatic instructional model. **4 marks**

Question 3

Examine the figure below that outlines Hoop Ball, a small-sided modified game suitable for use in game sense instruction.

The aim of the game is to keep possession of the ball and to score by passing to a teammate standing in one of the four available hoops. The defensive team attempts to intercept the offensive team's passes.



a. Identify the game category to which this modified game is most applicable. **1 mark**

b. The game is designed to teach the learner how to make position to receive a pass. Provide an example of a 'guiding question' the coach may ask to facilitate this learning goal. **1 mark**

c. Suggest a modification you could make to this game to further develop effective passing. **2 marks**

Question 4

A recent research paper investigating sociocultural influences on international cricketers found that many elite performers attributed their early skill development to 'backyard cricket' with family and friends.

a. Name this type of skill development session. **1 mark**

b. Explain how these types of practice sessions help the learner to develop into an effective competitor. **3 marks**

Question 5

a. Design a short-sided game that enhances the skill of dribbling in hockey. **2 marks**

b. Explain a potential task constraint modification to your game that is designed to further improve the players' dribbling. **2 marks**

INQUIRY QUESTION
How would the organisation of a practice session for a beginner differ from the organisation of a practice session for an elite performer? What factors does a coach need to consider to provide the most effective type of feedback for their athletes?

CHAPTER

4 Practice and feedback

Feedback and practice are essential for skill learning. Furthermore, to facilitate effective skill learning, feedback and practice should be tailored to match the performer's stage of learning as well as the particular type and complexity of the movement skill.

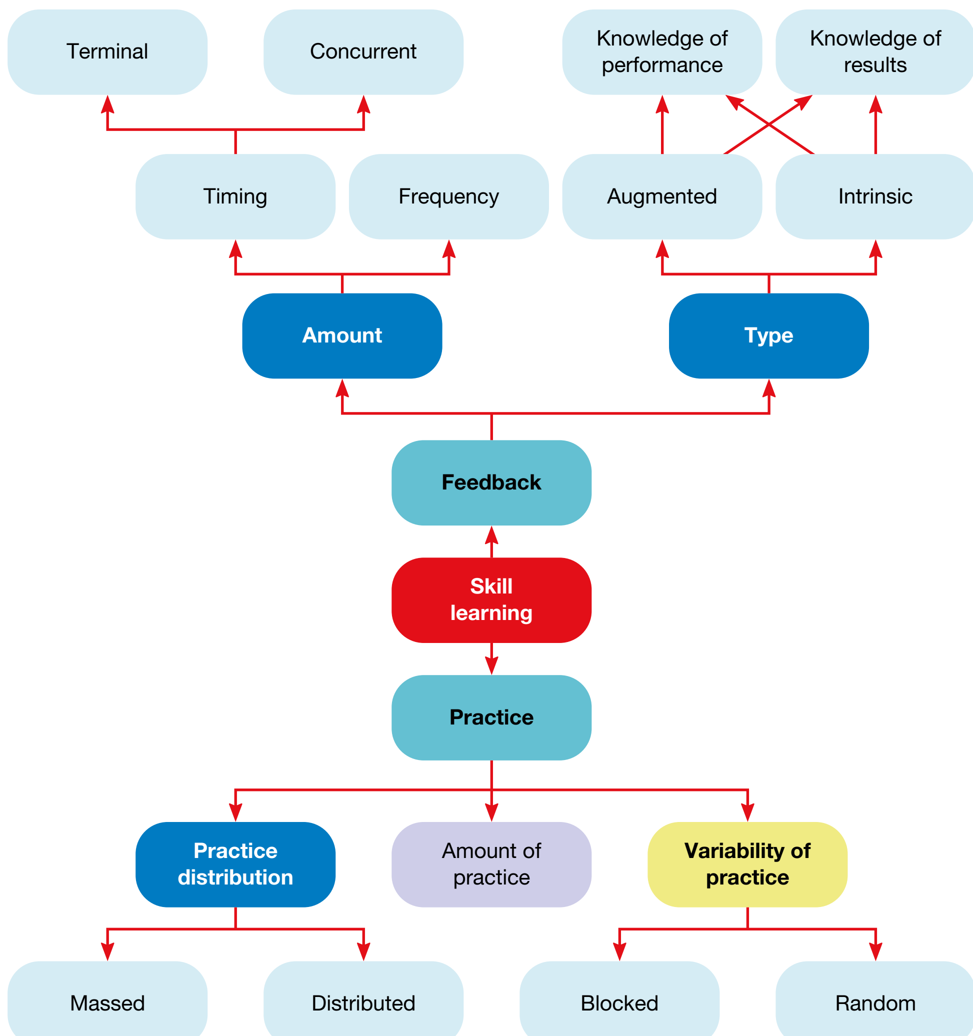
KEY KNOWLEDGE

- Practice strategies to improve movement skills including amount, distribution (massed and distributed) and variability (blocked and random)
- Feedback including type (intrinsic, augmented, knowledge of results and knowledge of performance) and frequency

KEY SKILLS

- Discuss how skill classification affects the selection of appropriate practice strategies
- Participate in, observe and record the characteristics of different types of practice strategies
- Perform, observe, analyse and report on the role of feedback in improving performance through practical-based activities

CHAPTER PREVIEW



4.1 Practice amount and distribution

KEY CONCEPT The volume of practice undertaken and the way in which practice sessions are structured and organised has a significant impact on skill learning.

FIGURE 4.1 Ballet dancers spend many hours practising. How do we determine the ideal amount of practice to facilitate skill learning?

Amount of practice

It is generally accepted that the more we practise, the more we learn. The more time an individual practises a new movement skill, the greater chance they have of mastering that skill.

In the best-selling book *Outliers: The Story of Success,* author Malcolm Gladwell investigates factors that have contributed to the success of high-achieving individuals in all walks of life. Loosely based on the research of eminent psychologist Anders Ericsson, Gladwell's theory contends that success is closely aligned with what he calls the 10 000 Hours Rule; that is, the key to achieving mastery in any field, including elite sport, is to engage in applicable practice for a cumulative period of 10 000 hours.

However, while Malcolm Gladwell has alerted us to the effectiveness of practice time, it's important to acknowledge that a sports coach or teacher does not have the luxury of limitless time at their disposal. In most sports, there are many skills to be learnt within the time constraints of a training schedule and a competition season. Consequently, a coach cannot afford to spend too much time focused on one skill at the expense of others. Practice time is also influenced by player fatigue, motivation levels, skill complexity, the participant's age and stage of learning, as well as environmental constraints such as availability of appropriate training facilities.

FIGURE 4.2 Learners should spend most of their time actively engaged in practice.

Maximising practice time

The general recommendation to facilitate effective skill learning within a limited time frame is to allow the learner to spend as much time as possible in meaningful practice. For example, within a 45-minute Physical Education lesson, the teacher should maximise the time the participants spend practising the relevant skills and minimise the time spent on long-winded instruction, setting up equipment or participants waiting in line for their turn. Maximising practice time also ensures greater learner engagement and motivation.

FIGURE 4.3 Time spent waiting for your turn should be minimised.

Time spent on task

Coaches must make on-balance decisions about how long they spend on one particular skill before they move on to another. A coach can't afford to take a perfectionist approach to learning individual skills; rather they must be pragmatic about developing a degree of competence across a range of skills in the limited time available. The coach also runs the risk of their learners losing interest if they spend too long on a single skill or activity.

The principle of **diminishing returns** states that as a performer becomes more competent in their skill performance and progresses to the latter stages of learning, there is a gradual reduction in the rate of improvement in skill performance in response to practice.

Diminishing returns

Coaches should also be aware of the principle of **diminishing returns**. The principle of diminishing returns dictates that performers in the early stage of learning will improve rapidly in response to practice. However, as the performer becomes more competent and progresses to the latter stages of learning, their rate of improvement, in response to practice, decreases (see figure 4.4). Therefore, a coach will need to weigh up whether it's worth spending a large amount of time trying to make small improvements to their performers' already refined movement skills or whether they could better use this time for developing new movement skills.

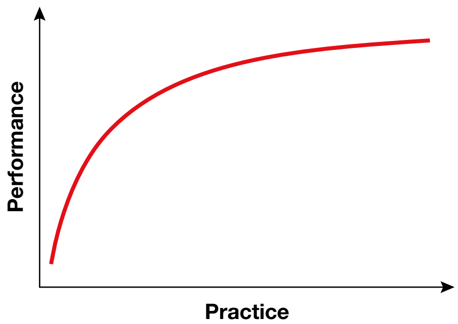


FIGURE 4.4 The rate of improvement in response to practice diminishes over time.

In summary, coaches should consider the following points:

- Generally, the more you practise, the more you learn.
- Maximise meaningful skill practice within the time available.
- In the interest of learner engagement, develop a sense of when it's best to stop working on one skill and move on to a new activity.
- Be aware of the principle of diminishing returns when deciding how to make the most of training time.

Practice distribution

Practice distribution refers to the ratio between time spent actively practising and time spent resting during a practice session.

Practice distribution refers to the ratio of time spent actively practising compared to time spent resting. Practice distribution design is an important aspect in facilitating movement skill learning.

There are two broad categories of practice distribution: massed practice and distributed practice.

Massed practice

Massed practice is a form of practice in which there is little or no rest between repeat performances of a skill.

Massed practice involves little or no rest between repeat performances of a skill. As such, massed practice is sometimes referred to as continuous practice. Massed practice sessions can be useful in developing discrete skills; for example, a golfer working on their swing by hitting multiple shots one after the other. Practising these discrete skills in one continuous training block can assist the learner to replicate efficient movement patterns. Discrete skills, unlike continuous skills such as swimming or bike-riding, tend not to be as fatiguing and hence long rest periods are not required. Massed training also helps to maximise the time the learner spends actively practising.

However, more recently there has been a shift away from using repetitive massed practice as a means of developing discrete, closed skills. This is discussed later in the chapter (see 'Practising discrete/closed movement skills').

Massed practice also suits the highly motivated and experienced performer. Experienced athletes are more suited to massed practice as they are able to focus their attention on skill practice for longer, and massed practice also affords them more time to work on complex skills. Massed practice requires participants to work and concentrate for extended time intervals, which can help the experienced athlete develop mental and physical resilience.

Distributed practice sessions

Distributed practice sessions are broken up into smaller practice intervals, interspersed with rest periods. In distributed practice sessions, there is either more rest time than work time or at least equal parts work and rest.

Distributed practice is a form of practice in which smaller practice time intervals are interspersed with rest periods

FIGURE 4.5 US champion swimmer Katie Ledecky. Physically demanding skills are suited to distributed practice.

FIGURE 4.6 A skill being learnt for the first time is best rehearsed in a distributed format.

The rest periods in distributed practice enable the learner to digest the coach's instruction and reflect upon what they have learnt. In other words, it allows time for the learning to sink in, sometimes referred to as memory consolidation.

FIGURE 4.7 Complex skills are best suited to distributed practice.

eBook*plus*

Interactivity
Practice distribution
Searchlight ID: int-6786

Distributed practice sessions are highly recommended in the following scenarios:
- learning a new skill
- learning a complex skill
- the skill being rehearsed is physically and mentally fatiguing
- the performer is young and/or lacks concentration
- the performer lacks motivation.

TABLE 4.1 Massed versus distributed practice

Practice distribution	Emphasis	Advantages	Weaknesses
Massed practice sessions	Continuous practice Little or no rest between repeat rehearsal of skill	Maximises practice time May suit a non-fatiguing discrete skill practice May suit an elite, highly motivated performer	Physically and mentally fatiguing Repetitious and boring
Distributed practice sessions	More or equal time spent resting between practising skills Practice in shorter intervals interspersed with recovery periods	Greater learner engagement Assists beginner or less motivated performer Reduction of fatigue during practice May help to learn a complex skill Recovery period allows for memory consolidation	More time-consuming May be less suited to discrete skill rehearsal

Practising discrete/closed movement skills

Highly repetitious practice has traditionally been considered the most effective way to rehearse discrete/closed skills; for example, a golfer hitting shot after shot on the practice range in order to replicate effective technique. This type of practice is considered to be massed and blocked (blocked practice is discussed in section 4.2) where the golfer will generally hit the same shot, with the same club and at the same target for an extended period of time. A similar example is a basketballer who repetitively practises his shooting from the free-throw line. Research has established that this type of rehearsal is very effective at enhancing performance during a practice session. However, this highly repetitious blocked practice does not always bring about substantial improvements in competition performance.

It is important that practice is more than merely replicating the physical mechanics of the movement skill. Effective practice requires the learner to engage in the cognitive processes of skill planning and organisation, error detection and implementing correctional strategies. A coach should ensure that the cognitive demands in practice reflect the cognitive demands of competition. Practice that combines both the mechanical and cognitive demands of skill performance facilitates more effective skill learning and ensures the learner is better prepared for competition (see figure 4.8).

'Skill acquisition researchers suggest that it's not how much the performer practises (i.e. the absolute number of physical repetitions of the biomechanical pattern, such as a golf swing), but how the performer completes each repetition (i.e. active involvement of the brain during planning and interpretation of subsequent motor behaviour) as the practice factor that contributes most to the motor learning process.' Jae T. Patterson and Timothy D. Lee, *Developing Sport Expertise*, 2nd Edition.

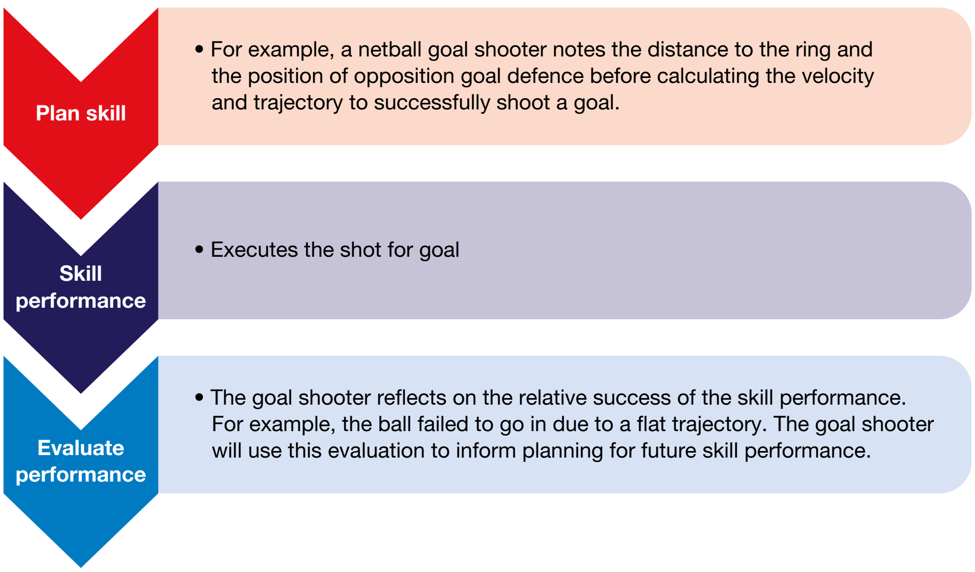


FIGURE 4.8 Each skill should have elements of planning, performance execution and outcome evaluation.

FIGURE 4.9 Mindless repetitive practice does not always improve performance in competition.

FIGURE 4.10 A golfer plans the movement skill in his or her pre-shot routine.

In the example of the golfer working on their shots (discrete skills) at the driving range, the following considerations should apply to the practice session to aptly prepare for the competitive environment.

- Before each practice shot, the learner should stand behind the ball, understand the goal of the skill (i.e. distance, intended target and ball flight) and plan the appropriate movement (i.e. swing speed, swing plane, stance, posture and appropriate club selection).
- The learner observes the ball flight, assesses the relative performance success, evaluates potential flaws in skill execution and applies correctional strategies.
- The learner should frequently change the club used.
- The learner should regularly change the target.

Researcher Stephen Scott believes a movement skill can be broken down into three components: brains, biomechanics and behaviour, otherwise referred to as the 'B's' of skill movement. These are set out as follows:

FIGURE 4.11 The three B's of skill movement

Coaches and athletes should ensure that all three components (brain, biomechanics and behaviour) are instilled in practice to facilitate effective movement skill learning. Coaches need to be aware that this may result in a greater number of skill errors during practice; however, in the long run, it will lead to better transfer of learning and superior performance in competition.

study on

Unit 3 | AOS 1 | Topic 4 | Concept 1 — **Practice amount and distribution**

TEST your understanding

1 Explain the difference between massed practice and distributed practice. Using a coaching example, explain when it is appropriate to use massed practice and when it is appropriate to use distributed practice.
2 Outline three factors a team coach must consider in order to maximise skill learning and ensure that all relevant skills are developed equally.
3 In relation to skill learning, explain the concept of 'diminishing returns'.

APPLY your understanding

4 Choose a sport that requires competitors to perform a closed/discrete skill.
(a) Describe the relevant skill.
(b) With reference to the three B's model, explain how you would structure a practice session to improve this skill.
5 The head coach of the Hockeyroos wants to improve the players' dribbling skills: to enhance their ability to dribble around opposition defence, avoid 'turnovers' and maintain their skills throughout a long and physically demanding game.
With reference to practice distribution, discuss the ideal organisation of a training session in order to achieve the coach's goals.
6 **Practical activity: massed versus distributed practice**
The aim of this learning activity is to investigate the effect of practice distribution.

Equipment: Hoops

Method: Work in pairs. Each partner will attempt to master the hula hoop. If a student is already proficient in hula hoop, set them a more challenging task: e.g. use two or three hoops.

Trial conditions: In each trial, the student is pre- and post-tested; that is, time how long they can spin the hula hoop before the hoop falls.

Trial 1: The first student in your pair attempts to master the hula hoop action in one continuous practice session lasting for 15 minutes. The partner who watches can provide correctional feedback.

Trial 2: The second partner then attempts to master the hula hoop action. In this trial, the student rehearses the movement for three minutes and rests for two minutes (the student does this three times in the course of 15 minutes). The observing partner can provide feedback.

Results: Record and analyse the results from each of the trials. Average the results for the entire class.

Discussion
(a) Classify the type of practice distribution in each trial.
(b) Which type of practice distribution was more effective at facilitating skill learning?
(c) Outline potential reasons for discrepancies in skill learning between the two types of practice distributions.

4.2 Practice variability

KEY CONCEPT A coach should apply appropriate levels of practice variability depending on the participant's stage of learning and the specific demands of the movement skill.

We know that when a learner repetitively practises the same skill, in the same way and in the same predictable environmental conditions, they will develop a consistent and successful movement pattern in a relatively short period of time. However, what happens when the same learner has to apply this skill to a more open, game environment; an environment in which the newly developed skill must be adapted to meet the specific demands of game constraints, as well as being spliced together with other skills? More than likely the learner's skill execution will be seriously compromised. To prevent this detriment to game performance and to maximise skill learning, coaches must give careful consideration to providing suitable practice **variability**.

Variability refers to the amount of change and uncertainty in an environment or in the performance of a skill.

FIGURE 4.12 Short-sided games force the participants to develop applicable and versatile skill sets.

Practice variability refers to the degree to which a coach varies the conditions in which skills are rehearsed, as well as the number and variety of skills that are practised in a particular training session. The design of effective practice variability is largely dependent on the type of skill and the performer's stage of learning.

Practice variability helps develop versatile movement skills that are applicable to game situations. It allows the learner to explore what works and what doesn't work; for example, hockey players taking part in a short-sided game of keepings-off are forced to develop passing skills that are applicable to a game of hockey. In other words, the players develop passing skills that enable them to distribute the ball quickly and accurately, skills they may not learn in uncontested partner work.

Furthermore, a varied practice session is generally more interesting for the learner, ensuring high levels of motivation and engagement.

Three types of practice that describe the extent of practice variability are, in order of least varied to most varied: blocked, serial and random.

Blocked practice

Blocked practice sessions involve practising the same skill repetitively in the same practice conditions for a set period of time; for example, a volleyball coach works on their player's serve for a 15-minute time period before working on the player's dig for 15 minutes. Blocked practice sessions have relatively low levels of practice variability.

Blocked practice is a type of practice in which each skill component is practised repetitively as an independent block.

Blocked practice is effective in the early stages of learning, particularly with complex movement skills. It enables the learner to become familiar with the basic mechanics of the skill, replicating and refining skill execution before having to contend with other skills, as well as less predictable environmental factors. Blocked practice generally results in significant improvements in skill performance during practice sessions, however these improvements do not necessarily transfer to competition performance.

As performers become more familiar with the new skill, the need for variability in practice becomes more apparent.

FIGURE 4.13 Blocked practice: repetitively practising the same skill in isolation

Serial practice

Serial practice sits halfway between blocked and random practice in regard to variability. In serial practice, different skills are rehearsed but in a fixed and predictable sequence; for example, a tennis coach makes their junior players hit four to six forehands, then four to six backhands, followed by four to six volleys, before starting on the forehand again and repeating the sequence over and over.

Serial practice is a form of practice that involves rehearsing different skills but in a fixed and relatively predictable sequence.

The advantage of serial practice is that it provides the benefits of both blocked and random practice. In other words, it has sufficient repetition to allow for the refinement of basic skill mechanics but also provides enough practice variability to prepare the learner for competition. Serial practice is ideal for the intermediate learner but can also be used effectively on elite-level performers.

FIGURE 4.14 Serial practice: one player feeds the ball to allow the other player to perform a variety of skills (e.g. volley, header, trap) in relatively predictable order.

Random practice

Random practice is a form of practice that involves rehearsing a number of different skills in an unpredictable sequence.

In **random practice**, a variety of skills are rehearsed within the same session. Unlike blocked practice, no one skill is worked on for a defined period of time or in a repetitive manner. Rather, skills are practised in combination and rehearsed in random order; for example, a golfer working on their putting stroke practises different length putts in random order. Random practice, once the learner can consistently perform the basic mechanics of the relevant skills, is a means by which a high degree of variability can be added to practice. The learner is not afforded the time to replicate the mechanics of a particular movement skill but rather they are forced to meet the cognitive challenges of executing multiple skills within a relatively short period of time.

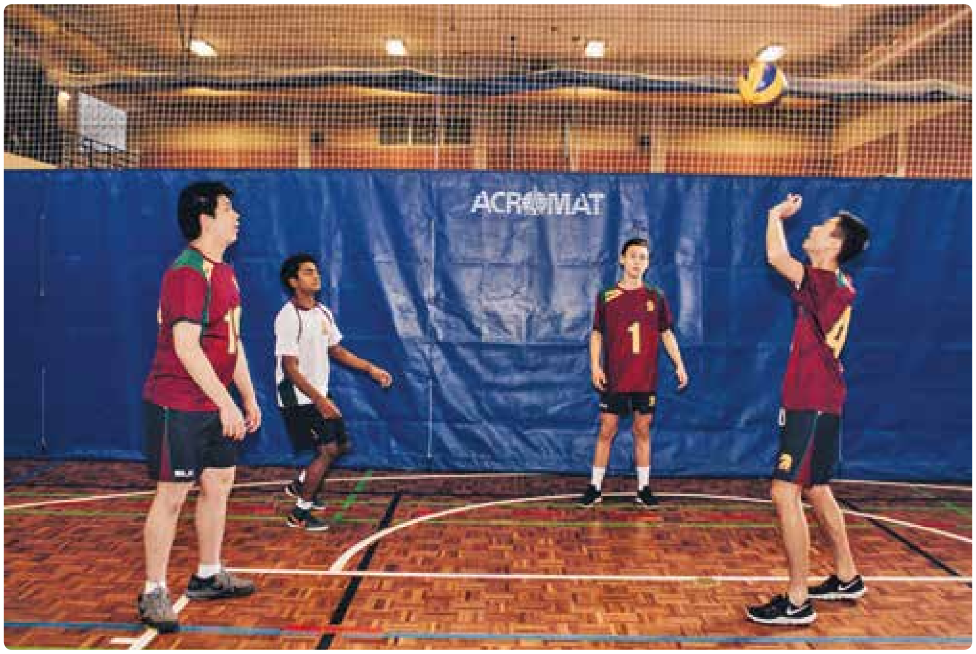


FIGURE 4.15 Multiple skills practised in an unpredictable sequence improves transfer of learning. Students engage in a volleyball rally, using a range of skills in an unpredictable order.

Random practice has a significant impact both on learning (skill acquisition) and performing in a game environment. By constantly changing the skill that is being performed, the learner is forced to recreate the mental action plan (the basic blueprint for the successful movement) for each skill. This constant redesigning and implementing of the action plan works to improve the memory of the relevant skills. Random practice also encourages the learner to be proactive about solving movement skill challenges that are comparable to the challenges they will face in competition. In other words, random practice encourages participants to be active learners rather than rote learners.

During highly variable practice sessions, it is not uncommon for there to be a relatively high number of performance errors. However, in the long term, variable practice ultimately leads to greater transfer of learning (the retention of skills learnt in practice) and more substantial improvements in competition performance.

FIGURE 4.16 Random practice prepares athletes for competition.

TABLE 4.2 Blocked, serial and random practice

	Blocked practice	Serial practice	Random practice
Suitability for stage of learning	Cognitive	Associative	Autonomous
Emphasis	Very little or no practice variability The learner's attention is predominantly on executing and replicating ideal skill technique	A number of skills are practised in the same practice session Different skills are practised in a predictable sequence The learner's attention is divided equally between executing skill technique and decision making	A number of skills are practised in the same practice session Skills are practised in random order Specific to the relevant game environment The learner's attention is predominantly given to decision making
Advantages	The novice learner is able to concentrate on one skill at a time, free from distractions The learner replicates the basic mechanics of skill technique Facilitates significant improvement in skill execution during practice sessions Helps the learner to develop confidence in their skill performance	Enables a moderate degree of practice variability for the intermediate or associative learner Is an important progression towards skill mastery and game preparedness	Most effective at preparing the learner for the games environment: – more closely resembles the physical and cognitive demands of a game – enables the learner to develop more applicable skills – enables the learner to improve applicable decision-making skills Greater transfer of learning Encourages participants to be active learners

eBook*plus*

Interactivity
Practice variability
Searchlight ID: int-6787

Consideration for varying practice for skill learning

There are a number of factors a coach must consider when designing the appropriate level of variability for practice.

- Practice variability can be added to training sessions by changing the practice conditions. For example, a netballer can choose to rehearse their goal shooting by themselves or under the pressure of an opposing goal-keeper. This type of practice, where the same skill is practised in a different manner, is referred to as intraskill.

  Practice variability can also be added by changing the skills being rehearsed. This is referred to as interskill and is most applicable to random or serial practice sessions.

FIGURE 4.17 Practising in isolation (blocked) may not adequately prepare the performer for the demands of competition.

- As a general rule, there should be less variability of practice in the early stages of learning and more variability of practice in the latter stages of learning. In the early stages, the more predictable/closed environment helps to establish the basic skill performance. However, as the learner becomes more competent in skill execution, they will benefit more from practice variability.
- There should be a higher degree of practice variability for open sports than closed sports. However, intraskill variability is important to enhance closed skill performance.
- The physical and cognitive demands of variable practice should mirror the physical and cognitive demands of the relevant games environment. Variable practice ensures the skills learnt in training can be successfully applied in competition.
- Constraints-based instruction, the process of varying game constraints (chapter 3) to direct learning, relates closely to varying practice. Constraints-based instruction is a form of variable practice designed to achieve a designated learning outcome.
- Lower variability in practice will lead to better performance in practice, however greater variability of practice will result in greater learning and better preparedness for the game environment.
- There are circumstances in which it is preferable to produce immediate success, albeit in a low-variability environment. For example, in a pre-game warm-up, basketballers practise their lay-ups in uncontested line drills so as to develop confidence and feel before they are exposed to the highly variable demands of the game itself.

FIGURE 4.18 Warming up without the pressure of competition gives the players confidence.

FIGURE 4.19 Deliberate practice is a well-defined task with opportunities for repetition and correction of errors.

Deliberate play, practice and programming

A considerable amount of research has gone into establishing the ideal amount and type of practice required to achieve skill mastery. It was Anders Ericsson (Ericsson et al., 1993) who attributed increases in skill performance almost solely to the number of hours spent in what he categorises as **deliberate practice**. In Eriksson's words, deliberate practice amounts to performing a 'well defined task with the appropriate difficulty level for the particular individual, (with) informative feedback, and opportunities for repetition and corrections of error'. Interestingly, Ericsson contends this type of practice does not necessarily need to be enjoyable.

Deliberate practice is a highly structured form of practice aimed at enhancing specific skill performance, which usually involves instruction from an expert coach. Most participants involved in high level or elite sport would be familiar with this type of practice and would acknowledge its role in movement skill development.

However, it is not always the case that 'more is better' in regard to deliberate practice and resultant skill development. Some coaches and parents subscribe to the idea of **early specialisation** regarding sport participation in an effort to gain a performance advantage; that is, specialising in one sport at a very young age in an effort to maximise the hours of deliberate practice. This early specialisation suits sports such as gymnastics where body size, in particular power-to-weight ratio, has a significant impact on skill performance.

Deliberate practice is any activity that is undertaken with the specific purpose of increasing performance, requires cognitive and/or physical effort and is relevant to promoting positive skill development in a particular sport.

Early specialisation is the participation in a single sport from a very young age, involving a high level of structured practice and a low level of deliberate play in an attempt to fast-track skill development and gain a competitive advantage.

FIGURE 4.20 Performance levels reflect the time spent in deliberate practice.

Deliberate play is a form of sporting activity involving early developmental physical activities that are intrinsically motivating, provide immediate satisfaction, and are designed to maximise enjoyment. They are activities that are regulated by rules adapted from standardised sport rules and are set up and monitored by the participants themselves.

However, while early specialisation may lead to early gains in skill performance, it may also put the young athlete at risk of burn-out. For an athlete suffering from burn-out, sport is no longer enjoyable and they lack the intrinsic motivation to apply themselves to practice. Early specialisation and the accompanying heavy and repetitive training load may also put the young participants at risk of overuse injuries.

Another researcher, Jean Côté, devised the developmental model of sports participation as a framework to better understand potential pathways to sport expertise (elite sport). Côté's developmental model identifies three distinct development phases in which the learner is exposed to different types of practice.

FIGURE 4.21 Deliberate play: designed for maximum fun

The three phases are:

- the sampling years (childhood; 5–12 years)
- the specialising years (early adolescence; 13–15 years)
- the investment years (late adolescence: 16+ years).

In the sampling years, the learner participates in practice Côté refers to as **deliberate play**. Deliberate play, as mentioned in chapter 3, generally takes the form of an enjoyable backyard or neighbourhood game, in which the participants can experiment with different skill techniques without the pressure and expectation associated with more structured and coach-centred practice. Deliberate play cultivates an independent and intrinsically motivated learner empowered to discover and develop effective movement skills and game tactics.

FIGURE 4.22 Deliberate play: experimenting with new skill techniques

In the specialising years, the skill learner participates in one or two competitive sports and refines skill development through an even mix of structured play and structured practice. In the investment years, the athlete focuses on a single sport and practice is almost entirely structured practice.

Côté recognised that the chances of a learner reaching elite level sport can be enhanced through participating in a range of sports and activities at a young age. This diverse range of experience enables the young athlete to develop fundamental physical and cognitive skills that can be applied across a number different sports (see table 4.3). These cognitive and physical attributes enable the learner, after a period of investment in heavy deliberate practice, to attain elite level performance.

TABLE 4.3 Classification of elements that may be transferable across sports

Elements	Transferable aspects	Example
Movement	Biomechanical and anatomical actions required to perform a task	Throwing a baseball overhand and an overhand serve in tennis
Perceptual	Environmental information that individuals interpret to make performance-related decisions	Field hockey and soccer both require participants to accurately interpret the actions of their opponents in order to be successful.
Conceptual	Strategies, guidelines and rules regarding performance	Gymnastics and diving share conceptual elements (e.g. similar roles).
Physical conditioning	Physiological adaptations across similar modes of training	Short-term interventions of combined run–cycle training are as effective as running alone in increasing aerobic capacity.

Source: Based on Schmidt, RA & Wrisberg, CA 2000, *Motor learning and performance: a problem-based learning approach*, Human Kinetics, Champaign, IL.

Côté's development model for sports participation actually tracks three different pathways:

1. recreational participation
2. elite performance through sampling (diverse experience in early learning)
3. elite performance through early specialisation (little or no sampling in early learning).

The model not only describes these three pathways and their respective learning experiences but also looks at outcomes in terms of health and enjoyment (see figure 4.23). Clearly, early specialisation is a legitimate pathway to elite sport; however, it comes at a cost to the participant's health and wellbeing.

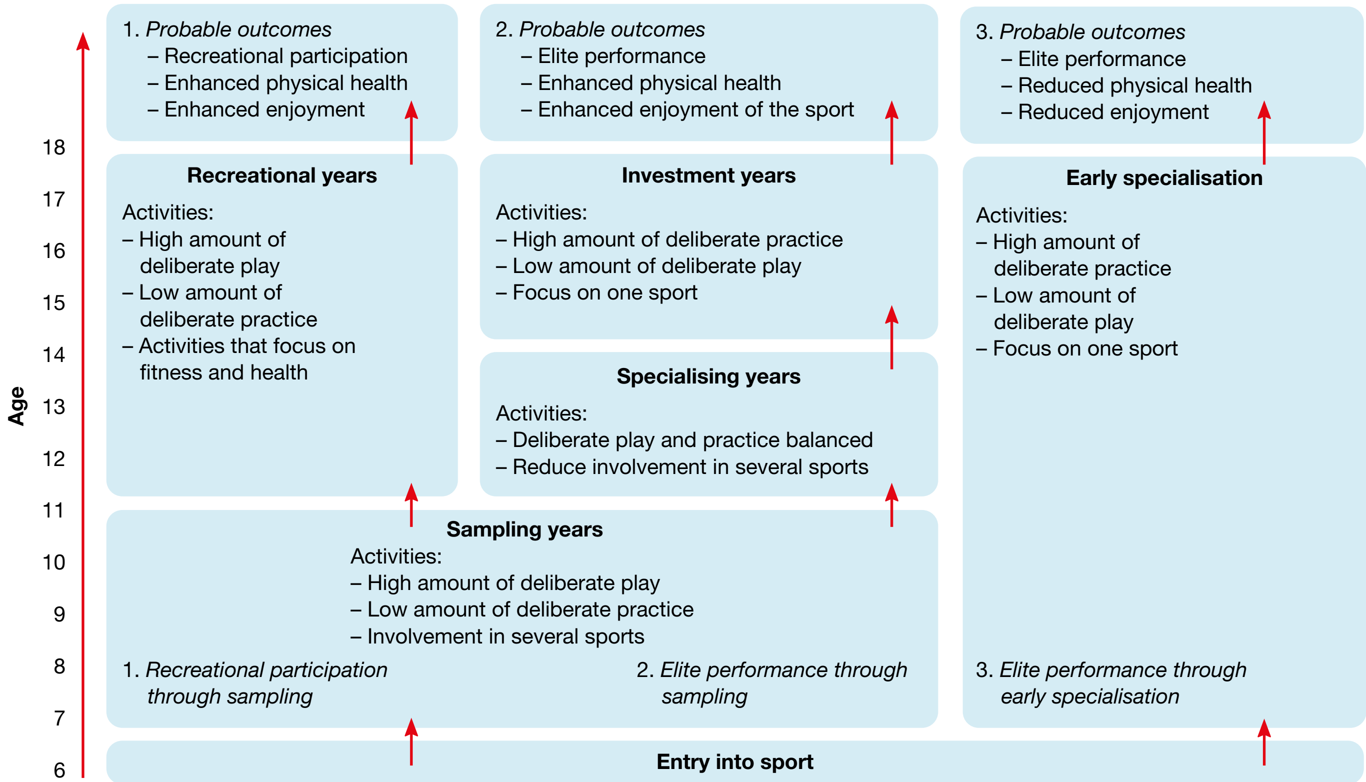


FIGURE 4.23 Developmental model of sports participation

Source: Adapted from Côté, J, Baker, J & Abernethy, B 2007, 'Practice and play in the development of sport expertise', in G Tenenbaum & RC Eklund (eds), *Handbook of sports psychology*, 3rd edn, Wiley, New York, p. 197.

Understanding Ericsson's deliberate practice and Côté's development model including the concept of deliberate play, helps coaches to plan and facilitate learning experiences that ensure effective movement skill development. Coaches learn that goal-orientated, coach-driven deliberate practice is necessary to advance the learner on their pathway to skill mastery. But coaches also learn that it is necessary to give the young learner time and space to experiment with different techniques and, most importantly, contrary to Ericsson's belief regarding deliberate practice, have fun.

The Australian Institute of Sport has borrowed ideas from the likes of Ericsson and Côté and, in an effort to hasten sports expertise, has engaged in a process of deliberate programming. Rather than looking solely at the impact of types of practice on skill development, deliberate programming takes a more holistic view of the pathway to sport expertise. Deliberate programming looks to fast-track the pathway to elite sport through the strategic coordination of sports science, sports medicine and expert coaching. This deliberate programming approach to hot-housing elite talent was inspired by the Australian Winter Olympics skeleton program. In 2005–6 the Australian Winter Olympic team used talent identification to select female athletes from a range of sports and then attempted to make these complete novices into Olympic-standard skeleton racers within a 14-month period.

The story of the Australian women's skeleton team and their efforts to make the Calgary Winter Olympics in 2006 has been made into a documentary: *Nerves of Steel*. To watch the documentary, an excellent example of trying to 'hot-house' skill performance through deliberate programming, use the ***Nerves of Steel* documentary** weblink in your eBookPLUS.

FIGURE 4.24 Skeleton, Winter Olympics

eBook*plus*

Weblink
Nerves of Steel documentary

The deliberate programming approach relates closely to the AIS' FTEM (Foundation, Talent, Elite and Mastery) model, which in turn borrows heavily from Côté's development model. As outlined in *Developing Sport Expertise,* Farrow et al., Chapter 4, '. . . the strategic and combined layering of sports science and sports medicine, excellent coaching, early and aggressive competition immersion, close program and individual case-management, challenging and enjoyable daily training environments, upward pressure through competitive cohort immersion, and novel qualification and selection strategies collectively typify the multi-dimensional aspects of performance progression central to the FTEM philosophy.'

eBook*plus*

Interactivity
Types of practice
Searchlight ID: int-6785

TABLE 4.4 **Summary table of practice considerations applicable to different stages of learning**

Type of learner	Novice	Intermediate	Elite
Practice distribution	Distributed	Distributed (task dependent)	Distributed/massed (task dependent)
Practice variability	Blocked	Serial	Random
Type of practice	Deliberate play	Deliberate play/deliberate practice	Deliberate practice

study on

Unit 3
AOS 1
Topic 4
Concept 2

Practice variability

TEST your understanding

1 Outline each of the following:
(a) practice variability
(b) deliberate play
(c) deliberate practice
(d) early specialisation.

2 Explain the difference between blocked, serial and random practice.

3 Outline three ways in which highly variable practice can benefit the learner.

APPLY your understanding

4 (a) Make a copy of the table below in your notes. Tick the column to indicate the type of practice distribution and amount of practice variability appropriate to both the stage of learning and the particular movement skill.
(b) In each case, explain your choice of appropriate practice design in relation to distribution and variability.

Skill learning	Practice distribution		Practice variability		
The learner and the movement skill	**Massed**	**Distributed**	**Blocked**	**Serial**	**Random**
An elite tennis player practising their ground strokes, volleys and overheads					
A novice soccer player practising passing					
An intermediate golfer practising various iron shots					
A novice swimmer practising butterfly					
A highly motivated elite netballer player practising game play					

5 **Practical activity: variability of practice**
The aim of this learning activity is to investigate the effect of variability of practice on performance.
Equipment: Tennis balls and targets
Method: Use your non-preferred hand to bounce the ball on the floor before hitting a target on the wall. Score one point for each target hit.

Test conditions
Test 1: For half the class (group 1), run 15 practice trials standing three metres from the target.

Test 2: For the other half (group 2), run five practice trials standing three metres from the target, five trials standing four metres from the target and five trials standing five metres from the target.
Test 3: Both groups run 10 trials standing six metres from the target.
Results: Record and analyse the results from each of the trials

Discussion

(a) Which group would you have expected to score more points in tests 1 and 2? Why?
(b) Which group scored the most points in their trials standing six metres from the target?
(c) How does variability of practice improve performance?

EXAM practice

6 **ACHPER Trial Exam 2016, question 12**

Select the response below that best describes random practice.

(a) Repetitive practice of the same task in one training session
(b) Performing the same task sequentially in one training session
(c) Performing varied sequencing of different skills in one training session
(d) Repetitive practice of different tasks over a number of training sessions

1 mark

7 **ACHPER Trial Exam 2016**

A tennis coach trains 3 different players. Player A is an experienced player who competes at an elite level, player B is an intermediate performer who is just starting to participate in competitive tournaments and Player C is a complete novice. Complete the following table.

Player	Relevant stage of learning	Type of practice variability	Benefit of practice variability to relevant stage of learning
A			
B			
C			

5 marks

4.3 Feedback

KEY CONCEPT Feedback is the essence of skill learning, enabling the learner to correct and refine skill performance.

Feedback is information concerning the performance and/or outcome of a movement skill, including information about errors and how to correct them.

Feedback is any form of information a learner receives about their skill performance. Feedback can come from a variety of sources and provide information about skill error(s) or information that reinforces successful movement patterns. Coaches must think carefully about the types of feedback they provide and how to best tailor feedback to the specific needs of the learner.

Whatever the coach decides, it's important to recognise that feedback is a critical and indispensable part of skill acquisition.

Feedback works on a number of different levels:

- Feedback motivates the learner by providing information on the progress of skill learning.
- Feedback highlights skill errors and enables the learner to make appropriate corrections.
- Feedback also provides positive reinforcement, confirming when the learner is performing correctly.

Types of feedback

There are many forms of feedback, each of them critical to the ongoing development of the learner.

FIGURE 4.25 Olympic aerial skier Lydia Lassila undertaking water jumps as part of her training. Lydia relies on different types of feedback to improve her skill performance.

Intrinsic feedback

Intrinsic feedback is sensory information the learner receives directly from skill execution.

Intrinsic feedback is the information the performer receives directly from their sensory systems. Intrinsic information is provided by the learner's visual and proprioception systems as well as their cutaneous system (the skin: pain, temperature and pressure). For example, the basketballer shooting at the free-throw line is aware of the coordination of their body parts to execute the shot (proprioception), feels (cutaneous) the spin they impart on the ball at the point of release and sees (visual) the flight path relative to the ring. Intrinsic feedback often allows the athlete to correct or improve their skill execution during the performance.

Coaches may use questioning as a strategy to enhance the performer's use of intrinsic feedback; for example, the cricket coach asks 'do you feel balanced or unbalanced when you successfully hit an off-drive in cricket?'

FIGURE 4.26 Augmented feedback from a coach

Augmented feedback

Augmented feedback refers to information that comes from sources external to the performer. Traditionally, augmented feedback describes the information that comes from an instructor or a coach; for example, a basketball coach telling a player that their free-throw shots are falling short because of a lack of knee bend. This could also be reinforced by another form of augmented feedback such as video analysis. The player and coach are able to review game video, recognise faults in the shooting technique and subsequently make the appropriate corrections. Apps such as Hudl have made it easier to analyse technique and share information between coach and athlete.

Augmented feedback is information about a skill performance that comes from an external source.

In endurance sports involving continuous skills, such as cycling and running, augmented performance feedback can come in the form of monitors that record heart rate, cadence, speed and wattage. While this feedback does not relate directly to skill execution, it does provide information on the relative success or failure of that skill performance. Hence we can say feedback can be divided into two broad categories: knowledge of performance (e.g. the basketballer's shooting technique) and knowledge of results (e.g. did the basketball go in the hoop?, did the cyclist reach their target speed?).

Knowledge of performance

Knowledge of performance refers to feedback that provides information about the process of performing the skill; for example, a golfer is able to recognise they have a problem with their weight transferral after watching a video of their swing. It provides feedback on how the skill is performed, rather than the outcome or result of that skill performance. Knowledge of performance can be an augmented form of feedback, as in the case of video analysis or, more commonly, verbal feedback from the coach. Knowledge of performance can also be an intrinsic form of feedback, such as the performer's sense of feel or proprioception; for example, the golfer can feel when their weight is too far back in their stance, or if the club face is not square through the ball strike.

Knowledge of performance is feedback regarding how a skill is performed; assessing performance on the basis of process and skill technique.

FIGURE 4.27 Knowledge of performance: feedback regarding skill execution

Coaches, for the most part, should concentrate on providing knowledge of performance feedback as this is the most effective means of correcting faults and facilitating learning.

Knowledge of performance can be further broken down into either descriptive feedback or prescriptive feedback. Descriptive feedback gives an account of the learner's skill performance and provides details of what they performed correctly and what they performed incorrectly. Prescriptive feedback points out the skill error and prescribes a strategy to correct it. Prescriptive feedback is suited to a beginner who has no skill correction strategies yet, whereas descriptive feedback is more suited to an experienced performer.

Knowledge of results is information about the outcome of skill performance; information regarding the relative success or failure in regard to the intended goal of the movement skill.

Knowledge of results

Knowledge of results is information about the outcome of your skill performance. Using the previous example, the golfer receives knowledge of results regarding the golf shot by seeing the resulting ball flight and where the ball lands.

Generally speaking, knowledge of results is clearly evident to the learner. The learner can see when the basketball goes into the hoop or when the softball is struck into the foul zone. As such, the coach doesn't need to spend as much time providing knowledge of results feedback.

Knowledge of results can be important in the early stages of learning, particularly as successful outcomes can be a strong motivating factor for the beginner performer. Also, a beginner may need to be educated as to what constitutes a successful result. An inexperienced player will recognise scoring a goal in soccer as an obvious example of a successful skill performance; however, they may not recognise less obvious, yet nonetheless important, skill performance outcomes. For example, a soccer player who dribbles the ball to draw a defender to create space for their teammates to receive a pass is also achieving a successful performance. However, this type of result may need to be explained to a novice participant.

FIGURE 4.28 Seeing the basketball successfully go through the hoop is an example of knowledge of results.

Other forms of augmented feedback classifications include the following.

Correct versus incorrect feedback

Incorrect feedback focuses on the learner's skill errors, while correct feedback focuses on what the learner is doing well. Correct feedback is important as a learner will be motivated to practise more if they are experiencing relative success. Incorrect feedback is crucial for effective skill learning; correcting skill errors in an effort to develop effective technique.

Precision of feedback: qualitative versus quantitative

Qualitative feedback provides general feedback about movement skill performance; for example, a sprint coach tells their athlete 'your hips are too high and your back leg is too straight in the set position during the sprint start and this is causing a lack of push off the rear block'.

FIGURE 4.29 Quantitative feedback is precise and uses numerical values.

Quantitative feedback is more precise feedback, which uses numeric values; for example, the sprint coach informs the athlete the angle at the knee in their rear leg is 140 degrees. An experienced athlete can interpret and utilise this precise form of feedback, while a novice athlete will prefer more general qualitative feedback.

Prescriptive versus descriptive feedback

Prescriptive feedback refers to feedback that sets out recommendations about how to correct skill errors and how to improve future performances. Prescriptive feedback is well suited to the novice performer.

Descriptive feedback provides a detailed account of the process of skill performance. The performer digests this feedback and makes skill changes based upon the information they deem most pertinent. Descriptive feedback is more suitable for the experienced performer.

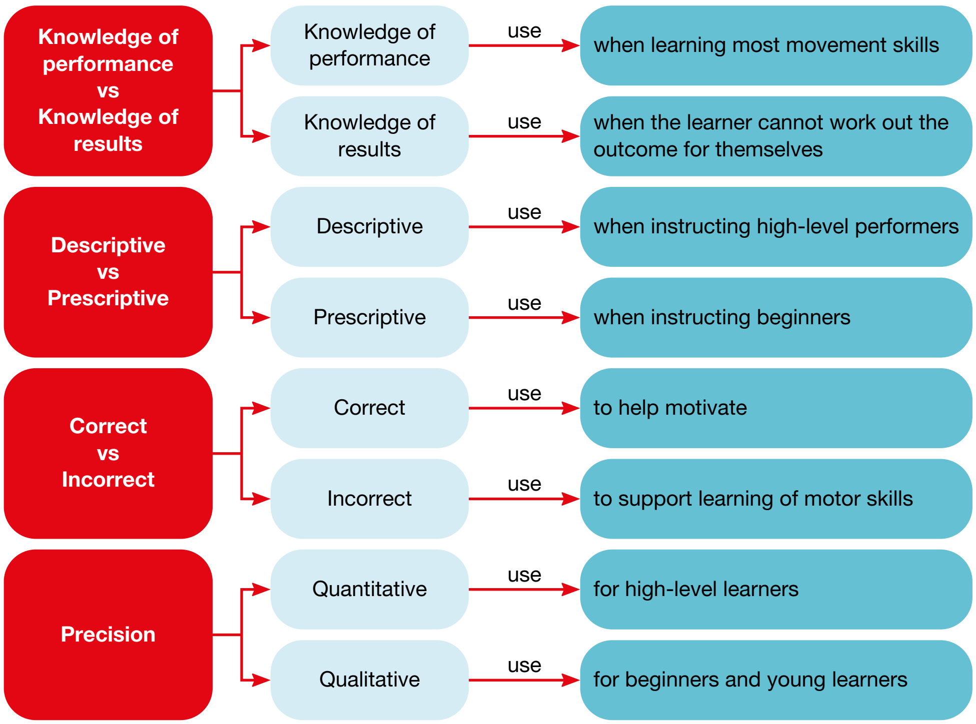


FIGURE 4.30 A summary of different forms of feedback and their appropriate application

studyon

Unit 3
AOS 1
Topic 4
Concept 3

Types of feedback

TEST your understanding

1 (a) Explain what is meant by augmented feedback.
(b) Outline four examples of augmented feedback in relation to sports coaching.

2 (a) Explain what is meant by intrinsic feedback.
(b) Outline four examples of intrinsic feedback in sports performance.

3 Research the following sensory systems:
(a) proprioception
(b) cutaneous.
With the use of a sporting example, explain the type of feedback these systems provide and the significance of this feedback in terms of successful skill performance.

4 Explain why knowledge of performance feedback is generally more effective than knowledge of results with respect to facilitating skill learning.

APPLY your understanding

5 **Practical activity: feedback**
The aim of this learning activity is to investigate the effect that the amount and type of feedback has on skill performance.

Equipment: Volleyball and hoop

Method: Working in pairs, stand three metres from your partner, holding the ball and keeping your back to them. Try to throw the ball over your head (without looking) and through a hoop held by your partner. You have 10 chances.

Write down the number of successful scores for each of the following scenarios (use the point system to work out the total scores):
(a) Ball goes through hoop (3 points)
(b) Ball makes contact with the hoop (2 points)
(c) Complete miss (1 point).

Test conditions
Test 1: Receive no feedback
Test 2: Receive limited feedback: 'yes the ball went through the hoop' or 'no, you missed'
Test 3: Receive as much feedback as possible about the ball flight in relation to the hoop and about the relative success of the performance. Your partner can also make suggestions about how to improve your performance.

Results: Record and analyse the results for each of the trials for your entire class; that is, what was the average result for tests 1, 2 and 3?

Discussion
(a) Define the types of feedback received in tests 2 and 3.
(b) What do the results of test 1 tell us about the importance of feedback in regard to skill learning?
(c) Which test accrued the highest average score? Explain why.
(d) What other types of feedback could your partner provide to further enhance your performance?

EXAM practice

6 Select the best example of internal feedback.
(a) An athlete using knowledge of results to change their performance
(b) An athlete using knowledge of performance to change their performance
(c) A coach giving feedback on an athlete's technique to help improve their performance
(d) An athlete using their own senses including visual, auditory and proprioception to adjust their technique **1 mark**

7 **adapted from ACHPER Trial Exam 2016, question 8**
The table below has the results of a Year 11 Physical Education class who were investigating the effect of feedback on performance. The results were achieved by performing the same skill, with each group practising using different styles of feedback. Students were given 20 shots at throwing a basketball over their head into a net. They received two points for a basket, one point if they hit the edge and no points if they missed. The average score for each group is listed below.

Feedback	Condition 1	Condition 2	Condition 3
Average score	8 pts	12 pts	16 pts

(a) Consider the average scores above for conditions 1, 2 and 3. Match each of the conditions above to the correct description below.
i. Extensive feedback on their performance and detailed feedback on results
Condition ________________________ **1 mark**
ii. No feedback at all
Condition ________________________ **1 mark**
iii. Feedback on results only (e.g. 'in basket' or 'missed basket')
Condition ________________________ **1 mark**
(b) Explain your choices in part a (i.e. why did you associate a particular point score with a particular type of feedback?). **3 marks**

4.4 Frequency and timing of feedback

KEY CONCEPT Determining the ideal amount of feedback and the most effective manner in which this feedback is provided will be influenced by the specific needs of the learner and the characteristics of the relevant movement skill.

Frequency of feedback

Feedback frequency refers to how often an external source (e.g. coach) provides feedback to the skill learner.

Frequency refers to how often a coach provides augmented feedback. Frequency can be measured as an absolute value (the total number of times feedback is provided) or a relative value (the percentage of the learner's practice efforts for which feedback is provided). It's impossible to say with certainty what the perfect **feedback frequency** is to maximise skill learning. However, the following principles should be considered.

- Feedback should be provided regularly to facilitate skill acquisition.
- Provide more feedback in the early stages of learning and less in the latter stages of learning. A beginner performer needs assistance understanding when they have made skill errors and also needs to be given strategies to correct these errors.
- Too much feedback can lead to information overload, particularly in the early stages of learning. Performers in the cognitive stage of learning need to dedicate a substantial amount of attention to understanding the basic mechanics of a new skill, as well as engage in a trial-and-error learning style. If the coach provides feedback too frequently, they risk compromising the learner's attention as well as disrupting their learning style.
- Too much feedback in the latter stages of learning can lead to the learner becoming overly dependent on the coach's guidance to achieve success. As the learner becomes more competent in skill performance, it's important they learn to use their own intrinsic feedback to detect skill errors and put in place strategies to correct these errors. A low level of feedback frequency can reduce the standard of performance in training; however, it aids inquiry-based learning and results in better transfer of learning to the games environment.

FIGURE 4.31 It's important that athletes don't become overly dependent on the coach's feedback.

Summary feedback

An effective strategy regarding feedback frequency is for the coach to only provide feedback after they watch a series of skill attempts. This is referred to as summary feedback. The advantage of summary feedback is that it allows the coach to address and prioritise the most significant and underlying causes of skill error. This will increase the chances of improving skill performance and reduce the occurrence of information overload. Summary feedback also allows the learner sufficient time to attempt the coach's corrective strategies, as well as cross-reference these changes with their own intrinsic feedback.

FIGURE 4.32 Feedback should be given after a series of skill attempts.

Further to summary feedback, other forms of feedback that facilitate skill development and encourage participants to be independent learners are as follows.

Faded feedback

Feedback frequency is high at the beginning of a practice session but is progressively reduced the longer the session goes on. Learners initially process a relatively high amount of information regarding correct skill execution but are then given time to practise and apply this information.

Bandwidth feedback

The coach and athlete agree on an acceptable bandwidth of performance or margin of error. Precise, quantitative feedback is only supplied if the athlete's performance falls outside these margins; for example, if a swimmer's 100-metre training splits are five seconds too slow.

If the performance is within the bandwidth, the athlete is offered qualitative feedback; for example, 'well done, your 100-metre split times are excellent'. How the bandwidth is set is influenced by the learner's relative level of skill development; that is, an elite performer may have a narrow bandwidth, whereas the coach may accept a wider margin for error for a novice performer.

Performer-regulated feedback versus coach-regulated feedback

Performer-regulated feedback is feedback provided at the athlete's request. This kind of self-regulated feedback is more suited to experienced performers. Often an elite performer is the best judge of the causes of their own skill errors and, as such, can request the most pertinent information to facilitate skill correction. Otherwise, for less experienced or novice performers, it is best that an experienced coach regulates the type and amount of feedback given to facilitate effective skill learning.

Timing of feedback

Timing of feedback refers to when feedback is provided to the skill learner in relation to their performance.

Timing of feedback refers to when augmented feedback is provided to the learner in relation to their performance.

For feedback to be effective, it should be accurate, relevant and immediate. The immediacy of feedback refers to the idea that feedback should be given to the learner soon after their performance, while the relative success or failure of skill execution is still fresh in their mind. Therefore, the timely provision of feedback allows the learner to address skill errors and make appropriate skill adaptations.

If the learner received corrective feedback several days after their initial performance, they would be less likely to contextualise this information, less motivated to make the suggested changes and consequently unlikely to improve.

Feedback can be given at the completion of a skill (terminal) or during the performance of the skill (concurrent).

FIGURE 4.33 Terminal feedback: feedback given at the completion of skill performance

Terminal feedback

Terminal feedback is information that is given at the completion of a skill performance.

Terminal feedback is information that is given at the completion of the skill. For example, a tennis coach watches their player perform a serve and then provides feedback regarding the positioning of the ball toss.

Some considerations regarding the use of terminal feedback are:

- The advantage of terminal feedback is that it enables the performer to give their full attention to the coach. This is particularly important for the novice performer who finds it difficult to listen to and process feedback while performing a skill.
- It is recommended the coach momentarily delays the delivery of feedback post skill performance as this allows the learner to first attend to and evaluate their own intrinsic feedback regarding their performance. The learner can then cross-reference their intrinsic feedback with the coach's augmented feedback and increase their capacity to make positive change.

studyon
Unit 3 | AOS 1 | Topic 4 | Concept 4
Frequency and timing of feedback

FIGURE 4.34 Concurrent feedback: feedback received during skill performance

Concurrent feedback

Concurrent feedback is information given during the skill performance; for example, a rowing coach speaks to their athletes as they row on a waterway. The athletes are able to hear the coach's feedback and make the appropriate skill adjustments while they are rowing.

Concurrent feedback is information that is given during a skill performance.

Advantages of concurrent feedback include:

- it can have an immediate impact on skill performance
- it can provide greater opportunity to receive feedback; that is, the performer does not have to wait until a designated rest period before receiving information regarding skill fault correction
- in physical, continuous sports such as rowing, cycling and kayaking, it's important that training intervals are not interrupted. Concurrent feedback allows a coach to provide important information regarding skill performance without compromising the physiological benefits of the training session.

Concurrent feedback should not be used if it distracts the learner and deflects their attention from performing the basic skill mechanics. This is more likely to be the case in the early stages of learning.

Coaches should be wary of using concurrent feedback if it reduces the performer's use of intrinsic feedback.

FIGURE 4.35 Even though Lydia Lassila's ski jumps last for just a few seconds, she is still able to receive and process concurrent feedback from her coach. The coach yells instructions to cue the appropriate timing of key components of the skill performance.

TABLE 4.5 Summary table of feedback use in relation to the type of learner

Type of learner	Novice	Intermediate	Elite
Type of feedback	Knowledge of results Qualitative Correct Prescriptive	Knowledge of performance Qualitative Correct/Incorrect Prescriptive	Knowledge of performance Quantitative Incorrect Descriptive
Frequency of feedback	Higher frequency Summary feedback Coach-regulated	Faded feedback Summary feedback Coach-regulated	Lower frequency Summary feedback Performer-regulated
Timing of feedback	Terminal	Terminal/Concurrent (task dependent)	Terminal/Concurrent (task dependent)

TEST your understanding

1 Compare and contrast the ideal feedback frequency for a novice performer with that for an expert performer.

2 Identify and outline three considerations when deciding whether concurrent or terminal feedback is most appropriate for facilitating skill learning.

3 Why is it important that an athlete does not become overly reliant on their coach's feedback to facilitate a successful performance?

APPLY your understanding

4 Watch a sports practice session or a PE lesson. Observe the following:

(a) How often does the coach provide feedback to the participants?

(b) What is the main form of feedback — knowledge of performance or knowledge of results, verbal augmented feedback or performers reliant on intrinsic feedback?

(c) Was the majority of feedback provided during performance (concurrent) or at the completion of the skill performance (terminal)?

(d) Did the learner's performance improve in response to feedback or was the feedback a distraction that ultimately compromised their performance?

Reflect on the feedback given during the practice session. Discuss how the type of feedback, the frequency of the feedback and the timing of the feedback could be changed in order to further enhance skill learning.

5 **Practical activity: juggling**

The aim of this learning activity is to investigate the effect feedback timing has on skill learning.

Equipment: Juggling balls

Method: Your teacher will give you some basic instruction on how to three-ball juggle and/or display a short video demonstration. Students work in pairs. One student tries to juggle while the other plays the role of coach.

Pre-test the juggler: how long can they juggle continuously before they drop the balls?

Post-test the juggler: at the end of a double period or after several lessons of practice, test the juggler again.

Trial conditions

Divide the jugglers into two groups. One group completes trial 1 conditions and the other group trial 2.

Trial 1: Coaches can only provide feedback while their partner is attempting to juggle.

Trial 2: Coaches can only provide feedback while their partner is resting. Coaches can film their partner and refer to the footage in rest breaks if they wish.

Results: Record and analyse the results for each trial for your entire class.

Discussion

(a) Classify the type of feedback received in trial 1 and the type of feedback received in trial 2.

(b) What type of feedback was more influential on skill learning? Explain why you think this is the case.

(c) In which trial did you think the feedback was more frequent? Do you think this helped skill learning or hindered it? Explain.

(d) As the juggler, did video analysis help you learn the skill? What other types of feedback would be effective in this learning scenario?

KEY SKILLS PRACTICE AND FEEDBACK

KEY SKILLS

- Discuss how skill classification affects the selection of appropriate practice strategies
- Participate in, observe and record the characteristics of different types of practice strategies
- Perform, observe, analyse and report on the role of feedback in improving performance through practical-based activities

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- Skill classification describes the type of skill in terms of precision of movement (fine or gross), the predictability of the performance environment (open or closed), whether it is complex (multiple sub-routines) or whether it is continuous or discrete
- Practice can be designed and organised in many different ways: massed, distributed, blocked, serial or random
- Different types of practice suit different types of skills; for example, complex or highly fatiguing skills are best suited to distributed practice
- A coach/teacher should decide upon the type of feedback provided, feedback frequency and the timing of the feedback based on the classification of the relevant movement skill and the participant(s) stage of learning
- Appropriate practice and feedback facilitate effective movement skill learning.

PRACTICE QUESTION

1 **Adapted from 2014 ACHPER Trial Exam, question 5**

(a) **Define** the difference between open and closed skills, using examples from the sport of hockey. *(2 marks)*

(b) Using your examples from part (a), **outline** what would be the ideal type of practice to enhance a closed skill and the ideal type of practice to enhance an open skill. **Explain** and **contrast** how these different types of practice help to enhance the respective open and closed skills. *(4 marks)*

(c) **Describe** the type of feedback elite Hockeyroo Anna Flanagan would use while playing a match and **explain** how she would utilise this feedback to enhance her skill performance. *(5 marks)*

SAMPLE RESPONSE

(a) A closed skill is performed in a predictable environment and is self-paced; for example, a free hit or a penalty stroke. An open skill is performed in an unpredictable environment and is externally paced; for example, dribbling the ball around a defender.

(b) Random practice has a high level of practice variability, provides a less predictable and externally paced environment and is therefore suited to developing open skills. Blocked practice involves working on a single skill in isolation for a period of time. Blocked practice provides a stable and self-paced practice environment and is therefore suited to developing closed skills.

(c) Anna would be reliant on concurrent augmented feedback from her coach on the sideline, as well as her own intrinsic feedback; for example, Anna can feel when she has struck the ball with the appropriate speed and accuracy. As an experienced hockey player, Anna can process her coach's instructions while playing and further enhance her skill performance and her contribution to the team's success.

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Define — accurately state or explain the meaning of the term
  Outline — general description but not in detail
  Describe — provide a detailed account of
  Explain — to make the meaning of something clear and understandable
  Contrast — explain points of difference. It is not enough to just list the differences; you need to explain *how* they are different
- **Key terminology:**
  Open and closed skills — understand skill classification
  Elite — describes an autonomous performer, an experienced performer
- **Key concepts:**
  Types of practice — different skills require different types of practice
  Types of feedback — different types of feedback suit different types of performers; i.e. what type of feedback suits the elite performer?
- **Marking scheme:** *a. (2 marks) b. (4 marks) c. (5 marks)* — always check marking scheme for depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

a.
- **2 marks:** define open and closed skills. No marks will be given without an example of the appropriate skill from hockey.

b.
- **2 marks:** random practice suits open skills and blocked practice can suit closed skills
- **2 marks:** explain the differences in practice variability between random and blocked practice

c.
- **1 mark:** acknowledge Anna is an experienced performer
- **2 marks:** for two types of feedback: concurrent and intrinsic
- **2 marks:** for providing examples for each type of feedback

CHAPTER SUMMARY

Practice

Amount of practice

- In the interest of effective skill learning, a coach should endeavour to maximise the time the learner spends actively engaged in practice.
- Coaches should carefully monitor 'time on task'. Equal time should be apportioned to all relevant skills. Coaches should be aware that their athletes may become disengaged and less motivated if they spend too long on one task.
- The principle of 'diminishing returns' dictates that as the level of skill performance increases, the relative rate of skill learning diminishes.

Practice distribution

- Massed practice involves participants rehearsing for one continuous period of time, with few or no rest breaks. Massed practice suits highly motivated, competent performers.
- Distributed practice involves breaking practice sessions up into shorter work periods, interspersed with substantial rest periods. Distributed practice is well suited to the novice performer and the performer who lacks concentration and/or motivation. Distributed practice is also ideal for learning a complex skill or a skill that is highly fatiguing. The rest breaks in distributed practice help the performer to consolidate their learning.

Practice variability

- Practice variability refers to the degree to which a coach varies practice conditions, as well as the number and variety of skills that are practised in a particular session. Practice variability also refers to the number and variety of skills that are rehearsed in a particular session.
- Practice variability develops versatile, game-applicable movement skills and improves decision-making and game sense.
- Random practice involves a high degree of practice variability. Random practice is well suited to the experienced performer and is particularly applicable to open sports.
- Serial practice involves an intermediate level of practice variability. Serial practice involves regularly changing the skill being rehearsed but in a set and predictable order.
- Blocked practice has very low levels of practice variability. Blocked practice involves working on the same skill, in the same practice conditions, in a stable and predictable environment for an extended period time. The novice learner is well suited to blocked practice.
- Low practice variability is generally the most efficient way for a novice performer to learn a new skill; that is, the performer can learn the basic mechanics of the skill with few or no distractions.
- As a general rule when organising training sessions, there should be low levels of practice variability for participants in the early stages of learning, whereas there should be high levels of practice variability for participants in the latter stages of learning.
- Practice variability should reflect the physical and cognitive demands of competition.
- A coach can enhance the performance of a closed skill by regularly varying practice conditions.
- Practice sessions for closed skills should involve the athlete planning the movement skill, executing the movement skill and evaluating the outcome of the movement skill.
- Deliberate practice is a highly structured form of practice, aimed at enhancing a designated skill(s) performance. Deliberate practice is repetitious, involves a degree of difficulty appropriate to the learner and allows for the provision of feedback to correct skill errors.
- Deliberate play involves participating in an activity or game loosely based on an established sport. The rules are designed by and for the participants, with the primary objective of having fun. This discovery-based learning environment allows the participants to trial and develop different movement skill techniques.

Feedback

- The role of feedback is to motivate the learner, correct skill errors and reinforce successful performance.
- Different types of feedback suit different types of tasks and different stages of learning.

Types of feedback

- Intrinsic feedback is information the performer receives from their sensory systems; for example, how it feels when the cricket ball strikes the middle of the bat.

- Augmented feedback is feedback received from an external source; for example, a coach yelling instructions from the sideline.
- Knowledge of results is feedback relating to the outcome of a skill performance; for example, in AFL, whether the football went through for a goal or a behind.
- Knowledge of performance is feedback relating to how a skill is performed; for example, a golfer can feel their bodyweight shift effectively from their back foot to their front foot during a golf swing.
- Qualitative feedback is a general form of feedback regarding skill performance and/or a form of encouragement; for example, a tennis coach compliments a player for 'reaching high' during the service action.
- Quantitative feedback is a precise form of performance feedback involving numerical values; for example, a tennis coach informs their player 'your arm was 10 degrees off vertical at the top of the service arc'.
- Qualitative feedback suits the novice, whereas quantitative feedback suits the experienced athlete.

Frequency of feedback
- Frequency of feedback refers to how often a coach gives feedback.
- As a general rule, a novice performer will require more frequent feedback than an experienced performer.
- An elite performer requires less frequent, but more precise, feedback.
- A coach must be careful not to overload the novice performer with information.
- If feedback is consistently too frequent, there is a risk the athlete will become overly dependent on the coach to facilitate successful performance.
- The goal of the coach should be to develop autonomy in their learners, an ability to use their own intrinsic feedback to enhance performance, particularly during competition.
- Summary feedback enables the coach to address the underlying causes of skill error and allows the learner to rehearse a number of skill attempts before having to process further performance feedback.

Timing of feedback
- Timing of feedback refers to when the coach gives feedback relative to the skill performance.
- Feedback can be concurrent (during the performance) or terminal (at the completion of the performance).
- Concurrent feedback may be a time-efficient means of improving an experienced athlete's performance, however it can compromise a novice performer's attention to skill execution,
- Terminal feedback allows the athlete to give the coach their undivided attention and is well suited to the novice performer.

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 The term 'diminishing returns' in skill acquisition refers to
  (A) a learner's state of arousal and preparedness to learn.
  (B) the notion that massed practice diminishes skill development.
  (C) the principle that the more competent the performer, the harder they must practise for further improvement in skill performance.
  (D) the principle that the less competent the performer, the harder they must practise for further improvement in skill performance.

2 Random practice is best described as
  (A) predictable and repetitive.
  (B) highly varied practice involving numerous skills.
  (C) working on one skill in several different ways.
  (D) practice that suits less-fatiguing skills.

3 A soccer player watches his penalty kick sail past the keeper and into the back of the goal net. This is an example of which type of feedback?
  (A) Intrinsic feedback, knowledge of results
  (B) Augmented feedback, knowledge of results
  (C) Intrinsic feedback, knowledge of performance
  (D) Concurrent feedback

eBook*plus*
Interactivity
Practice and feedback quiz
Searchlight ID: int-6788

studyon
Sit VCAA exam

4 Amy is a 10-year-old circus-skills student learning to juggle for the first time. What type of feedback and feedback frequency should Amy's instructor use to facilitate effective skill learning?
(A) Infrequent, concurrent feedback
(B) Athlete-regulated, terminal feedback
(C) Infrequent, terminal feedback
(D) Summary, terminal feedback

5 Blocked practice can assist
(A) in the development of game sense.
(B) a novice performer to become familiar with the basic mechanics of a new skill.
(C) in adding a high degree of practice variability.
(D) in the simultaneous development of many skills.

6 Immediately after a training session, a coach shows a swimmer a video of her stroke and discusses strategies to enhance performance. This is an example of which type of feedback?
(A) Concurrent, intrinsic
(B) Concurrent, augmented and knowledge of results
(C) Terminal, augmented and knowledge of performance
(D) Concurrent, augmented and knowledge of performance

7 James is taking part in Little Athletics and learning to high jump using the Fosbury Flop technique for the first time. Which of the following would be the most appropriate practice structure and the most effective type of feedback?
(A) Distributed practice and summary feedback
(B) Massed practice and summary feedback
(C) Massed practice and incorrect feedback
(D) Distributed practice and incorrect feedback

8 When coaching hockey players to improve their penalty strokes, the coach should
(A) vary the practice conditions.
(B) organise blocked practice to replicate effective technique.
(C) ensure the physical and cognitive demands of practice are similar to those in a match.
(D) make the player practise visualisation.

9 Deliberate practice can be best described as
(A) structured, goal-orientated practice involving repetitive rehearsal and augmented feedback.
(B) 10 000 hours of physically and mentally demanding rehearsal.
(C) a self-discovery learning environment, allowing the learner to experiment with different skill techniques.
(D) the foundation for any athlete to reach sports expertise.

10 A rowing coach providing technical information from a speedboat to his moving crew is an example of
(A) concurrent feedback regarding knowledge of results.
(B) terminal feedback regarding knowledge of performance.
(C) terminal feedback regarding knowledge of results.
(D) concurrent feedback regarding knowledge of performance.

TRIAL EXAM QUESTIONS

Question 1 **(ACHPER Trial Exam 2015, question 3)**

The Davis Cup Tennis competition is different from any other tennis competition in that not only do players represent their country in a team format, but the team and coaches also sit on the sidelines during the matches.

a. Define feedback and provide an example of **two** types of feedback that players would rely on during a Davis Cup match to improve their performance. **4 marks**

b. In tennis, one of the most difficult and complex skills to master is the serve. Explain **two** types of practice that would increase the learning and mastery of a tennis serve. **4 marks**

Question 2 **(ACHPER Trial Exam 2013)**

Cricket, unlike many other team sports, does not provide many opportunities for players to receive feedback from coaches during play.

a. Define and provide an example of the main type of feedback that a batsman would rely on while out in the middle. **2 marks**

b. Outline **three** key roles feedback plays in any sport. **3 marks**

Question 3 **(ACHPER Trial Exam 2014)**

a. Outline the difference between open and closed skills, using examples from the game of hockey to support your response. **2 marks**

b. What is the type of feedback a hockey player would rely on while playing in a game? Provide an example of this type of feedback in your discussion. **2 marks**

c. Suggest how and when a coach could use the following types of practice in hockey for maximal benefit:

Random practice

Massed practice **4 marks**

Question 4

During practice, the Eltham Dragons Under-14 soccer team regularly takes part in small-sided modified games that mimic the physical and cognitive demands of a proper soccer match. However, parents at the soccer club are concerned that this type of training results in the Under-14 players making too many skill errors. The parents would rather see the players doing repetitive, uncontested skill drills instead.

Imagine you are the head coach of the Eltham Dragons Soccer Club. How would you reassure and explain to the parents that the small-sided games are exactly what these young players need to develop into successful gameday performers?

Your explanation must include reference to **practice variability**. **5 marks**

Question 5

Mandy is an under-12 netballer who is attempting to improve her goal shooting. Mandy understands the fundamentals of goal shooting but lacks consistency in performance. Using the table below, circle the most appropriate form of feedback and the most appropriate form of practice for Mandy to improve her goal shooting. In the spaces provided, explain your choices. **12 marks**

Type of practice (circle the most suitable)	**Explain why this practice is most appropriate for Mandy.**
Massed or distributed	
Blocked or serial	
Type of feedback (circle the most suitable)	**Explain why this feedback is most appropriate for Mandy.**
Knowledge of results or knowledge of performance	
Descriptive or prescriptive	

INQUIRY QUESTION
How is energy produced to enable this physical activity?

CHAPTER

5 Energy systems and interplay of energy systems

Energy is required for all kinds of bodily processes including growth and development, repair of body tissue, the transport of various substances between cells and, of course, muscle contraction, which enables movement to occur.

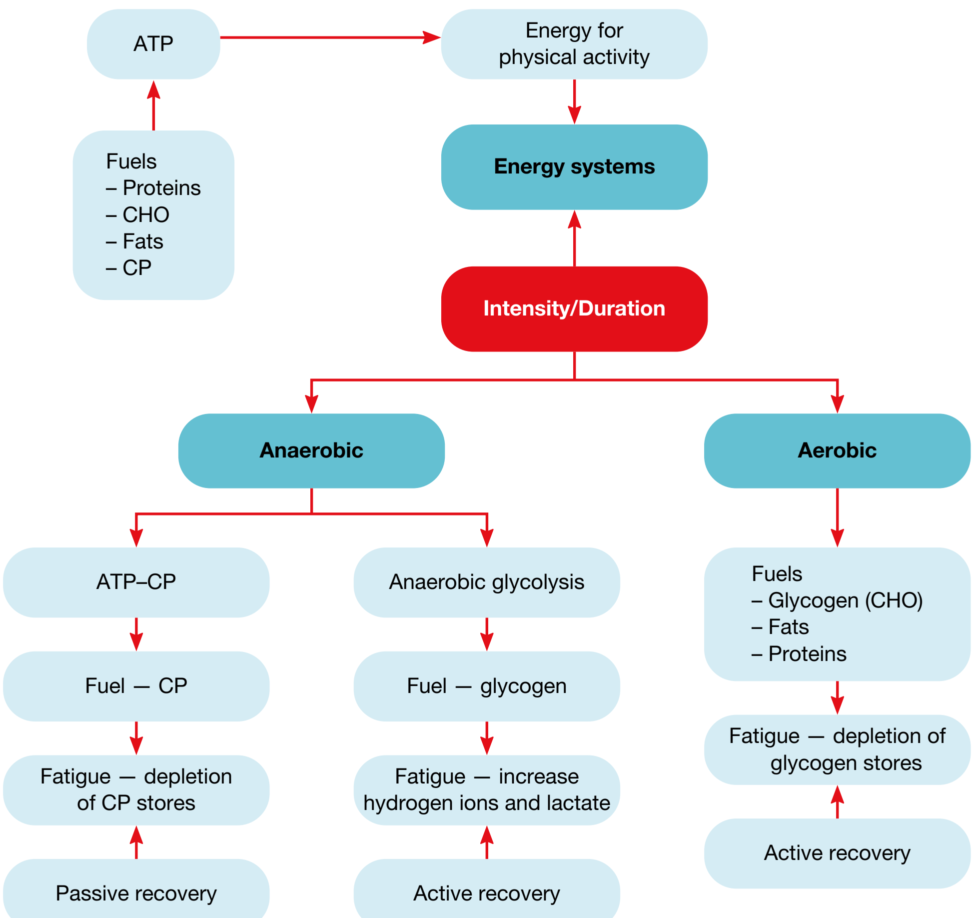
KEY KNOWLEDGE

- Fuels (both chemical and food) required for resynthesis of ATP at rest and during physical activity, including the relative contribution of fuels at varying exercise intensities
- Characteristics of the three energy systems (ATP–CP, anaerobic glycolysis, aerobic systems) for physical activity, including rate of ATP production, the yield of each energy system, fatigue/limiting factors and recovery rates associated with active and passive recoveries
- Interplay of energy systems in relation to the intensity, duration and type of activity

KEY SKILLS

- Participate in a variety of physical activities and describe, using appropriate terminology, the interplay and relative contribution of the energy systems
- Perform, observe, analyse and report on laboratory exercises designed to explore the relationship between the energy systems during physical activity and recovery
- Explain the fatiguing factors associated with the use of the three energy systems under varying conditions

CHAPTER PREVIEW



5.1 Adenosine triphosphate (ATP): the body's energy currency

KEY CONCEPT Adenosine triphosphate (ATP) provides energy for muscular contraction.

Adenosine triphosphate (ATP) is a high-energy molecule stored in muscle cells and other parts of the body. It is the energy currency for biological work.

Adenosine triphosphate (or ATP as it is more commonly referred to) is the chemical energy 'currency' of all body cells, including muscle cells. It powers all of the cell's metabolic activities, including in the case of muscle cells, the ability to contract. An ATP molecule consists of adenosine and a chain of three inorganic phosphate groups bound together by high-energy chemical bonds (see figure 5.1).

The energy that powers the mechanisms involved in muscular contraction is obtained from the catabolism (breaking down) of ATP. However, the body stores only a very small quantity of this 'energy currency' within the cells, enough to power only 1–2 seconds of maximal exercise. As most sporting activities last longer than this, the body must replace or resynthesise ATP on an ongoing basis. Understanding how the body does this is the key to understanding energy systems.

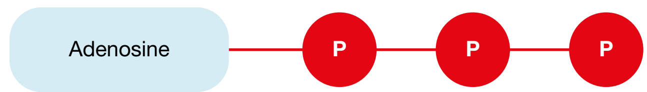


FIGURE 5.1 An ATP molecule consists of adenosine and a chain of three inorganic phosphate groups bound together by high-energy chemical bonds.

Adenosine diphosphate (ADP) is a by-product that results when ATP breaks down and loses one of its phosphate groups located at the end of the molecule.

The phosphate 'tail' of ATP is the actual 'power source' that the cell taps into. Available energy is contained in the bonds between the phosphates and is released when they are broken. Usually only the outer phosphate is removed from ATP to yield energy; when this occurs ATP is converted to **adenosine diphosphate** (or ADP) and inorganic phosphate (or Pi — free phosphate molecule).

The energy released during the breakdown of ATP to ADP and Pi is used to power cell processes such as the mechanisms involved in muscular contraction. This can be represented by the formula ATP ↔ ADP + Pi + Energy (see figure 5.2).

eBook*plus*

eLesson
Breakdown of ATP
Searchlight ID: eles-0469

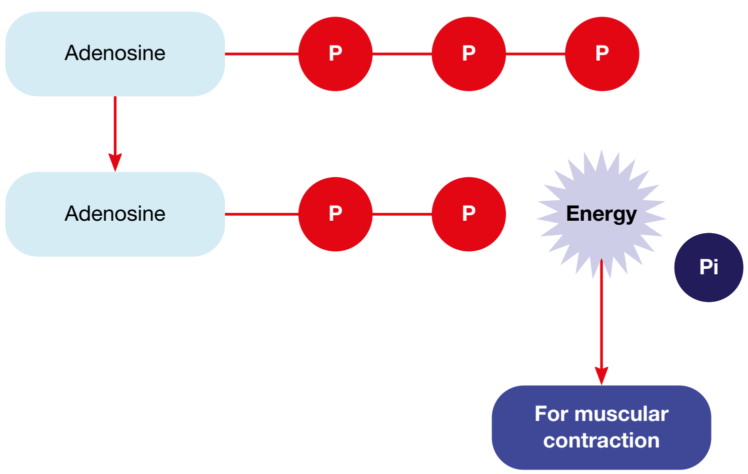


FIGURE 5.2 The energy released during the breakdown of ATP to ADP and Pi is used to power cell processes such as the mechanisms involved in muscular contraction.

Replenishing ATP stores

While the breakdown of ATP is required in order to provide the energy that powers the mechanisms involved in muscular contraction, muscular stores of ATP are very limited. It is estimated that the total quantity of ATP in the average human body is about 0.1 mole or approximately 50–100 grams. Yet estimates put the daily energy requirement of an average person upwards of 100–180 moles of ATP, which is equivalent to 50–75 kilograms of ATP (see figure 5.3).

The limited stores of ATP within the body are used up within about 1–2 seconds of maximal intensity activity. If it were not for the fact that ATP stores are constantly replenished during activity, muscular contraction could not continue. Once intramuscular ATP stores begin to deplete, chemical reactions within the muscle start to replenish ATP stores, allowing the muscles to keep working.

The replenishment of the limited stores of ATP occurs via a process known as **phosphorylation**. This is a biochemical process that involves the addition of a phosphate group to an organic compound or molecule. In this particular circumstance it involves the addition of a phosphate group to ADP to form ATP. In other words, ATP is replenished or resynthesised from ADP and Pi. However, this resynthesis requires energy to connect the phosphate group back to ADP to create ATP (ADP + Pi + Energy ↔ ATP). This energy can be obtained from the breakdown of several energy fuels or substrates that are also present within the muscle. These fuels or substrates include creatine phosphate (or phosphocreatine as it is also known), forms of carbohydrate (glycogen), fats and protein. These fuels can provide the energy required for the resynthesis of ATP during physical activity for as long as sufficient stores of the fuels or substrates are available (see figure 5.4).

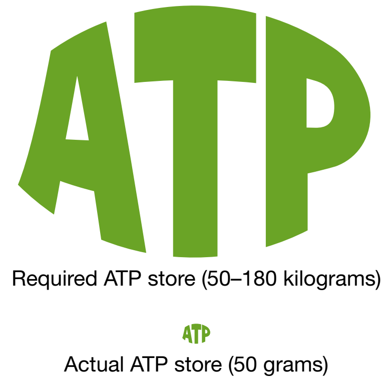


FIGURE 5.3 It is estimated that the total quantity of ATP in the average human body is 50–100 grams; much less than what is required in a 24-hour period.

Phosphorylation is a biochemical process that involves the addition of a phosphate group to an organic compound or molecule. It involves the addition of phosphate to ADP to form ATP (ADP + Pi + Energy → ATP).

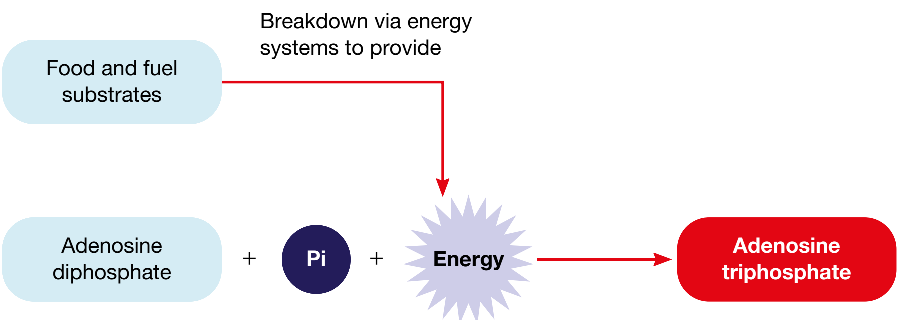


FIGURE 5.4 The resynthesis of ATP from ADP and a free phosphate molecule requires energy available from the breakdown of energy fuels.

The energy that is required to enable ATP resynthesis to occur can be released from these energy fuels via three distinct yet closely integrated metabolic pathways or energy systems. If ATP resynthesis occurs via energy systems or pathways that require the presence of oxygen, it is referred to as **aerobic metabolism** (or oxidative phosphorylation). If it occurs via energy systems or pathways that do not require oxygen then it is referred to as **anaerobic metabolism**.

Aerobic metabolism is when ATP resynthesis occurs via energy pathways that require the presence of oxygen.

Anaerobic metabolism is when ATP resynthesis occurs via energy pathways that do not require the presence of oxygen.

TEST your understanding

1. Explain what is meant by 'ATP is the energy currency of the cell'.
2. Draw a diagram to show the basic structure of ATP.
3. Explain how ATP differs from ADP.
4. Define the term *phosphorylation*.
5. What is the difference between anaerobic and aerobic metabolism?

EXAM practice

6. Outline the role of ATP in producing energy for physical activity. **2 marks**

eBook*plus*

eLesson
ATP breakdown and resynthesis
Searchlight ID: eles-0454

5.2 Energy fuels: converting food to energy

KEY CONCEPT Energy fuels or substrates are used to provide the energy required for ATP resynthesis.

Several energy fuels or substrates can be used to provide the energy required for the resynthesis of ATP from ADP and Pi. These include creatine phosphate (a chemical fuel) and carbohydrates, fats and protein (food fuels).

Creatine phosphate

Creatine phosphate (CP) is a chemical compound found in muscle cells that is capable of storing and releasing energy that can be used to resynthesise ATP from ADP and Pi.

Creatine phosphate (CP), or phosphocreatine (PC) as it is also known, is a chemical compound that, like ATP, is stored in limited quantities within muscle cells. Also like ATP, creatine phosphate is a high-energy substance capable of storing and releasing energy via the high-energy bond that binds the creatine and phosphate together (see figure 5.5). When this bond is broken, energy is released that enables ATP to be resynthesised from ADP and Pi.

FIGURE 5.5 The chemical compound creatine phosphate (CP) consists of creatine and phosphate bound together by a high-energy bond.

Creatine in the diet

Creatine is an organic substance that occurs naturally in humans and helps to supply energy to muscle.

Appproximately 50 per cent of the **creatine** stores within our bodies are obtained through the foods we eat, while the other 50 per cent are manufactured in the kidneys and liver. Roughly 95 per cent of the human body's total creatine is located in skeletal muscle. The rest is located in the brain or heart. Approximately one-third is found within our bodies in its free form as creatine, while the remainder is bound with phosphate to form creatine phosphate.

Carbohydrates

Carbohydrates are naturally occurring compounds that consist of carbon, hydrogen and oxygen.

Carbohydrates are found in many of the foods we eat. Traditionally, carbohydrates have been generally divided into two groups:

1. simple carbohydrates or sugars, composed of one or two glucose molecules (monosaccharides and disaccharides)
2. complex carbohydrates or starches, made up of many hundreds of glucose molecules (polysaccharides).

Glycaemic index

Glycaemic index (GI) is a ranking of carbohydrates on a scale from 0 to 100 according to the extent to which they raise blood-glucose levels after eating.

The **glycaemic index (GI)** is a ranking of carbohydrates on a scale from 0 to 100 according to the extent to which they raise blood-glucose levels after eating. Foods with a high glycaemic index (70 and above) are those that are rapidly digested and absorbed and result in a rapid increase in blood-glucose levels (see figure 5.6). Foods that have a high glycaemic index include sugar, potatoes, watermelon, many breakfast cereals (e.g. Corn Flakes), most white rices (e.g. jasmine) and white bread. Foods with a low glycaemic index, by virtue of their slow digestion and absorption, produce gradual rises in blood-glucose and insulin levels, and have proven benefits for health. Foods that have a low glycaemic index (55 or less) include most fruits and vegetables (except potatoes and watermelon), grainy breads, pasta, lentils, milk and yoghurt. Table 5.1 is a guide to the glycaemic index of many common carbohydrate foods.

Use the **University of Sydney GI database** weblink in your eBookPLUS to analyse the foods you have eaten in the last 24 hours and to develop a meal plan for the next 24 hours using four low-GI foods.

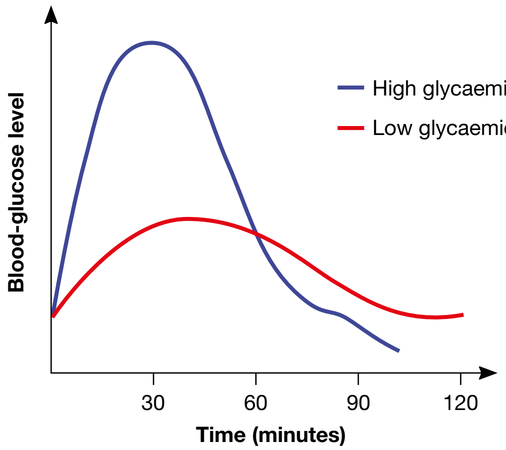


FIGURE 5.6 Rate of release of glucose for foods with a high and low glycaemic index

TABLE 5.1 Average glycaemic index of some common carbohydrate-rich foods

	Food	Glycaemic index (glucose = 100)
High glycaemic index	Rice crackers	87
	Cornflakes	81
	Porridge, instant oats	79
	Potato, boiled	78
	Watermelon	76
	White bread	75
	White rice, boiled	73
Moderate glycaemic index	Popcorn	65
	Sweet potato, boiled	63
	Honey	61
	Soft drink	59
	Pineapple	59
	Muesli	57
	Porridge, rolled oats	55
Low glycaemic index	Sweetcorn	52
	Pasta, white	49
	Orange	43
	Chocolate	40
	Milk, full fat	39
	Apple	36
	Lentils	32

Source: Copyright ©2008 American Diabetes Association From: *Diabetes Care*, December 2008 31:2281–2282. Reprinted with permission from The American Diabetes Association.

eBook*plus*

Weblink
University of Sydney GI database

Knowledge of the glycaemic index allows athletes, coaches and sports dietitians to determine what carbohydrate foods to eat and when to eat them. Manipulated correctly, this can enable the athlete to optimise their carbohydrate availability and thereby optimally enhance their performance and recovery. Put more simply, there would appear to be times when foods with a low glycaemic index provide an advantage, and times when foods with a high glycaemic index are better. For best performance, athletes need to understand which foods have high and low glycaemic index ratings and when it is best to eat them.

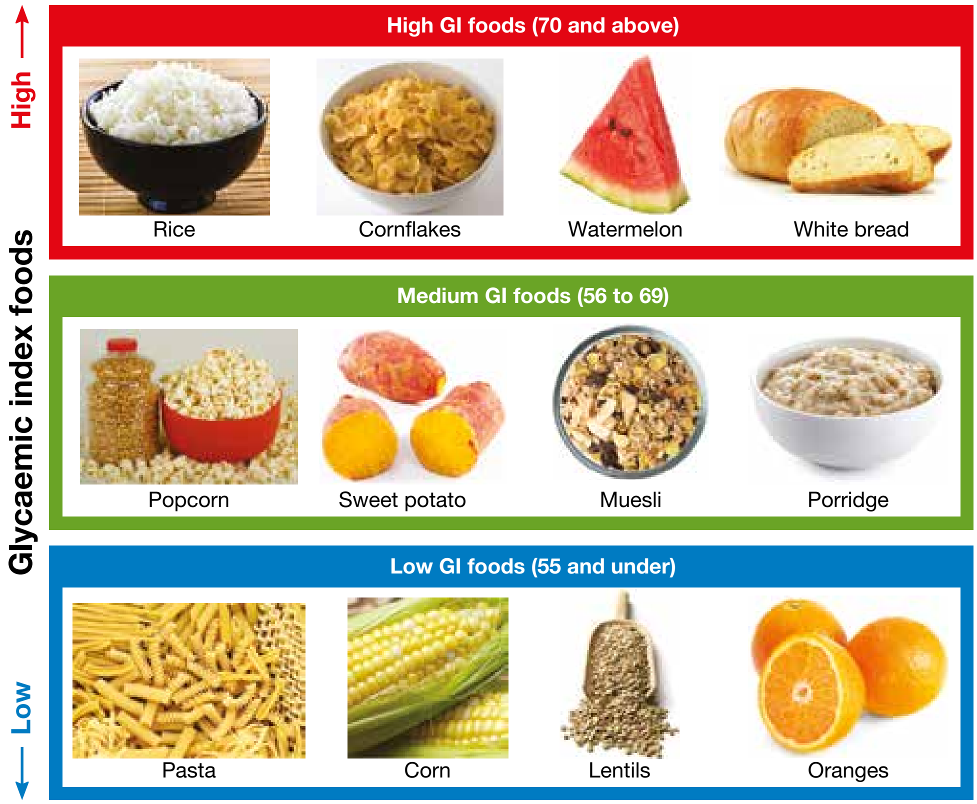


FIGURE 5.7 Examples of carbohydrate foods and their glycaemic index rankings

Glucose is the simplest form of carbohydrate and the basic ingredient for anaerobic and aerobic glycolysis.

Glycogen is the storage form of glucose found in the muscles and in larger quantities in the liver.

Carbohydrates in the body

When carbohydrates are digested, they are broken down into **glucose** for transportation via the circulatory system (blood) and then stored as **glycogen** in the muscles and liver. Any excess carbohydrates can be stored as fat in the form of triglycerides within adipose tissue around the body.

Carbohydrates as an energy source

Carbohydrates are the most versatile fuel source available to supply energy for ATP resynthesis. Carbohydrates in the form of glycogen can provide the energy for ATP resynthesis under both anaerobic (no oxygen required) and aerobic (oxygen required) conditions. For example, glycogen can supply energy for ATP resynthesis during both high-intensity, short-duration activities, such as sprinting 200 metres or repeated work periods during a game of football (anaerobic activities), as well as being able to provide energy during submaximal, longer-duration activities, such as a 1500-metre swim or 5-kilometre jog (aerobic activities). At rest and during low-intensity exercise, carbohydrates contribute approximately one-third of the body's energy requirements, with fats providing the other two-thirds.

Carbohydrates in the diet

Carbohydrates should make up approximately 55–65 per cent of total daily energy intake, although athletes in heavy training and competition may require a higher percentage intake (60–80 per cent) to ensure adequate levels in the body each day.

Fats

Fats (or lipids) are found in many different foods and can be divided into:

1. saturated fats
2. unsaturated fats.

Saturated fats are found in animal foods such as dairy products (e.g. milk, cheese) and meat products (see figure 5.8). This type of fat contains a substance called cholesterol that has been implicated in cardiovascular disease. When blood-cholesterol levels rise, blood vessels may become lined with cholesterol deposits leading to cardiovascular problems.

Fats (lipids) are an essential component of a balanced diet and should comprise about 20–25 per cent of the daily food intake.

FIGURE 5.8 Examples of foods containing saturated fats

Unsaturated fats (see figure 5.9) come in two forms: polyunsaturated and mono-unsaturated. Polyunsaturated fats are found in most vegetable oils (e.g. sunflower oil) and oily fish (e.g. tuna), whereas mono-unsaturated fats are found in foods such as olive oil, avocados and nuts. Both types of unsaturated fat help lower the total cholesterol level and contain essential fatty acids that the body cannot produce itself.

Fats in the body

Fats are broken down through digestion and made available to the bloodstream as **free fatty acids** and glycerol. They are stored intramuscularly as **triglycerides**, with excess amounts stored subcutaneously within adipose tissue around the body, where they act as a substantial energy reservoir.

Free fatty acids are a broken-down transportable form of fats.

Triglycerides are the stored form of fats found in adipose tissue and skeletal muscle.

FIGURE 5.9 Examples of foods containing unsaturated fats

studyon

Unit 3 | AOS 2 | Topic 1 | Concept 1

Fuels for energy
Summary screen and practice questions

Fats as an energy source

Fats are the most concentrated form of energy for ATP resynthesis. Gram for gram, fats provide more energy than carbohydrates, with fats providing about 9 kilocalories per gram whereas carbohydrates provide about 4 kilocalories per gram. Despite this, fats are primarily used during rest and low-intensity exercise. At rest, fats provide approximately two-thirds of the energy needs of the body, with carbohydrates contributing the remaining one-third. During exercise, the percentage of fats being used as an energy source decreases as the exercise intensity increases. This is because, metabolically speaking, fats are more difficult to break down and, therefore, their rate of energy release is too slow (considerably slower than that from carbohydrates) during high-intensity activity where ATP resynthesis must keep pace with the rapid rate of ATP use. However, fats as an energy source become increasingly important when stores of carbohydrate start to deplete during endurance exercise (usually after 90–120 minutes of continuous activity).

Fats in the diet

It is generally recommended that fats should make up about 20–25 per cent of the average daily energy intake, although for endurance athletes in training 25–30 per cent may be more appropriate.

Protein

Animal foods such as meat, poultry, fish, eggs and dairy products are rich in **protein** and contain all the essential **amino acids**. Plant foods such as cereals, grains, lentils, beans and peas are also good sources of protein, although they do not contain all of the essential amino acids.

Protein is an essential component of a balanced diet. Protein allows for muscle growth and repair, fights disease, helps chemical reactions and transports materials.

Amino acids are the building blocks of protein. Protein is broken down through the process of digestion into amino acids.

Protein in the body

Protein is broken down through digestion into amino acids of which there are two types:

1. essential amino acids — cannot be made by the body, so must be consumed as part of the diet

2. non-essential amino acids — can be manufactured from other amino acids in the body.

Excess protein (amino acids) is converted to fats and stored within adipose tissue.

Proteins help the formation, growth and repair of body tissue, especially muscle tissue and cells. They also help in the production of red blood cells, hormones and enzymes.

FIGURE 5.10 Examples of protein-rich foods

Protein as an energy source

Under normal circumstances protein contributes only minimal energy for ATP resynthesis (estimates put this figure at no more than 5–10 per cent). However, in extreme circumstances (such as starvation or ultra-endurance events), when the body has severely depleted its supplies of carbohydrate and fat, proteins can become a viable source of energy for the replenishment of ATP. Due to complex reactions required to break down the food fuels of fats and protein, energy is produced at a slower rate when produced from carbohydrate.

Protein in the diet

Nutritionists recommend that proteins contribute about 15 per cent of the average daily food intake. Athletes in training may require slightly more protein in their diet, especially athletes involved in strength and power sports.

Protein and carbohydrates

Protein and carbohydrates make excellent partners for post-exercise nutrition. When consumed together, they stimulate a greater release of insulin. Put more simply, the addition of protein amplifies the insulin response and promotes glucose delivery to depleted muscle cells.

- Insulin also plays a key role in the dynamics of protein synthesis.
- Insulin stimulates protein synthesis and helps to reduce protein breakdown.

The consumption of protein is therefore essential on two fronts:

- to help boost insulin release
- to provide the basic building blocks for muscle repair.

Examples of healthy snacks that include both protein and carbohydrates:

- yoghurt
- milk drinks
- fruit smoothies
- lean meat or cheese sandwiches.

Summary of food fuels

The elite athlete will adjust percentage food fuel intake in consultation with a coach/dietician to ensure their needs are met. For example, the elite athlete may require a greater level of protein intake if building and repairing muscle is needed. Most elite athletes will have a greater intake of fuel than will the general population, due to their excessive energy requirements.

Table 5.2 provides a summary of the food fuels that are used to provide energy for ATP resynthesis.

eBook*plus*

Interactivity
Summary of food fuels
Searchlight ID: int-6790

TABLE 5.2 Summary of food fuels

	Food sources	Transport form	Storage form in muscle	Excess
Carbohydrates	**Low glycaemic index:** most fruits and vegetables (except potatoes and watermelon), grainy breads, pasta, peas, lentils, milk and yoghurt **High glycaemic index:** sugar, honey, potatoes, watermelon, many breakfast cereals, most white rices and white bread	Glucose	Glycogen	• Liver — glycogen • Converted into fats — adipose tissue
Fats (lipids)	**Saturated fats:** meat products and dairy products **Unsaturated fats:** vegetable oils, oily fish (e.g. tuna), olive oil, nuts and avocado	Free fatty acids and glycerol	Triglycerides	Adipose tissue
Protein	**Animal foods:** meat, poultry, fish, eggs and dairy products **Plant foods:** cereals, grains, lentils, beans and peas	Amino acids	Amino acids	Adipose tissue

TEST your understanding

1. Explain the role of glycogen in providing energy for physical activity.
2. What percentages of carbohydrate, fat and protein are recommended as part of the daily dietary intake?
3. How would the dietary intake of food fuels differ for a weight-lifter compared with a long-distance runner?
4. Complete the following table to show the relationship between food fuels, the breakdown of these food fuels and the energy system or systems that use each food fuel.

Food fuel	Broken-down form	Associated energy system or systems
Carbohydrates	•	• •
Fats	• •	•
Protein	•	•

5. Carbohydrates and fats are the main food fuels used to supply energy for ATP resynthesis. Under what conditions would proteins be used to supply energy for physical activity?
6. How would knowledge of the glycaemic index of foods assist an athlete in terms of athletic performance?
7. Explain why, physiologically, it is inadvisable to consume a sugary food (with a high glycaemic index) just prior to beginning exercise.

APPLY your understanding

8. **Practical activity: individual diet and energy**
Record your total dietary intake for a continuous 3-day period. Record this intake in an appropriate table form. Assess the percentages of carbohydrate, fat and protein in your diet each day and for the 3-day period overall. Using your own dietary knowledge as a guide, how could you improve your diet to meet your energy needs? Write a brief report on your findings.

EXAM practice

9. Explain the role of creatine phosphate. **2 marks**
10. What is the most concentrated form of energy for ATP resynthesis? **1 mark**

5.3 Energy systems and pathways

KEY CONCEPT The energy required for ATP resynthesis is obtained via three energy systems or pathways.

The energy that is required to enable ATP resynthesis to occur can be obtained via three distinct yet closely integrated metabolic pathways or energy systems that operate together to satisfy the energy requirements of the muscle. Two of these energy systems are anaerobic pathways and the third is an aerobic pathway, as shown in figure 5.11.

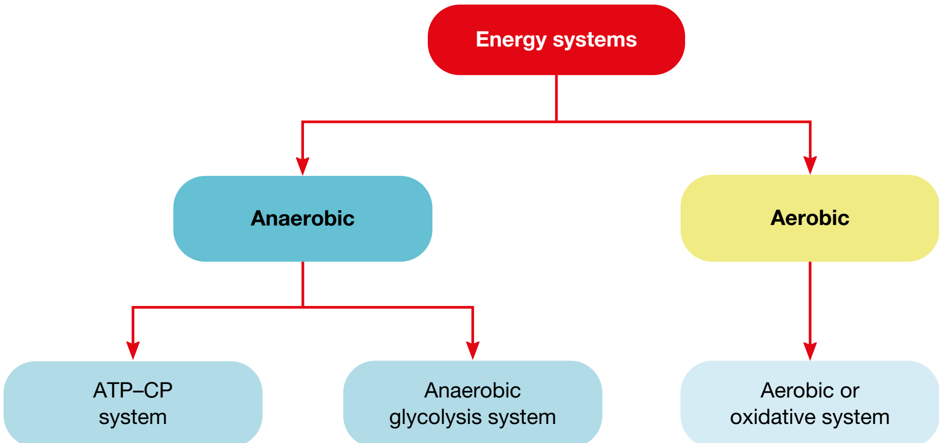


FIGURE 5.11 The body relies on three energy systems — two anaerobic systems and one aerobic system.

The ATP–CP system refers to the processes involved in the breakdown of stored phosphagens — ATP and creatine phosphate — without oxygen being involved. This system is also commonly referred to as the ATP–PC system, the phosphate energy system, the phosphocreatine (PC) system or the phosphagen system.

The anaerobic glycolysis system involves the metabolism of carbohydrates (glycogen) to lactic acid through a series of chemical steps that do not require oxygen, whereas the aerobic system (or oxidative system) refers to the complete metabolism of primarily carbohydrates (glycogen) and/or fats (triglycerides) in the presence of oxygen.

ATP resynthesis: demand, rate and yield

All three energy systems contribute to the resynthesis of ATP during physical activity. How each system works alongside the other energy systems is referred to as the interplay of energy systems. To determine which of the three energy systems is the predominant supplier of energy for ATP resynthesis at any point in time during an activity, and which energy system contributes energy predominantly over the duration of a total activity or event, we need to understand the concept of **ATP demand**.

During any activity, ATP resynthesis (supply) must be able to meet the ATP demand of the activity. Two factors determine the ATP demand of an activity:

1. exercise duration — how long the activity lasts for
2. exercise intensity — how hard the exercise is performed.

Exercise intensity determines the **rate** of ATP use and, consequently, resynthesis during the activity. Exercise duration determines the total amount or **yield** of ATP expended that is required to be resynthesised over the course of the activity. Generally

ATP demand refers to how much ATP is required during an activity and the rate at which it is expended and, therefore, needs to be resynthesised.

Rate refers to how quickly ATP is resynthesised.

Yield refers to the total amount of ATP that is resynthesised during an exercise bout.

speaking, as exercise duration increases, the intensity at which it can be performed decreases.

To help illustrate the concept of ATP demand, rate and yield, let us consider two different activities.

100-metre sprint

- Completed in around 10 seconds, the 100-metre sprint is a high-intensity activity, during which the rate of ATP expenditure is very rapid as the leg muscles are required to contract powerfully and very quickly. Consequently, the rate of ATP resynthesis must also be very rapid in order to keep pace with the demand. However, because of this event's short duration (less than 10 seconds), the yield (total amount) of ATP required is low.

Marathon

- Takes around two hours and 15 minutes to complete. Is undertaken at submaximal intensity and the rate at which ATP is required is much lower since the muscles are not required to contract as forcefully or as quickly as in the 100-metre sprint. Due to the marathon's much longer duration, though, the yield (total amount) of ATP required is much, much greater (see figure 5.12).

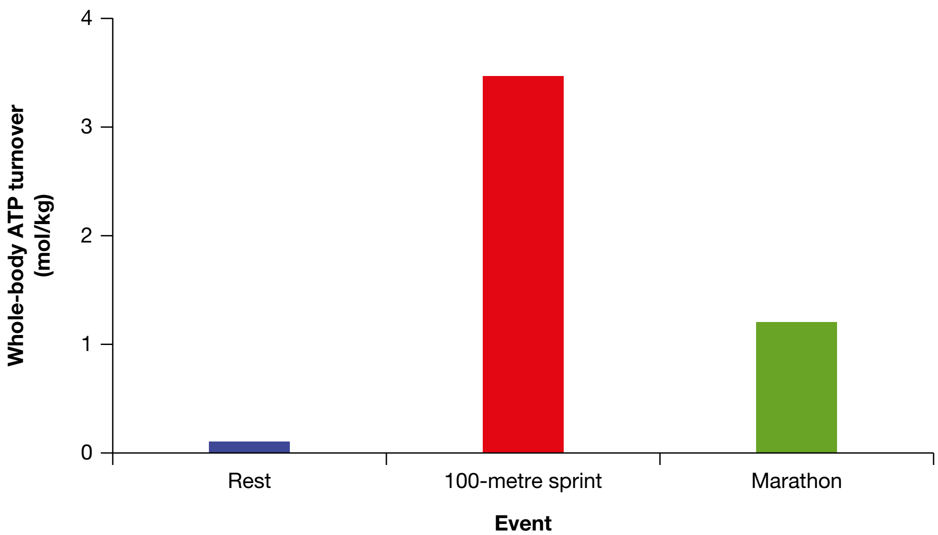


FIGURE 5.12 The 100-metre sprint and the marathon place different ATP demands on the athlete. Note that ATP turnover during a 100-metre sprint is estimated to be almost three times greater than during a marathon.

Source: Adapted from Poortmans JR 2004, *Principles of exercise biochemistry*, 3rd edn rev., Karger Publishing.

studyon

Unit 3 | AOS 2 | Topic 1 | Concept 2

Energy systems and pathways
Summary screen and practice questions

Meeting ATP demands

The two anaerobic energy systems (ATP–CP and anaerobic glycolysis) can supply energy for ATP resynthesis at a rapid rate. However, they can do this for only a short period of time, due to the much smaller yield of energy for ATP resynthesis. Therefore, the anaerobic pathways are the major energy systems used during high-intensity, short-duration exercise, since muscles need a rapid supply of ATP during such activities. The aerobic system, on the other hand, supplies energy for ATP resynthesis at a much slower rate than the anaerobic pathways, but is capable of supplying a much greater yield of energy for ATP resynthesis than the anaerobic pathways. Therefore, the aerobic system is the predominant supplier of energy for ATP resynthesis when we are at rest, and also during longer-duration exercise that is performed at submaximal intensity.

While the rate of energy production via the aerobic system is much slower than that of the two anaerobic systems, it produces far more energy for ATP resynthesis than either of these anaerobic systems for a given amount of 'fuel'.

Yield of ATP

In terms of ATP yield:

- the ATP–CP system can produce only 0.7 moles of ATP from 1 mole of CP
- the anaerobic glycolysis system can produce only 2 moles of ATP from 1 mole of glucose
- the aerobic system can produce 38 moles of ATP from 1 mole of glucose
- the aerobic metabolism of fats produces by far the most ATP from a given amount of 'fuel'. One mole of fat can produce in excess of 100 moles of ATP.

Rate of ATP

When we consider rate of ATP supply, the reverse applies.

- The ATP–CP system can supply ATP at maximal intensity rate of 3.6 moles per minute.
- The anaerobic glycolysis system can supply ATP at a high intensity rate of 1.6 moles per minute.
- The aerobic system can supply ATP at a slow rate of around 1 mole per minute.

These differences in the capacity of the three energy systems are summarised in table 5.3.

eBook*plus*

Interactivity
Capacities of the three energy systems
Searchlight ID: int-6791

TABLE 5.3 Capacities of the three energy systems

	ATP–CP system	Anaerobic glycolysis system	Aerobic system	
			Carbohydrate (glycolysis)	Fats (lipolysis)
Fuel source	Creatine phosphate	Glucose Glycogen	Glucose Glycogen	FFA Triglycerides
Rate	Most rapid 3.6 moles/min	Rapid 1.6 moles/min	Slow 1.0 mole/min	Slowest < 1.0 mole/min
Yield (moles of ATP per mole of fuel source)	Very small < 1	Small 2	38 (glucose) 39 (glycogen)	129 (FFA) 387 (triglycerides)
Dominant time period	0–10 seconds	10–75/90 seconds	75/90 seconds–90 minutes	4+ hours
Event	Power	Speed	Endurance	Ultra-endurance

Notes about table 5.3:

- There is a trade-off between rate and yield for each of the energy systems.
- As the rate of ATP resynthesis increases, the yield decreases.
- The values shown in the table are general values and can vary from individual to individual.
- The capacity to produce energy via each of the three energy systems can vary with training.
- There is a transition period where one energy system is increasing its relative contribution while another is decreasing its relative contribution (interplay of energy systems).
- Fatigue-limiting factors will determine the transition from one energy system to another.

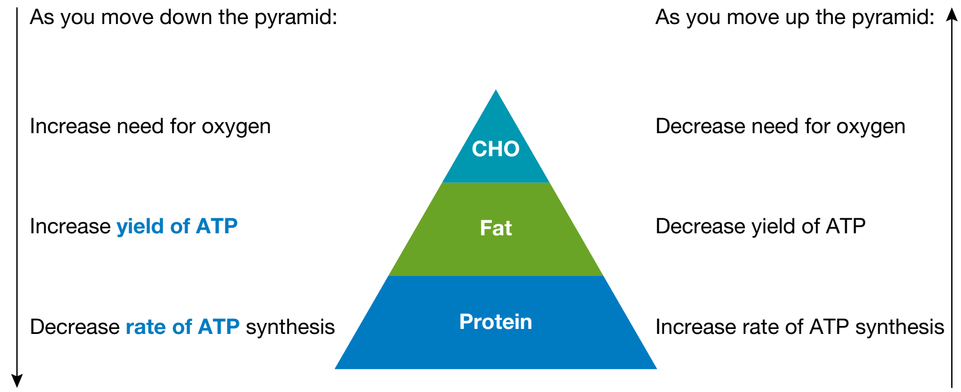


FIGURE 5.13 The characteristics of the food fuels

Yield of ATP is the amount of ADP that can be resynthesised to ATP. A higher amount of ATP available means more ATP can be broken down, providing larger amounts of energy for muscle contraction. For example, fats provide a large yield of ATP (100) compared to CHO (38 ATP).

Rate of ATP is the speed at which ADP can be resynthesised to ATP. The quicker that ADP can be resynthesised, the quicker it can be broken down again to provide energy for muscle contraction. For example, the rate of ATP using CHO is 1 mole/min compare with fats (< 1 mole/min).

TEST your understanding

1. List the three energy systems that are responsible for the production of energy for ATP resynthesis.
2. For each energy system, indicate the chemical and/or food fuels that can be used by that energy system.
3. What two factors determine the ATP demand of an exercise bout or activity?
4. Explain the difference between rate and yield in terms of ATP demand.
5. Rank the three energy systems in order from fastest (1) to slowest (3) in terms of the rate at which they are capable of providing energy for ATP resynthesis.
6. Rank the three energy systems in order from lowest (1) to highest (3) in terms of the yield of ATP they are capable of producing from an equivalent amount of their fuel source.

APPLY your understanding

7. **Practical activity: energy systems used in physical activities**
   As a class, perform the following series of physical activities and/or events, allowing adequate time for recovery in between each activity. Have a partner time how long it takes you to complete each activity and then swap and do the same for them.
   - A basketball lay-up
   - A 200-metre sprint
   - An agility circuit around the gymnasium
   - 20 situps
   - A 1-kilometre jog around the oval

   Record how you felt during and immediately after each activity. What energy system was predominant during your performance of each activity? Why was it important to record the time taken to complete each activity? Why was it important to allow for adequate recovery time (rest) between each activity? Present your findings and answers to these questions as a written report.

EXAM practice

8. State the rate and yield of ATP for anaerobic glycolysis. **2 marks**

5.4 The ATP–CP system

KEY CONCEPT The characteristics of the ATP–CP system for physical activity, including rate and yield of ATP, fatigue factors and recovery rates

The ATP–CP (or ATP–PC) system is the least complicated of the three energy systems, and it produces energy for ATP resynthesis most rapidly. The **ATP–CP system** relies on the muscular stores of ATP and creatine phosphate. When creatine phosphate is broken down, the energy and phosphate group released is then used to resynthesise ATP. Therefore, as rapidly as ATP is broken down for muscular contraction, it is continually resynthesised from ADP and Pi by the energy released by the breakdown of creatine phosphate. However, creatine phosphate stores within the muscle are also limited and they deplete rapidly, particularly during high-intensity activity. This process is shown in figure 5.14.

eBook*plus*

eLesson
ATP–CP
Searchlight ID: eles-0787

The **ATP–CP system** provides energy for the resynthesis of ATP through the breakdown of creatine phosphate without oxygen being involved.

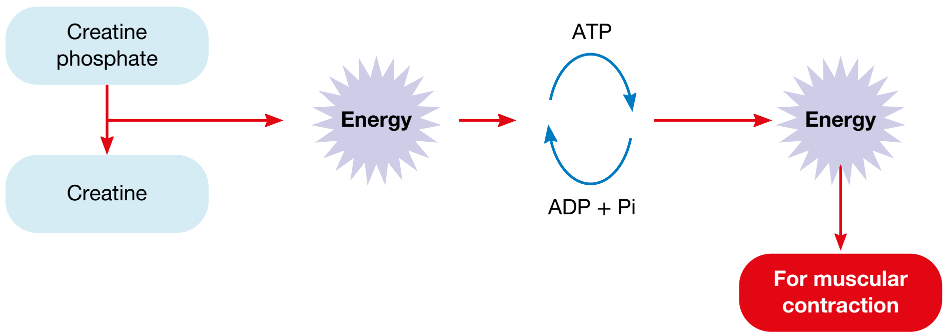


FIGURE 5.14 The release of energy via the ATP–CP system for ATP resynthesis is quick and efficient, but short-lived.

When undertaking maximal-intensity exercise, ATP stores in the muscle will last for approximately 1–2 seconds. Thereafter, the resynthesis of ATP from the breakdown of creatine phosphate will continue until such time that creatine phosphate stores become depleted. On average, this occurs after approximately 6–8 seconds of high-intensity exercise. Combined, the ATP–CP system can therefore sustain all-out (maximal) exercise for approximately 8–10 seconds. If the activity is to continue beyond this immediate period, the body must rely predominantly on another energy system to provide energy for ATP resynthesis.

In conclusion, the ATP–CP system can provide only a very limited amount (yield) of energy for ATP resynthesis, although it is able to supply this energy at a very rapid rate. As a consequence, this system is the predominant energy system used during high-intensity activities such as sprints, throws and jumps that take approximately 0–10 seconds to perform.

The ATP–CP system and exercise

To further illustrate how the ATP–CP system functions, let us consider two activities in sport: one that takes just a few seconds to perform — a drive off the tee in golf — and another that takes about 10 seconds to perform — the 100-metre sprint in athletics.

The golf drive

The drive off the tee in golf takes only a second or so to execute. The energy required to perform this movement is derived almost exclusively from the breakdown of the muscular stores of ATP, which on average will last for 2–3 seconds of all-out effort (see figure 5.15). Fatigue limiting factor is reduced levels of ATP, and a passive recovery will replenish ATP stores at the fastest rate.

FIGURE 5.15 The drive off the tee in golf is an example of a powerful movement that relies heavily on the ATP–CP system.

The 100-metre sprint

- At the beginning of a 100-metre sprint (see figure 5.16), all three energy systems are activated.
- From the explosive push-off from the starting blocks until a few seconds into the sprint, the muscles' ATP stores provide the energy for the repeated muscular contractions.
- During these few seconds, ATP stores in the muscles diminish, and the amount of ADP produced from the spent ATP increases.
- From this point in the event, the muscular stores of creatine phosphate now provide the energy and free phosphate for the resynthesis of new ATP from ADP, allowing the athlete to continue the sprint at maximal intensity.
- Rate of ATP is 3.6 moles/min
- Yield is <1 mole of ATP
- Towards the end of the race (from about 6 to 10 seconds onwards), the muscles' stores of creatine phosphate are greatly depleted. The percentage energy contribution from the anaerobic glycolysis system during the final few seconds of the race becomes much more significant.
- Fatigue limiting factor is depletion of creatine phosphate.
- Passive recovery through rest or low intensity cool-down will replenish ATP and CP stores at the fastest rate, with 87% of the ATP and CP restored within 60 seconds.

studyon

Unit 3 | AOS 2 | Topic 1 | Concept 3

ATP–CP system rate and yield
Summary screen and practice questions

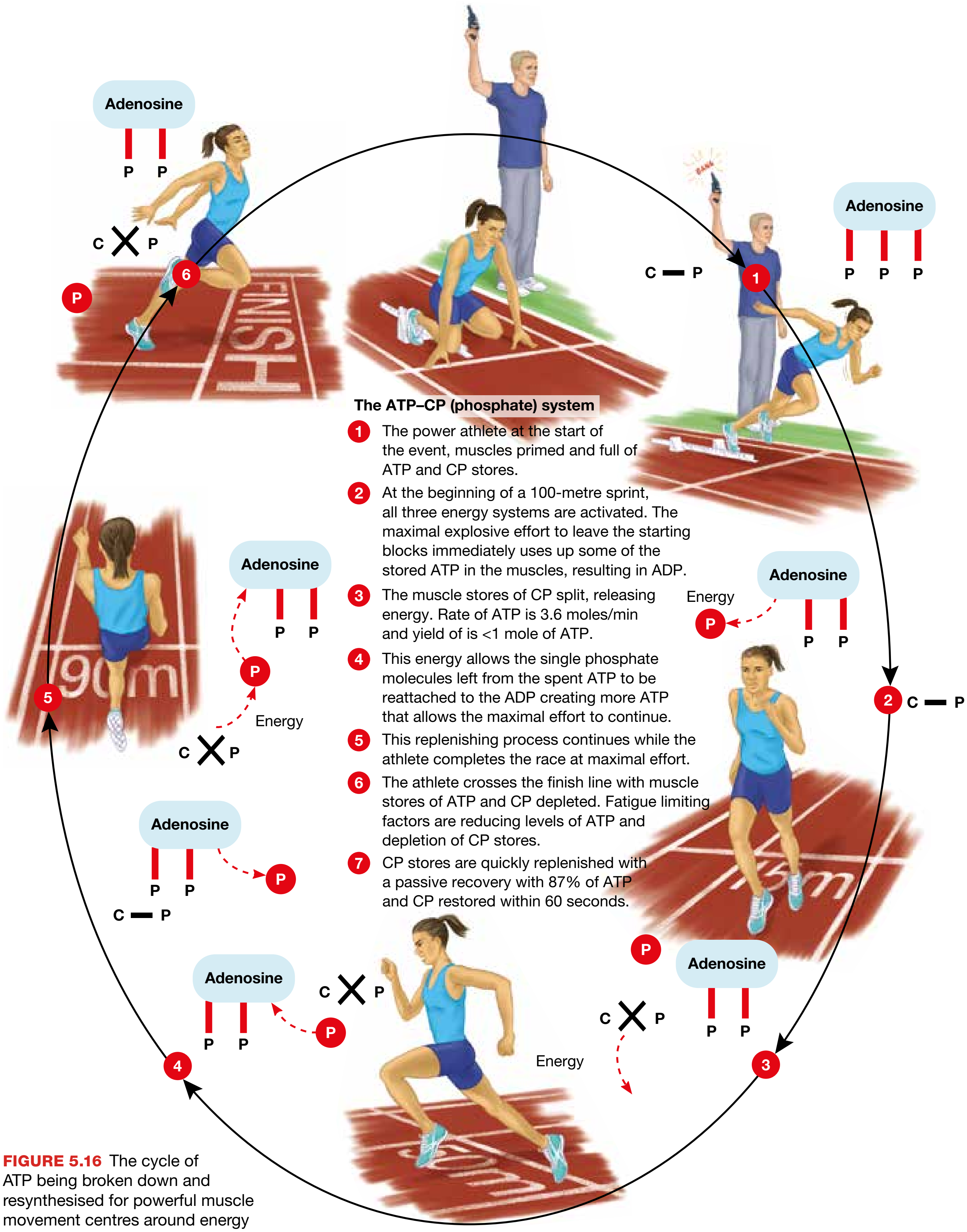


FIGURE 5.16 The cycle of ATP being broken down and resynthesised for powerful muscle movement centres around energy being released via the breakdown of creatine phosphate.

Fatigue can be defined as physical and/or mental lethargy or exhaustion triggered by stress, exercise, overwork, illness or disease.

Fatigue

The causal mechanisms of **fatigue** depend on the *type*, *duration* and *intensity* of the exercise being performed, as well as other considerations such as the fibre-type composition of the involved muscle or muscles, and the fitness and training status, nutritional state and mental state of the athlete. The fatigue experienced in these predominantly anaerobic events is very different from that experienced during and after a prolonged aerobic event, such as a marathon that takes over two hours to complete.

FIGURE 5.17 The fatigue experienced at the completion of a marathon is different from the fatigue felt after completing an event like the 400-metre run.

Fuel depletion

When we refer to fuel depletion as a fatigue-causing mechanism, we are in fact referring to the depletion of energy fuels or substrates that serve to power muscular contractions. They include adenosine triphosphate (ATP) and creatine phosphate (CP).

Creatine phosphate depletion

During maximal intensity, short-duration, anaerobic-type activities, muscular stores of ATP are used within the first few seconds of activity. Once these stores have been depleted, the muscles then use their creatine phosphate stores as fuel to provide energy to replenish ATP from ADP and Pi.

- Creatine phosphate stores also deplete rapidly, and after about 10 seconds of all-out effort, the muscles' stores of creatine phosphate are almost fully depleted.
- As creatine phosphate stores deplete, the ability to rapidly replenish ATP is considerably reduced.
- The consequence of this reduction in the rate of ATP resynthesis is that activity cannot be sustained at the same intensity.
- The failure of the metabolic processes to resynthesise ATP at the required rate results in energy deficiency or muscular fatigue. It is never more obvious than towards the end of a burst of sprinting that fatigue is not only loss of the force that muscles can produce but also impairment of their shortening speed.
- Creatine phosphate stores play a role in fatigue during single and repeated sprints but also may play a role in long duration exercise with bouts of short duration, maximal intensity work.

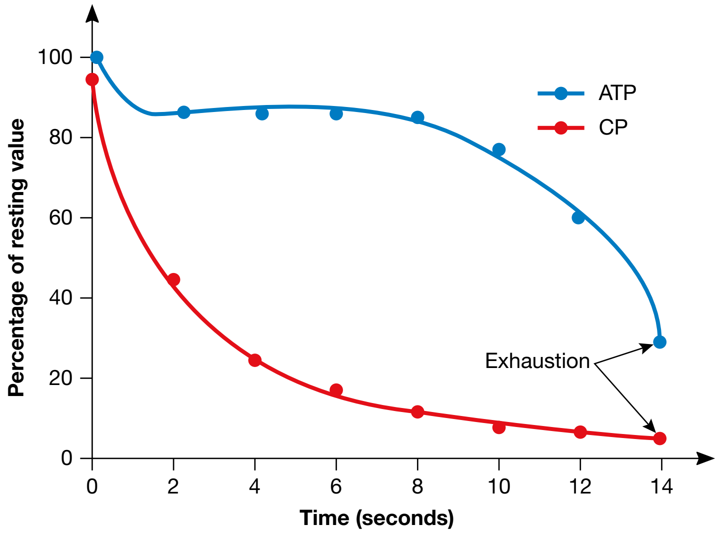


FIGURE 5.18 ATP and CP levels during maximal sprint exercise

Source: Reprinted with permission from J.H. Wilmore, D.L. Costill, and W.L. Kenney, 2008, *Physiology of sport and exercise*, 4th ed. (Champaign, IL: Human Kinetics), page 52.

Recovery

Post-exercise **recovery** aims to overcome the effects of fatigue and restore the body to its pre-exercise condition. Adequate and effective recovery is essential to provide the body with the opportunity to replenish, repair and rebuild itself in readiness for the next training session or exercise bout. Without sufficient recovery, subsequent performances will be compromised.

Recovery is the overcoming or reversal of the fatigue experienced as the result of participation in a training session or some form of exercise bout, where body systems repair damaged tissue and replenish energy stores.

Passive recovery

After an athlete has completed maximal intensity and short duration activities, the ATP and the creatine phosphate stores must be rebuilt within the muscle if the ATP–CP system is to be utilised as a fuel source for the next activity.

- At the end of the activity, breathing rate is above normal and during this passive recovery time of resting or low-intensity activity, ATP and CP within the muscle are being rebuilt during the time of excess post-oxygen consumption (EPOC).
- The extra oxygen is used to restore ATP and some of the restored ATP is broken down. The energy from this is used to combine creatine and phosphate back into CP stores within the muscle.
- During passive recovery:
  - 50% of the ATP and CP is restored within 20 seconds
  - 70% of the ATP and CP is restored within 30 seconds
  - 75% of the ATP and CP is restored within 40 seconds
  - 87% of the ATP and CP is restored within 60 seconds
  - most of the ATP and CP intramuscular stores are replenished within approximately 3 minutes.

studyon

Unit 3 | AOS 2 | Topic 1 | Concept 4

ATP–CP fatigue and recovery
Summary screen and practice questions

TEST your understanding

1 Describe the intensity and duration of a sporting activity where the ATP–CP system is the predominant energy system.
2 Outline the advantages and disadvantages associated with the ATP–CP system.
3 Which fitness components would be most closely associated with the ATP–CP system? Explain the reasoning for your responses.

APPLY your understanding

4 **Practical activity: phosphate recovery test**
As part of a class activity, undertake the phosphate recovery test. Refer to the **Phosphate recovery** document in your eBookPLUS for details of how to perform this test.
(a) Use your understanding of energy systems to explain the interplay of the three energy systems that would occur during the performance of the phosphate recovery test.
(b) Use your understanding of energy systems to explain why, during the phosphate recovery test, each participant's performance tends to decline over the course of the repetitions performed.
(c) Research a range of other laboratory and/or field tests that can be used to provide an indication of the capacity of the ATP–CP system. Explain how performance in each of these tests relates to the capacity of this system.

EXAM practice

5 The world record time for the 100-metre sprint is 9.58 seconds.
(a) State the energy system. **1 mark**
(b) Justify your response to part (a). **2 marks**

eBook*plus*

Digital document
Phosphate recovery
Searchlight ID: doc-1115

5.5 The anaerobic glycolysis system

KEY CONCEPT The characteristics of the anaerobic glycolysis system for physical activity, including rate and yield of ATP, fatigue factors and recovery rates

Pyruvic acid, also referred to as pyruvate, is an intermediate product in the metabolism of carbohydrates, formed by the anaerobic metabolism of glucose.

eBookplus

eLesson
Anaerobic glycolysis
Searchlight ID: eles-0788

In the anaerobic glycolysis system, muscular stores of glycogen are converted into glucose and then, with the aid of enzymes, this glucose is broken down into a substance called **pyruvic acid** (or pyruvate). If oxygen is not available in sufficient quantities at this stage in the metabolic pathway then pyruvic acid is further converted to lactic acid. During this series of reactions, energy is released, which is used to resynthesise ATP from ADP and Pi. The lactic acid that is produced dissociates into lactate and hydrogen ions (H^+) within the muscle. The process of anaerobic glycolysis is shown in figure 5.19.

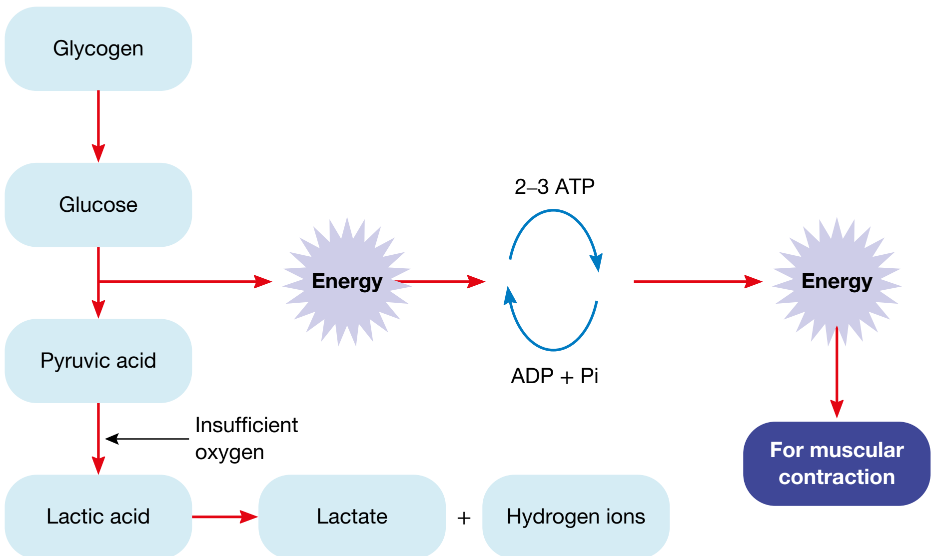


FIGURE 5.19 The process of anaerobic glycolysis is more complex than that involved in the ATP–CP system, with many more chemical steps involved.

The anaerobic glycolysis system and exercise

The **anaerobic glycolysis system** provides energy for the resynthesis of ATP through the breakdown of glycogen through a series of chemical steps that do not require oxygen.

The **anaerobic glycolysis system** is also activated at the onset of exercise and operates as the predominant supplier of energy for ATP resynthesis in the period from around 10 seconds of maximal effort (the time period when the ATP–CP system is no longer able to provide energy due to the depletion of CP stores) to around 60 seconds of high-intensity effort. However, the aerobic energy system could become the predominant supplier of ATP as early as 30 seconds. The anaerobic glycolysis system may also become the predominant energy supplier during repeated short, high-intensity efforts (such as repeated sprint efforts), where the recovery period between efforts is too short to allow full replenishment of creatine phosphate stores. Furthermore, when a performer has gone beyond their maximum oxygen uptake level during an exercise bout, the anaerobic glycolysis system increases its contribution to meet the demands of the task. At this intensity, the aerobic system is unable to produce ATP at a fast enough rate to fully meet the body's demands for the time until the performer is forced to either stop due to exhaustion or decrease the exercise intensity due to fatigue.

eBookplus

Weblink
Cathy Freeman

The 400-metre athletic event

To further illustrate how this system functions, let us consider the 400-metre running event in athletics. The men's world record for the 400 metres is currently held by Wayde van Niekerk of South Africa who set a time of 43.03 seconds in 2016, while the record for the women's 400 metres is currently 47.60 seconds set by Marita Koch of Germany in 1985. Cathy Freeman famously won the gold medal in the 400 metres at the 2000 Sydney Olympics in a time of 49.11 seconds (see figure 5.20).

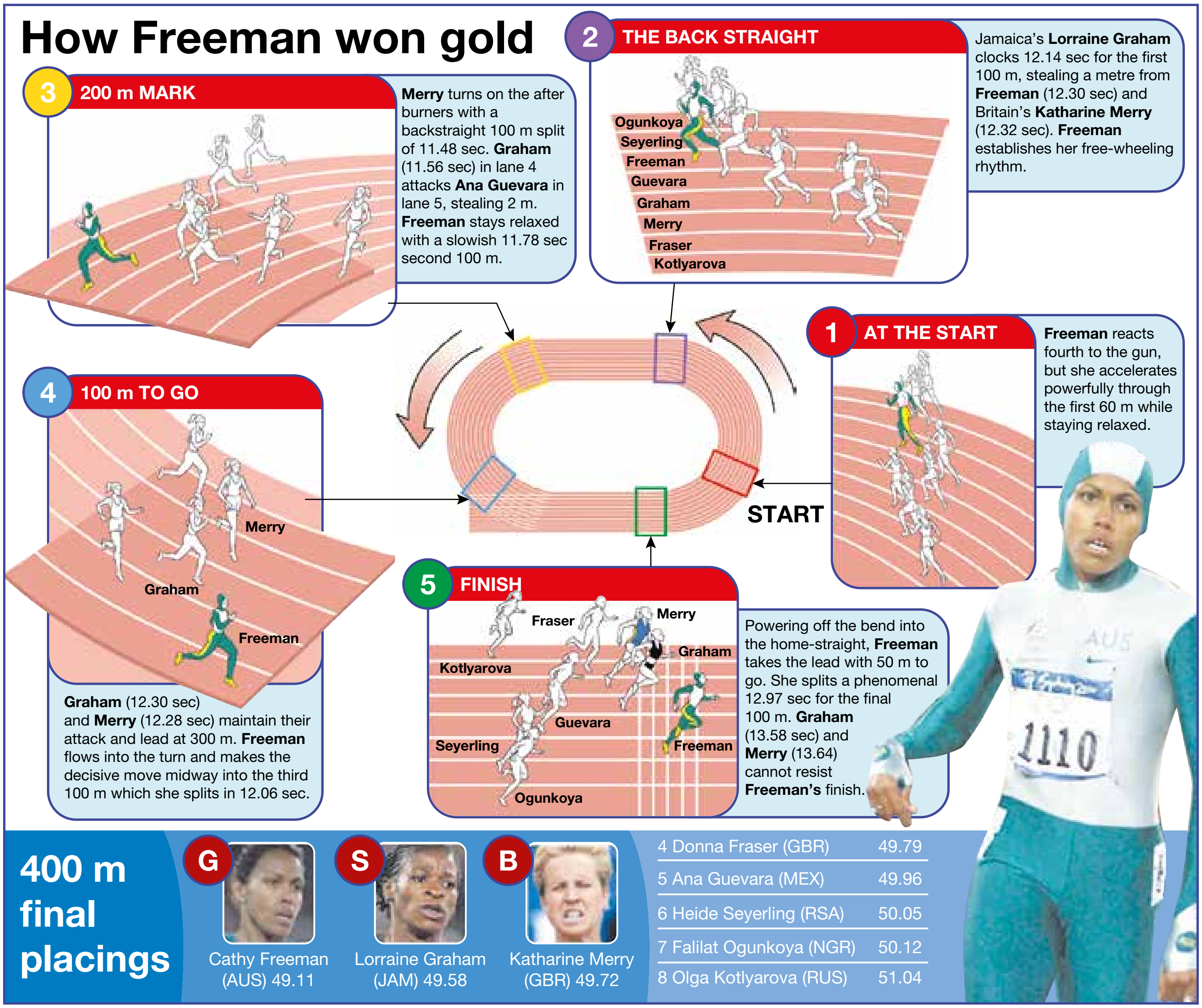


FIGURE 5.20 How Cathy Freeman won gold

- During the 400-metre athletic event, the production of ATP relies on all three energy systems but predominantly on anaerobic glycolysis (see figure 5.21).
- When the athlete pushes off the starting blocks, the ATP–CP energy system allows for an explosive start to the race.
- However, after about 6–10 seconds, the ATP–CP system quickly loses its primary role in the production of energy for ATP resynthesis as CP stores are rapidly depleted.
- For intensity to be maintained, anaerobic glycolysis assumes predominance throughout the middle to later stages of the race. During this time period (10 to 45+ seconds) glycogen stores within the muscle are used predominantly anaerobically in order to provide the energy needed to replenish ATP, thereby allowing the muscles to continue propelling the athlete around the track.
- The aerobic system also plays a significant role in providing energy for ATP resynthesis during the final phase of the event (the final 100 metres or so). Recent studies indicate that in a 400-metre event taking approximately 45 seconds to complete, the aerobic contribution to ATP resynthesis during the event could be as high as 40 per cent, with the other 60 per cent derived from the two anaerobic systems.

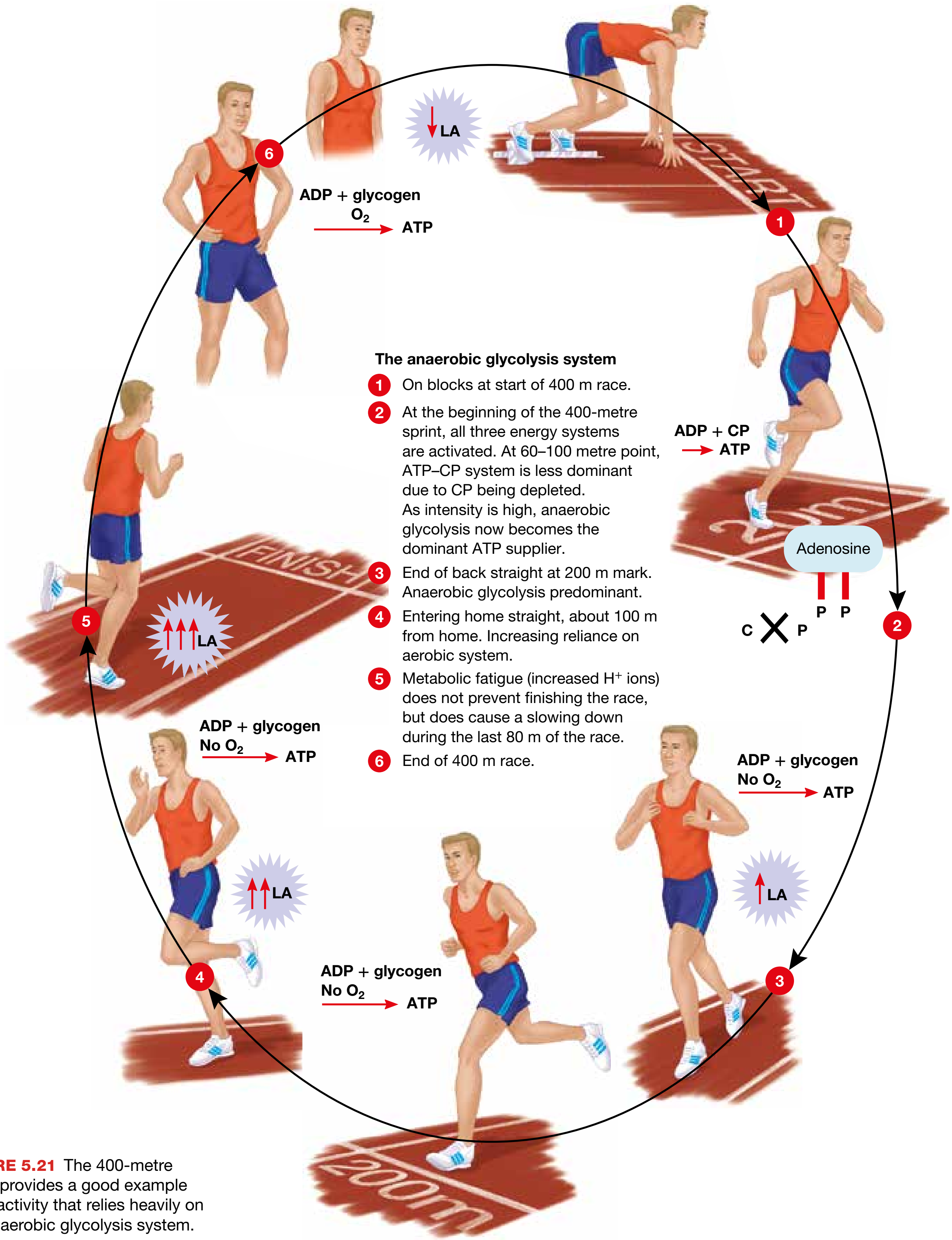


FIGURE 5.21 The 400-metre event provides a good example of an activity that relies heavily on the anaerobic glycolysis system.

A final word about anaerobic glycolysis

The contribution of the anaerobic glycolysis system to the supply of energy for ATP resynthesis increases rapidly after the initial 5–15 seconds of maximal-intensity exercise. This coincides with a drop in maximal power output as the immediately available phosphogens, ATP and creatine phosphate, deplete after approximately 6–10 seconds. For approximately between 10 and 30 seconds of sustained maximal intensity activity, the majority of energy comes from anaerobic glycolysis. After approximately 45 seconds of sustained maximal activity there is a second decline in power output as activity beyond this point corresponds with a growing reliance on the aerobic energy system.

studyon

Unit 3 | AOS 2 | Topic 1 | Concept 5

Anaerobic system rate and yield
Summary screen and practice questions

Fatigue

Accumulation of metabolic by-products

Metabolic by-products or metabolites are substances produced as a result of chemical reactions within the body associated with the production of energy for ATP resynthesis. They are the 'leftovers', and include lactic acid (lactate and hydrogen ions), as well as inorganic phosphate (Pi) and adenosine diphosphate (ADP).

A **metabolic by-product** or metabolite is a substance produced as a result of chemical reactions within the body associated with the production of energy for ATP resynthesis.

Lactic acid

Lactic acid accumulates in the muscles only after relatively short duration, high-intensity exercise.

Potential causes of lactic acid induced fatigue include:

- impaired isometric muscle contraction force
- impaired isometric muscle velocity force
- inhibition of glycolysis due to a decrease in intramuscular pH.

The lactic acid levels of endurance athletes, such as marathon runners and triathletes, at the completion of their events are not much higher than resting levels, despite their obvious fatigue.

Hydrogen ions (H^+)

Research indicates that the accumulation of hydrogen ions in the muscle cells (stemming from their dissociation from the lactic acid as a result of anaerobic glycolysis during high-intensity activity) results in an increase in the acidity within the muscle (otherwise known as **muscle acidosis**). This increased acidity results in a decrease in the muscle **pH** from the normal value of around 7.1 at rest to 6.4 at exhaustion, a value that appears to be incompatible with normal muscle cell function. Changes in pH of this magnitude adversely affect energy production and muscle contraction, resulting in muscular fatigue.

A reduction in intracellular pH to less than 6.9 has been shown to inhibit the rate of glycolysis and ATP production by inhibiting the action of essential glycolytic enzymes, particularly phosphofructokinase or PFK. Furthermore, hydrogen ion accumulation has been shown to disrupt the muscle contractile process through interference with the role that calcium (Ca^{2+}) plays in the mechanisms involved with the coupling of the actin–myosin cross bridges.

It is worth knowing that if the intramuscular pH level was to fall too low (e.g. down to a pH of 5.6), the muscle cells would effectively be killed. Fortunately, the body contains buffers, such as bicarbonate, which function to minimise the disrupting influence of the accumulating hydrogen ions. Because of this buffering capacity, the hydrogen ion concentration is kept lower than it otherwise would be, limiting the decline in pH to 6.6–6.4 at exhaustion. Lactate also plays a key role in reducing the accumulation of hydrogen ions and minimising the decrease in muscle pH and is an important source of fuel for skeletal muscles and the brain.

Muscle acidosis is a condition in which the pH of the muscle decreases as a result of the accumulation of metabolic by-products such as hydrogen ions within the muscle cells.

pH is a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.

Inorganic phosphate (Pi)

One of the consequences of rapid creatine phosphate hydrolysis during high intensity exercise is the accumulation of inorganic phosphate (Pi), which has also been shown to inhibit muscle contraction. You will recall that when ATP is used to provide the energy for muscular contraction, it breaks down to ADP + Pi + energy. At the same time, creatine phosphate breaks down to creatine + Pi + energy. These processes result in an increase in Pi within the muscle. The exact mechanisms by which the rising levels of Pi contribute to muscular fatigue are still not fully known, but it would appear that it too (like increasing hydrogen ions) may have something to do with interference with the role of calcium (Ca^{2+}) in the contractile process and/or interference with the cross bridge coupling cycle.

Adenosine diphosphate (ADP)

Some research also points to rising levels of ADP that accompany high-intensity exercise as a possible mechanism of fatigue during such activities, although its exact role is still not well understood. However, it appears that rising levels of ADP interfere with muscle excitation–contraction coupling in a complex way, but predominantly through interference with the role that calcium (Ca^{2+}) plays in the contractile process.

Recovery

Active recovery

Active recovery is low-intensity (60–70% MHR) activity completed at the end of an exercise bout that allows the body to recover by maintaining an elevated blood flow to the muscles and preventing venous pooling, gradually returning the body to its resting physiological state.

Research has shown that an **active recovery** is an efficient first step in enabling the body to recover from exercise, particularly exercise lasting for more than a few seconds. After an athlete has completed a strenuous high-intensity anaerobic exercise bout at intensity close to or at maximum oxygen uptake (VO_2 max.), the fastest lactate/hydrogen ions clearance is achieved by active recovery at exercise intensity lower than the individual's lactate inflection point. Rather than sitting or lying down as soon as exercise is completed, the athlete should undertake light activity at a low intensity for a period of 5–10 minutes. The active recovery can also take the form of light, aerobically based cross-training activities performed after the exercise session.

The active recovery is used to:

- reduce heart rate to resting levels
- replenish oxygen levels in the blood, body fluids and myoglobin
- increase blood flow to the working muscles
- remove higher lactate concentration levels
- accelerate oxidation as this boosts the clearance rate of lactate
- resynthesise high-energy phosphates
- support the small energy cost to maintain elevated circulation and ventilation
- remove metabolites after exercise.

eBook*plus*

eLesson
Active recovery
Searchlight ID: eles-2754

If previous exercise was strenuous, where lactate and body temperature have increased considerably, EPOC recovery would be slow (slow component). EPOC recovery may take several hours, depending on intensity and duration, before returning to pre-exercise oxygen consumption levels.

These activities should be different from those normally performed in the exercise bout. An example would be undertaking light pool work after a game of football. Studies have shown that active recovery can help to prevent **venous pooling** of blood after strenuous activity. Venous pooling occurs as the active muscles are no longer acting as pumps to propel the blood back to the heart. It can leave the athlete feeling dizzy as blood flow is compromised to the vital organs such as the brain.

Venous pooling is an accumulation of blood in the veins in inactive muscles following activity.

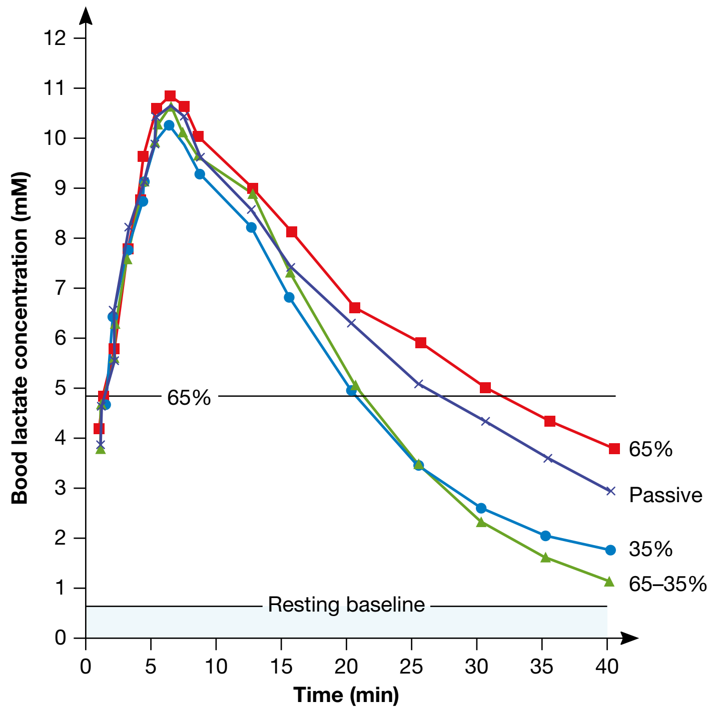


FIGURE 5.22 Blood lactate levels following maximal exercise during passive and active recoveries of VO_2 max.

studyon

Unit 3

AOS 2

Topic 1

Concept 6

Anaerobic system fatigue and recovery
Summary screen and practice questions

TEST your understanding

1 What is the only fuel food that can be catabolised anaerobically?
2 What is the name for the series of reactions in which this process takes place?
3 What are the end products of this anaerobic process?
4 Describe the intensity and duration of a sporting activity where this anaerobic process is the predominant energy system.
5 Outline the advantages and disadvantages associated with the anaerobic glycolysis system.

APPLY your understanding

6 **Practical activity: measuring the capacity of the anaerobic glycolysis system**
As part of a class activity, undertake a 400-metre run test. Use your understanding of energy systems to explain the interplay of the three energy systems that would occur during the performance of this test.

EXAM practice

7 (a) Name the predominant energy system for the 200-metre sprint. **1 mark**
(b) State the predominant fuel for the 200-metre sprint. **1 mark**
(c) Explain how the rate of ATP production influences the average rate of speed for a 200-metre sprinter. **3 marks**
(d) At the end of the sprint, an active recovery session was used. Explain how this facilitates a faster recovery compared to passive recovery. **2 marks**

5.6 The aerobic system

KEY CONCEPT The characteristics of the aerobic system enable it to produce the greatest yield of energy for ATP resynthesis but only at a slow rate.

The **aerobic system** provides energy for the resynthesis of ATP through the breakdown of various energy fuels (mainly glycogen and triglycerides) through a series of chemical steps that require oxygen.

eBookplus

eLesson
Aerobic metabolism of carbohydrates
Searchlight ID: eles-2756

The **aerobic system** (or oxidative system) is the slowest energy system to contribute towards ATP resynthesis due to the complex nature of its chemical reactions, but it is capable of producing the greatest yield of ATP energy when comparing all three energy systems. It is also the most versatile of the three energy systems in that it can use a variety of different fuels including carbohydrates (glycogen), fats (triglycerides and free fatty acids) and, under extreme conditions, proteins.

Aerobic energy production from carbohydrates

The aerobic metabolism of carbohydrates involves three processes to produce energy for ATP resynthesis (see figure 5.23):

1. aerobic glycolysis (increasingly referred to as slow glycolysis as opposed to anaerobic or fast glycolysis)
2. the Krebs cycle (citric acid cycle)
3. the electron transport chain.

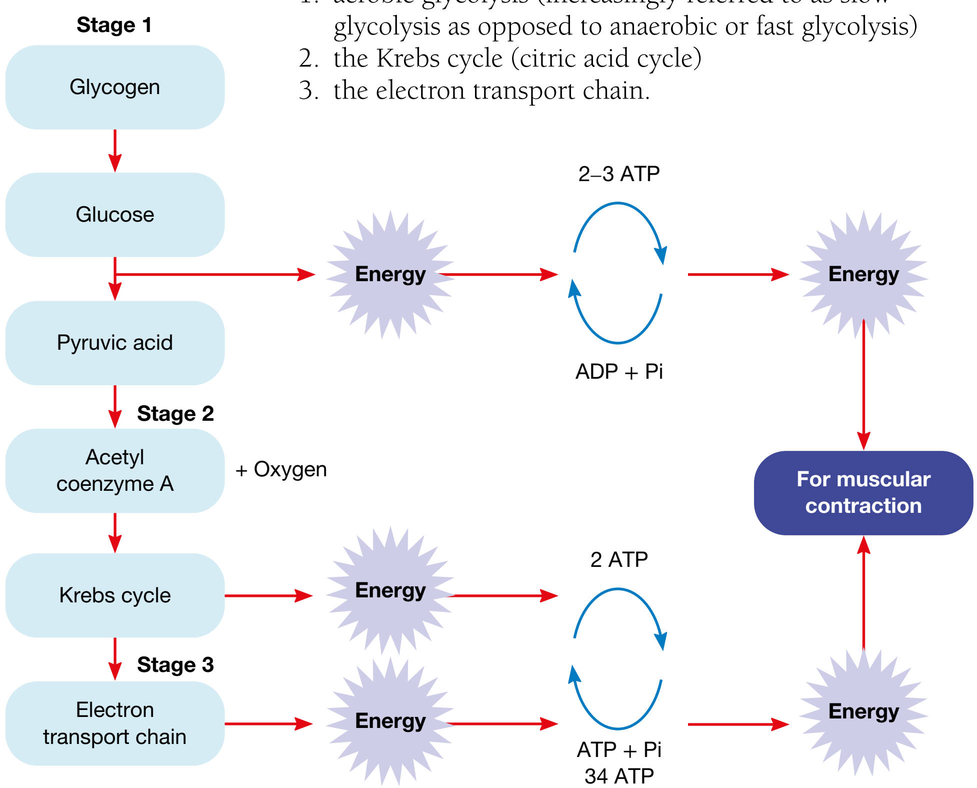


FIGURE 5.23 The process of aerobic metabolism of carbohydrates (glycogen) is more complex than that involved in the anaerobic metabolism of glycogen.

Aerobic glycolysis

Acetyl coenzyme A is an important molecule in metabolism. It is produced during the second stage of aerobic metabolism, which occurs in the mitochondria.

Aerobic glycolysis (or slow glycolysis) is exactly the same series of reactions as anaerobic glycolysis (or fast glycolysis) in that glycogen is converted to glucose and then broken down by a series of chemical steps to pyruvic acid (pyruvate). However, in the presence of sufficient oxygen, pyruvic acid is converted to a substance called **acetyl coenzyme A** and channelled into the Krebs cycle rather than being converted to lactic acid.

The Krebs cycle

The **Krebs cycle** is a series of enzymatic reactions involving the oxidative metabolism of acetyl coenzyme A, which releases energy for the resynthesis of ATP.

The **Krebs cycle** is a complex series of chemical reactions that continues the oxidisation of glucose that was started during aerobic glycolysis. Acetyl coenzyme A enters the

Krebs cycle and is broken down into carbon dioxide and hydrogen, allowing more energy for ATP resynthesis to be produced. The hydrogen ions produced in the Krebs cycle are then transported to the electron transport chain.

The electron transport chain

Hydrogen ions within the **electron transport chain** combine with oxygen to form water (H_2O). This process results in even more energy for ATP resynthesis being produced. The end products of this process are carbon dioxide (CO_2) and water (H_2O).

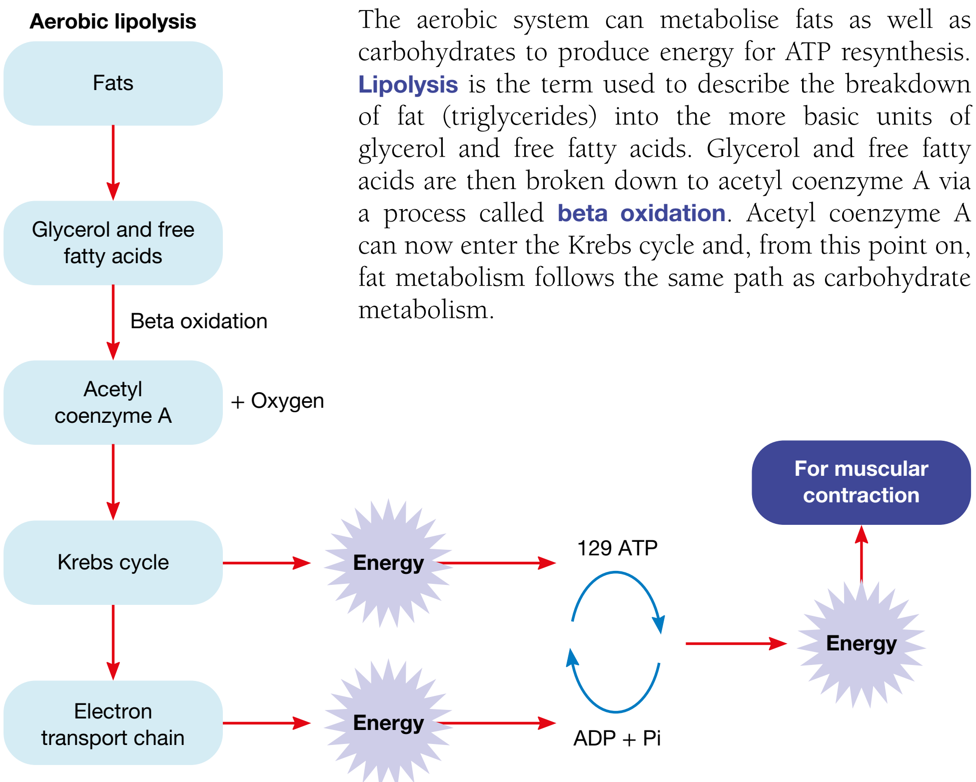
The **electron transport chain** is the third and final stage in aerobic metabolism in which hydrogen ions are converted into water and carbon dioxide while generating energy for ATP resynthesis.

Aerobic energy production from fats

The aerobic system can metabolise fats as well as carbohydrates to produce energy for ATP resynthesis. **Lipolysis** is the term used to describe the breakdown of fat (triglycerides) into the more basic units of glycerol and free fatty acids. Glycerol and free fatty acids are then broken down to acetyl coenzyme A via a process called **beta oxidation**. Acetyl coenzyme A can now enter the Krebs cycle and, from this point on, fat metabolism follows the same path as carbohydrate metabolism.

Lipolysis is the metabolic breakdown of triglycerides into free fatty acids and glycerol within muscle cells.

Beta oxidation is the process by which fatty acids are broken down in the mitochondria to generate acetyl coenzyme A, the entry molecule for the Krebs cycle.



eBook*plus*

eLesson
Aerobic metabolism of fats
Searchlight ID: eles-2757

FIGURE 5.24 The process of aerobic metabolism of fats produces a greater yield of energy for ATP resynthesis than the aerobic metabolism of carbohydrates, but requires more oxygen to do so.

Comparing carbohydrate and fat metabolism

The aerobic system can produce ATP through either fats (fatty acids) or carbohydrates (glycogen). The key difference is that the breakdown of fats produces significantly more ATP (greater yield) compared with that obtained from an equivalent amount of carbohydrates. However, the metabolism of fats requires far more oxygen than the metabolism of the equivalent amount of carbohydrates. Therefore, if your body is to use fats as the fuel source for ATP resynthesis it must be able to provide sufficient oxygen to meet the greater metabolic demand. If not, then the exercise intensity must decrease so that the oxygen requirement is reduced.

Aerobic energy production from proteins

Protein is thought to make only a small contribution (usually no more than 5–10 per cent) to energy production. However, amino acids, the building blocks of protein, can be either converted into glucose or into other intermediates used by the Krebs cycle such as acetyl coenzyme A. Protein may make a more significant contribution during very prolonged exercise (e.g. ultramarathons), perhaps as much as 15–20 per cent of total energy requirements.

The mitochondria

Mitochondria are cell structures or organelles that can be viewed as the power generators of the cell, converting nutrients into ATP.

Stages 2 and 3 of aerobic metabolism (the Krebs cycle and electron transport chain) occur within the **mitochondria**. The greater the number and size of mitochondria within the muscle cells, the greater the capacity for energy production.

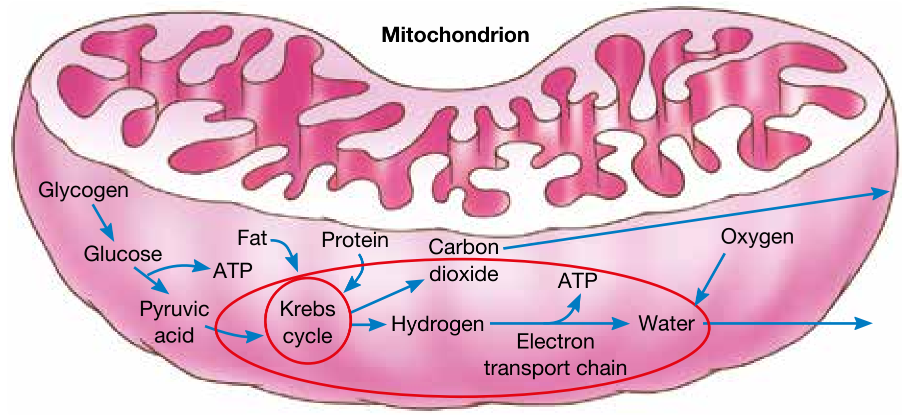


FIGURE 5.25 The mitochondria are cell structures that act as the power generators of the cell, converting oxygen and nutrients into ATP.

The aerobic system and exercise

The aerobic system is used predominantly when at rest and during low- to moderate-intensity exercise. When you are at rest, your body has an abundant oxygen supply, so the energy required for the resynthesis of ATP is provided almost exclusively by the aerobic energy system. It relies on the breakdown of fats to provide about two-thirds of the energy required, while the other one-third comes from the breakdown of carbohydrates. However, when we are exercising, the body's preferred fuel is generally carbohydrates, and the higher the exercise intensity the greater the reliance on carbohydrates. Carbohydrates are the preferred fuel source during exercise because:

- they can be metabolised aerobically or anaerobically
- carbohydrates produce energy at a faster rate than fat
- complete oxidation of carbohydrate requires less oxygen than complete oxidation of fat
- carbohydrate stores are more readily accessible than fat stores (this is true because triglycerides have to be reduced to glycerol and free fatty acids before they can be used to generate cellular energy).

The aerobic system, along with the other two energy systems, is also activated at the beginning of high-intensity exercise and it will become the predominant energy system after approximately 60 seconds of continuous activity. Of course, by this time the intensity of the activity will have decreased (it will now be what we refer to as submaximal exercise), and the body's supply and delivery of oxygen to the working muscles will have increased as a result of acute bodily responses to the demands of the activity. The aerobic system continues to be the predominant contributor to energy production for ATP resynthesis during continuous submaximal exercise that exceeds 1–2 minutes in duration.

studyon

Unit 3 | AOS 2 | Topic 1 | Concept 7

Aerobic system rate and yield
Summary screen and practice questions

Fatigue

The fatigue experienced in predominantly aerobic events is different from that experienced during and after a short, high-intensity anaerobic event, such as 100-metre or 400-metre sprints.

Fuel depletion

When we refer to fuel depletion as a fatigue-causing mechanism, we are in fact referring to the depletion of energy fuels or substrates that serve to power muscular contractions. Glycogen is also the preferred fuel used by the aerobic system during exercise of sustained submaximal intensity (endurance exercise).

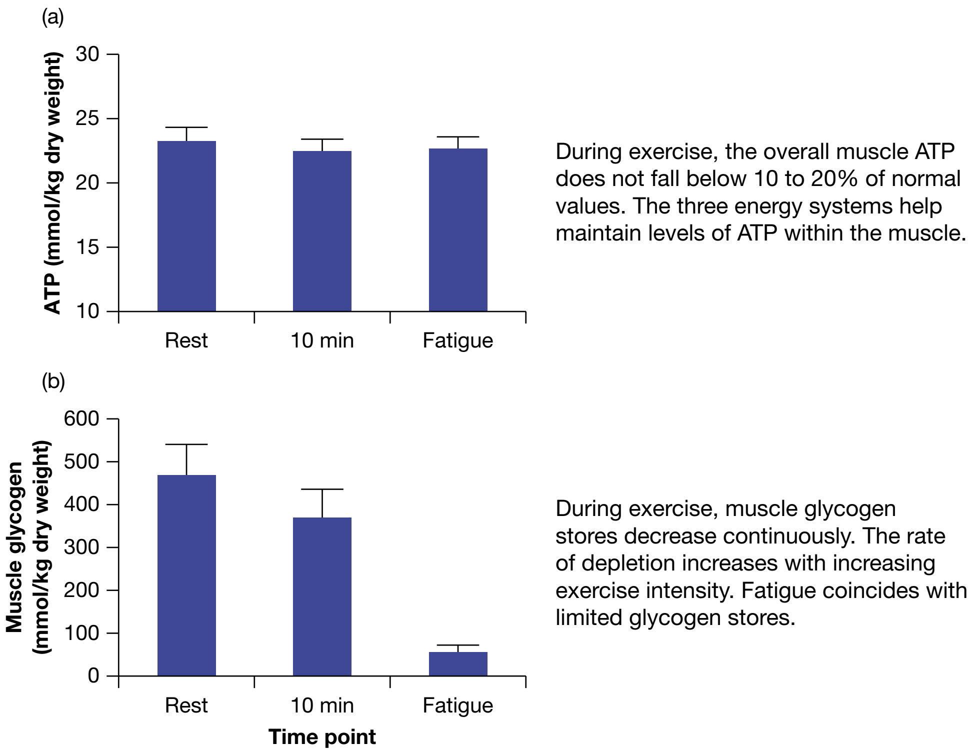


FIGURE 5.26 Muscle ATP concentration at rest and various stages of prolonged cycling (a) and muscle glycogen concentration at the same points during the same exercise bout (b)

Depletion of intramyofibrillar glycogen cluster

Glycogen is stored within the muscle as clusters in three different sites:

- sub-sarcolemmal glycogen cluster (muscle fibre membrane)
- intermyofibrillar glycogen cluster (between myofibrils)
- intramyofibrillar glycogen cluster (within the myofibril — major glycogen cluster).

The majority of muscle glycogen stores (approximately 75%) are stored in within the myofibril but exact distributions depend on training, muscle fibre type, fibre use and type of exercise. Most of the intramyofibrillar glycogen is stored near the t-tubules of the sarcoplasmic reticulum which has an important role for releasing calcium (Ca^+) for the excitation–contraction coupling process. Depletion of intramyofibrillar glycogen may cause a reduction in the production of ATP and impair the formation of actin-myosin cross bridges and the development of muscle force.

Depleted glycogen and hypoglycaemia

During various forms of exercise, the body will rely on four primary food fuel sources: muscle glycogen, muscle triglycerides, blood glucose and free fatty acids. The exercise mode, intensity and duration, training status, pre-exercise fuel status of the athlete and environmental conditions will determine which fuel is being utilised for ATP replenishment. During long endurance exercise, as muscle glycogen is depleted, blood glucose levels are maintained by the breakdown of glycogen in the liver. An increase in blood glucose use will lead to a situation where the liver can no longer supply glycogen and hypoglycaemia can develop. **Hypoglycaemia** may contribute to fatigue by limiting fuel supply to the working muscles and the brain.

Hypoglycaemia is when blood sugar levels have dropped too low due to prolonged strenuous exercise and depleted glycogen stores.

Glycogen depletion during aerobic (endurance) exercise

During prolonged submaximal intensity aerobic (or endurance) exercise, the body preferentially uses muscle glycogen stores as the fuel source for providing energy for ATP resynthesis. Unfortunately, muscle glycogen stores are also limited and deplete relatively quickly.

- Muscle glycogen stores can be depleted within as little as 40 minutes during intense prolonged exercise such as distance running, although, more typically, glycogen stores can fuel continuous submaximal exercise for periods of 90–120 minutes.
- As glycogen stores deplete during prolonged endurance exercise, there is an increased reliance on fat (free fatty acid) metabolism. This increased reliance on fat oxidation necessitates a decrease in exercise intensity. Research strongly suggests that there is a correlation between depletion of glycogen stores and muscular fatigue.
- Depletion of muscle glycogen during prolonged, exhaustive exercise causes a decrease in calcium release inside the muscle, reducing muscle contractions.
- At exercise intensities between 65 per cent and 85 per cent of maximal oxygen uptake (VO_2 max.), muscular fatigue is highly correlated with depletion of muscle glycogen stores.
- Furthermore, glycogen depletion typically results in exercise intensity having to decrease to a level that can be supported predominately by fat metabolism; around 50 per cent of maximal oxygen uptake.

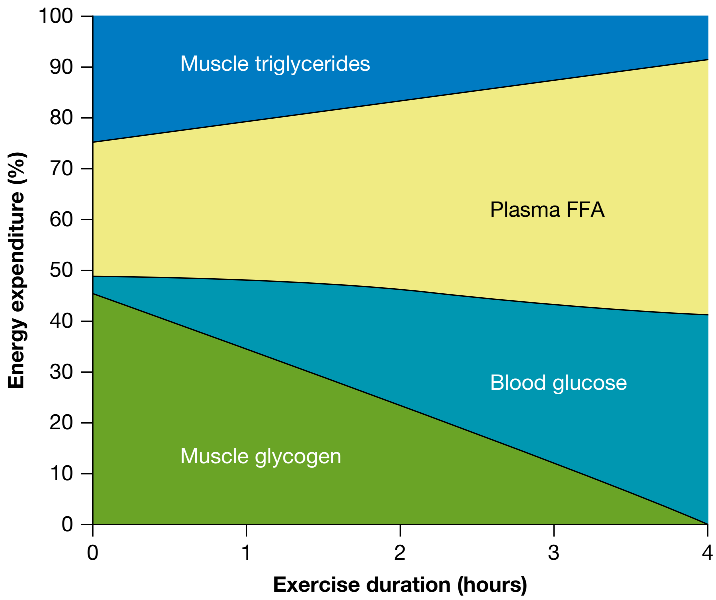


FIGURE 5.27 Contribution of primary food fuels during submaximal intensities and various durations

An increased reliance on fat oxidation further reduces an individual's exercise capacity, as less ATP is generated from fats compared to glycogen per litre of oxygen consumed. About 7 per cent less energy is produced per given amount of oxygen with fat as a fuel compared to glycogen (carbohydrate) as a fuel. Once glycogen is depleted and fats become the predominant substrate, exercise pace must slow because less energy can be produced. Thus, glycogen depletion is associated with an inability to maintain the rate of prolonged aerobic exercise. In marathon running, the point in the race at which this occurs (typically around 28–35 kilometres) is referred to as '**hitting the wall**'. In cycling, it is called 'bonking'. Studies on perceived exertion (how difficult an effort seems to be) also indicate that participants typically do not report exercise as

Hitting the wall is a term used in endurance sports to describe a condition caused by the depletion of glycogen stores in the muscles and liver, which manifests itself as precipitous fatigue and loss of energy.

being highly stressful or fatiguing until such time as muscle glycogen stores are near depletion (see figures 5.28 and 5.29). Thus, the sensation of fatigue during prolonged exercise seems to coincide with a decreased concentration of muscle glycogen.

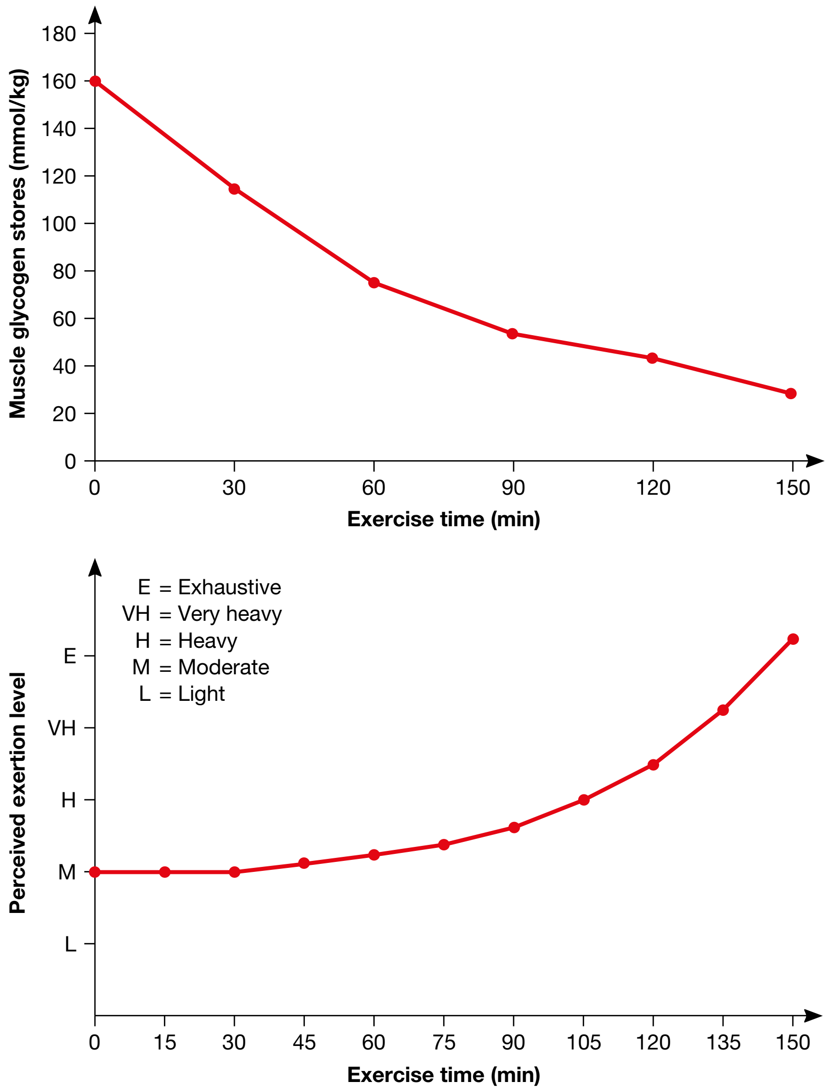


FIGURE 5.28 Glycogen depletion and perceived exertion levels

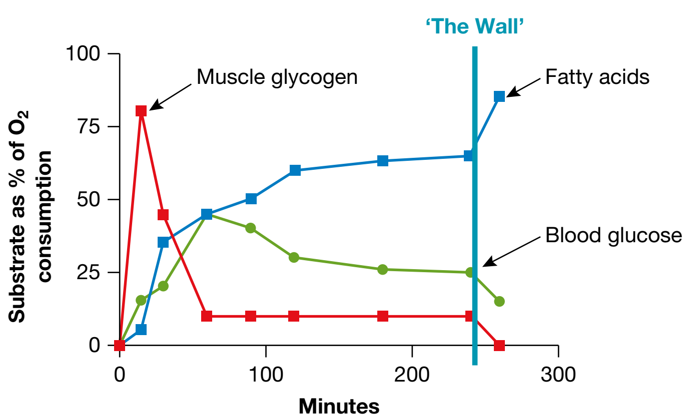


FIGURE 5.29 'Hitting the wall' (glycogen depletion)

While glycogen depletion is clearly associated with muscular fatigue during endurance-type activities, it is not an exclusive factor.

Summary

In summary, fuel depletion contributes to metabolic fatigue within the muscle due to a lack of intracellular energy to power muscle contractions. In essence, the muscle is unable to continue contracting at the same rate or force, basically because it lacks the energy to do so.

Impaired muscle excitability

Peripheral fatigue can also involve impairment of the mechanisms involved in muscle excitability; in other words, impairment in the processes involved in **muscle excitation–contraction (E–C) coupling**, which arises when a nervous impulse arrives at the muscle membrane. We have already seen that the accumulation of metabolic by-products such as hydrogen ions, inorganic phosphate and ADP are thought to interfere with the contractile process, including the excitation–contraction coupling process. Also implicated in interference with this process is potassium (K^+).

Muscle excitation–contraction (E–C) coupling is the term used to describe the physiological process of converting an electrical stimulus to a mechanical response.

Potassium

The excitability of the muscle membrane (membrane potential), or in other words its receptiveness to nervous stimulation, appears to be influenced by several substances that move into and out of the intracellular and intercellular spaces of the muscle during the contractile process. One of these substances is potassium (K^+). During muscle contraction, potassium moves out of the muscle cells into the intercellular space. It builds up in the **t-tubule system** and the muscle fibre in general, and has the effect of depolarising the muscle membrane, making it more difficult to excite the muscle and therefore muscle contractions are inhibited or reduced. This occurs most markedly during high-intensity exercise. This appears to be some kind of safety mechanism protecting the muscle from damage that might result from repeated nervous stimulation.

The **t-tubule system** is a network of tiny tubes in muscle fibres that allows electrical signals to move deep inside the muscle and excite the muscle fibre.

Recovery

Active recovery is also beneficial in accelerating the process of ridding the muscle cells of any metabolic by-products that may have been produced and accumulated during the exercise period. During the active recovery period, the rate of oxygen consumption by the athlete remains above the required rate, given their level of activity. The term 'excess post oxygen consumption' (EPOC) has typically been used to describe this phase. Active recovery is suitable after aerobic type activities and allows:

- resynthesis of high-energy phosphates
- replenishment of oxygen in the blood
- replenishment of body fluids
- replenishment of myoglobin.

If previous exercise was primarily aerobic, EPOC recovery would be completed within several minutes (fast component).

studyon

Unit 3	**Aerobic system fatigue and recovery**
AOS 2	Summary screen and practice questions
Topic 1	
Concept 8	

eBookplus

Interactivity
Mechanisms of peripheral muscular fatigue
Searchlight ID: int-6793

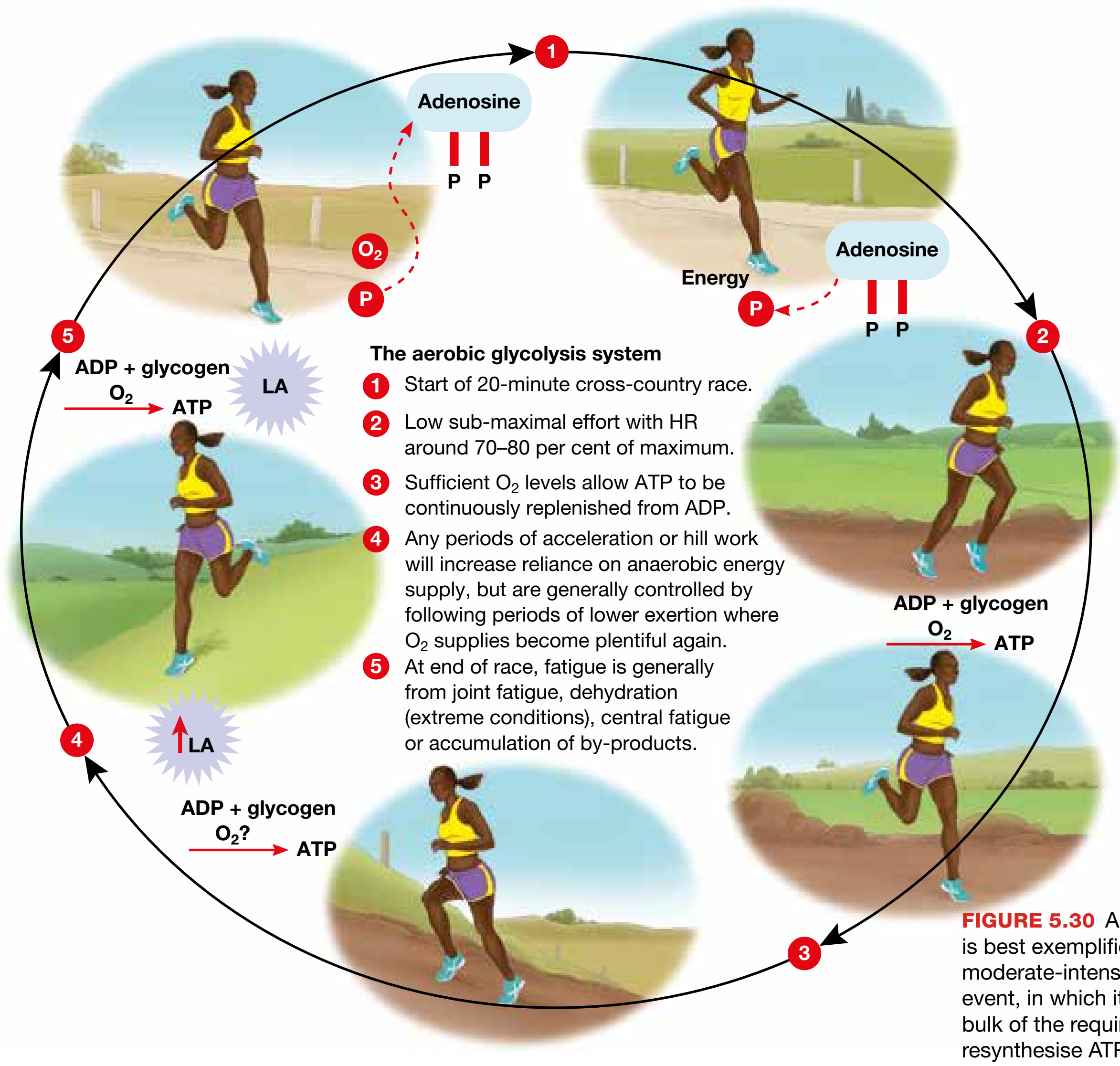


FIGURE 5.30 Aerobic glycolysis is best exemplified in any low-to-moderate-intensity longer duration event, in which it provides the bulk of the required energy to resynthesise ATP.

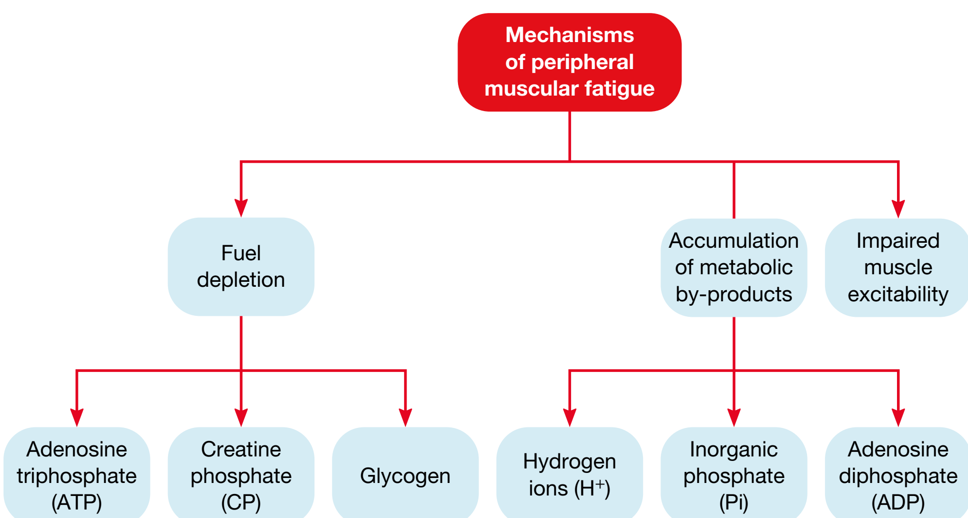


FIGURE 5.31 The mechanisms of peripheral muscular fatigue

TEST your understanding

1 Describe the intensity and duration of a sporting activity in which the aerobic system is the predominant energy system.

2 Outline a specific sporting activity or situation that clearly illustrates the use of the aerobic system as the predominant energy system.

3 Outline the advantages and disadvantages associated with the aerobic system.

4 What is the final common metabolic pathway for oxidative metabolism of fat, carbohydrate and protein?

5 Where in the cell do the reactions making up this pathway take place?

APPLY your understanding

6 **Practical activity: multi-stage fitness test**
As part of a class activity, undertake the 20-metre shuttle run test.

(a) Use your understanding of energy systems to explain the interplay of the three energy systems that would have occurred during your performance of the 20-metre multi-stage shuttle run test.

(b) Research a range of other laboratory and/or field tests that can be used to provide an indication of the capacity of the aerobic system. Explain how performance in each of these tests relates to the capacity of the aerobic system.

EXAM practice

7 (a) State the duration and fuel required for the aerobic pathway. **2 marks**

(b) Identify two by-products of the aerobic energy system. **2 marks**

(c) Explain why the average speed for a 1500-metre runner is slower than that for a 400-metre sprinter. **3 marks**

5.7 Energy systems at work: interplay of energy systems

KEY CONCEPT Energy systems work together to supply the energy required for ATP resynthesis.

This subtopic will look at how the energy systems contribute during rest and exercise conditions. This will help you understand how the body adapts its metabolic activity during the transition from rest to exercise.

ATP production at rest

When at rest your body is not under physical stress and it has an abundant oxygen supply, so the energy required for the resynthesis of ATP is provided almost exclusively by the aerobic energy system. It relies on the breakdown of fats to provide about two-thirds of the energy required (again because of the abundance of oxygen), while the remaining one-third comes from the breakdown of carbohydrates (see figure 5.32).

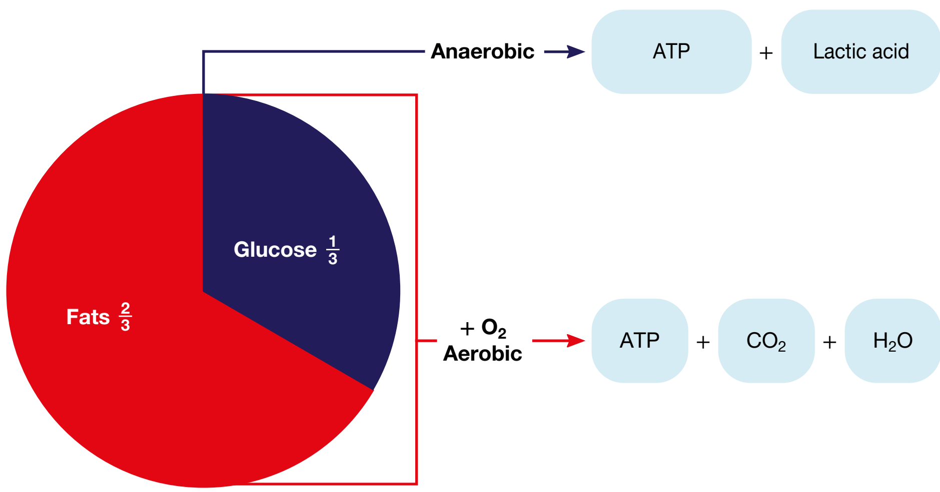


FIGURE 5.32 At rest we rely almost exclusively on the aerobic system for energy production, with fats acting as the major food fuel.

ATP production during exercise

There is no exact or definitive point where one energy system drops off and another energy system becomes the predominant energy supplier. Rather, there is a gradual transition from one system being predominant to another system assuming predominance.

Rest-to-exercise transitions

Three rest-to-exercise transition scenarios can help to illustrate this **interplay** or **transition of energy systems** and when each of the three energy systems are called upon to provide the major portion of the ATP needed to sustain exercise at any given intensity. In looking at each scenario, it is important to recall that all the energy systems are contributing towards ATP production simultaneously throughout any exercise bout, but the proportional contribution of ATP from each system to the metabolic demand will shift according to exercise intensity.

Interplay of energy systems refers to the energy systems working together, but at different rates, to supply the ATP required for an activity.

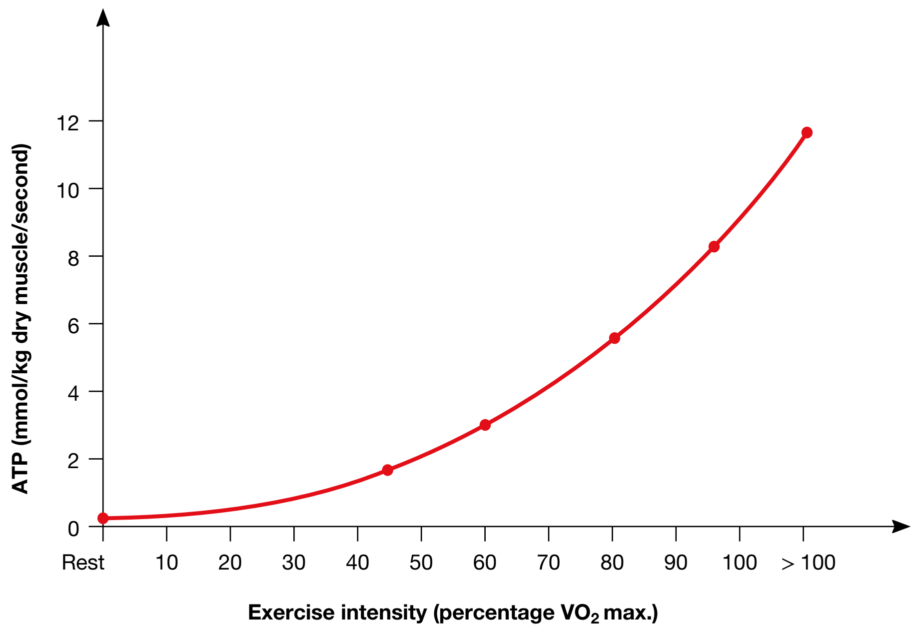


FIGURE 5.33 As the relative exercise intensity increases, the rate of ATP production rises concurrently to meet the exercise energy demand.

Source: Brown, SP, Miller, WC & Eason JM, 2005, *Exercise physiology: basis of human movement in health and disease*, Lippincott Williams & Wilkins, page 76.

Transition from rest to maximal-intensity exercise for 0 to 6 seconds

- The ATP–CP system is the only system with the capacity to meet the high power output demand of very high-intensity exercise.
- Although the other energy systems will produce ATP at slower rates during maximal intensity exercise, their proportional contribution to the energy supply will be minimal.

Transition from rest to high-intensity exercise for 30 to 45 seconds

- Because of the longer duration of this exercise bout, intensity has to be reduced in order for the activity to continue for this period of time.
- After the first 6–10 seconds of exercise, the primary responsibility for providing energy for ATP resynthesis shifts from the ATP–CP system to the anaerobic glycolysis system, as creatine phosphate stores become depleted.
- Towards the end of the exercise bout, the aerobic system will be contributing quite significantly to ATP resynthesis.
- If the activity were to continue beyond 45–60 seconds, the intensity would have to be decreased to a moderate or lower level. At this lower exercise intensity, the aerobic system will assume the role of predominant energy supplier

Transition from rest to low/moderate intensity exercise

- It is vital to understand that any time energy demand is increased above resting levels — whether it be starting out on a slow jog or pushing out of the blocks at the start of a 100-metre sprint — this increased energy demand immediately requires an increased oxygen supply to the working muscles as the body strives to continue to work predominantly aerobically.
- However, the respiratory and circulatory systems are unable to meet this increased demand immediately, so the body must use the anaerobic energy pathways to supplement the production of ATP until such time as the body is able to increase its oxygen delivery to meet the oxygen demand of the activity.

- If the activity is being performed at low intensity, then this increase in oxygen supply will not take long to achieve and the aerobic system will quickly resume the role of predominant energy supplier.
- However, with progressively higher exercise intensities, the relative energy contributions of the anaerobic systems become greater and greater.

Intermittent exercise

Many team sports require the players not only to run at maximal speeds for a short duration, but also to maintain their speed and endurance throughout the whole match. There may be periods within the match to recover CP and glycogen stores or reduce levels of lactate and hydrogen ions. For any intermittent activity, it is more accurate to consider the energy system contribution and interplay at various stages of performance by considering the key factors of intensity, duration, recovery periods and availability of fuels throughout the whole event. For example, an AFL footballer playing in the full-forward position will rely on the ATP–CP system for maximal intensity short duration sprints to mark the ball. During low-intensity periods, the player could have sufficient time to replenish CP stores or reduce levels of lactate and hydrogen ions.

The time–energy system continuum

A means by which exercise physiologists have explained the relative contribution and interplay of the three energy systems during exercise is via the time–energy system continuum. This continuum assumes that an individual is exercising at a maximum sustainable intensity for a continuous period of time. Figure 5.34 indicates the relative contributions of each of the energy systems to the total energy requirements under these conditions. Figure 5.35 also indicates the relative percentage contribution of the three energy systems to maximal exercise of various durations.

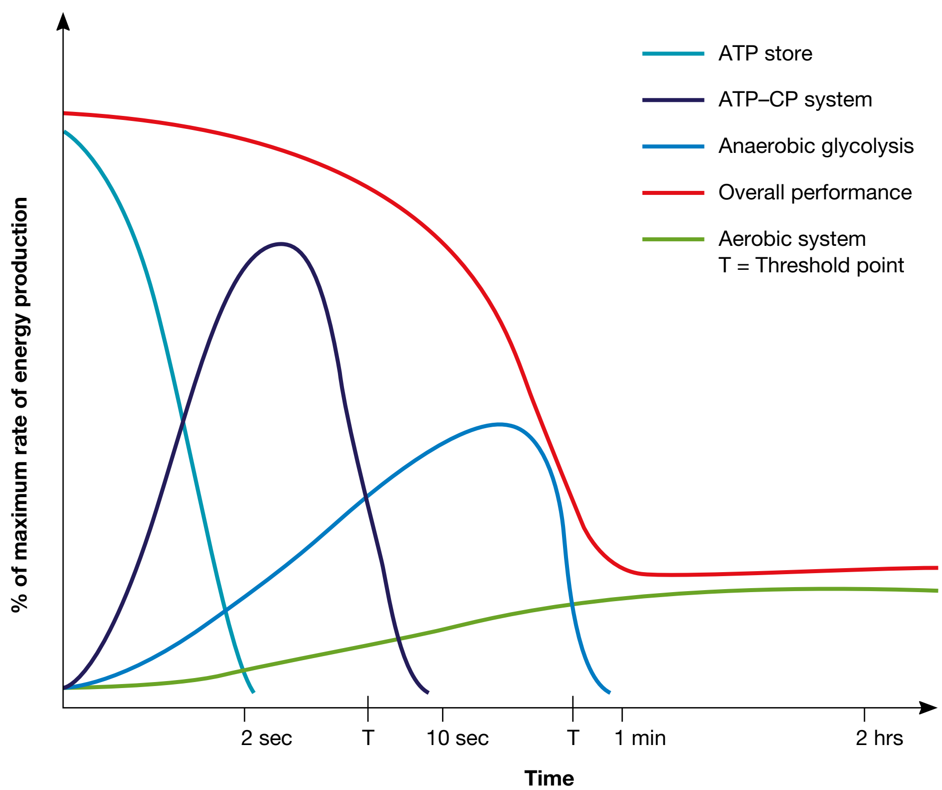


FIGURE 5.34 Approximate relative contributions of the three energy systems to energy production at maximum sustainable exercise intensity for varying durations

eBook*plus*

Interactivity
Understanding energy terms
Searchlight ID: int-6789

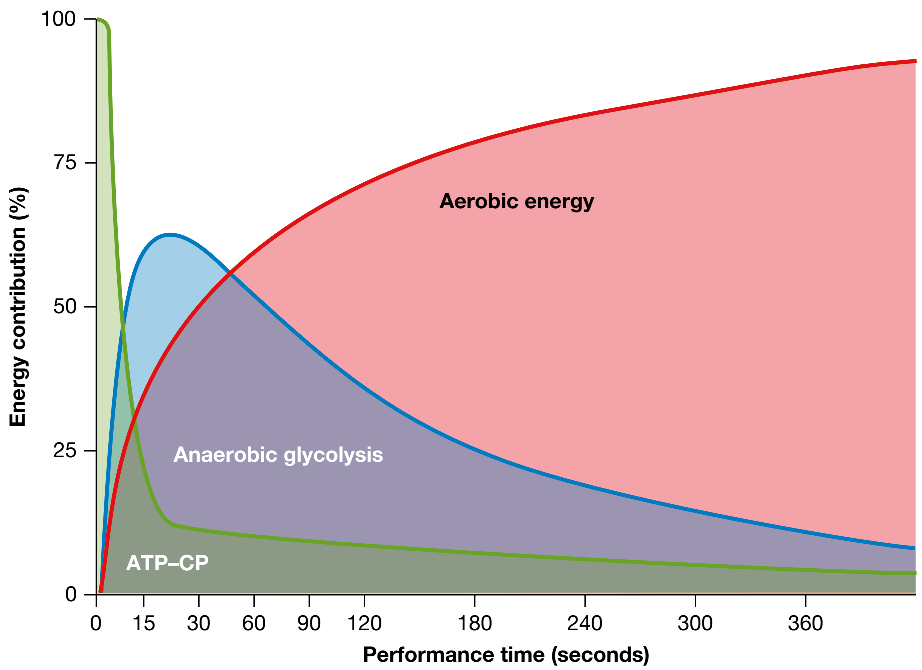


FIGURE 5.35 Relative percentage contribution of the three energy systems to maximal exercise of various durations

The identified percentage contributions of each energy system shown in the two graphs may vary due to data being obtained from different researchers. Table 5.4 presents a compilation from a number of studies over the last 10 years of the relative anaerobic and aerobic contribution to maximal exercise efforts of different durations.

studyon

Unit 3 | AOS 2 | Topic 1 | Concept 9

Interplay of energy systems
Summary screen and practice questions

TABLE 5.4 Anaerobic and aerobic energy system contributions to maximal exercise efforts of different durations

Duration of exhaustive exercise (seconds)	Percentage anaerobic contribution	Percentage aerobic contribution
0–15	88	12
0–30	73	27
0–45	63	37
0–60	55	45
0–90	44	56
0–120	37	63
0–180	27	73
0–240	21	79

Data obtained from both trained and untrained individuals during run, swim, bench or cycle ergometry exercise (Gastin, 2001).

TEST your understanding

1 At the onset of exercise, why are ATP and creatine phosphate the preferred energy sources over carbohydrates and fats?
2 During aerobic exercise the body may use both carbohydrates and fats to provide energy. Their relative contribution depends on the intensity of the exercise. Explain the relationship between intensity of aerobic exercise and relative use of carbohydrates and fats as fuel.
3 If the body starts to deplete carbohydrate (glycogen) stores during prolonged exercise bouts, it relies on fats as the food fuel for providing energy for ATP resynthesis. What is the major disadvantage of using fats as a fuel during exercise of this nature?
4 Netball is a physically demanding sport that requires many skills. The energy demand on players depends on the skills they are performing and the position they are playing. Identify the predominant energy system required to perform the following in netball:
   (a) The Goal Keeper jumping up to grab a rebound
   (b) The Centre covering much of the court throughout the match
   (c) The Goal Defence breaking away from her opponent and receiving a pass from the Goal Keeper
   (d) The Goal Attack sprinting 10 metres to receive the ball from the Goal Keeper, passing to the Centre player, sprinting into the goal third to receive a pass from the Centre player and then shooting a quick bounce pass to the Goal Shooter in the goal circle
   (e) The Umpire running up and down the sidelines throughout the match
5 Complete the table below outlining the characteristics of the three energy systems.

APPLY your understanding

6 **Practical activity: interplay of energy systems**
Select a specific activity from a sport of your choice. Explain the interplay of energy systems that would occur during performance of this activity. Make sure you indicate the typical duration and intensity of the activity.
7 **Practical activity: 400-metre sprint test**
Cathy Freeman's win in the 400 metres at the 2000 Sydney Olympics has been voted the greatest Australian Olympic performance of all time. Freeman won the race in a time of 49.11 seconds. In small groups, conduct your own 400-metre sprint test. Using stopwatches and heart rate monitors, each group is to collect data on their sprinter in 100-metre splits. Clearly and accurately outline in your own words how the three energy systems would have contributed to the sprinter's performance. Ensure that you use data when discussing the interplay of the energy systems.

EXAM practice

8 Paul Biedermann broke the world record for the 400-metre swim with a time of 3:40:07 minutes in 2009. Explain how the energy systems interplayed to provide energy for Paul to complete this swim in record time. **6 marks**

eBook*plus*

Interactivity
Characteristics of the three energy systems
Searchlight ID: int-6792

Characteristic	ATP–CP	Anaerobic glycolysis	Aerobic
Fuels used (chemical and food)			
Intensity and duration of peak energy production			
Examples of activities in which the system is the predominant source of energy			
Rate of energy supply			
Energy yield per comparative amount of fuel source			
By-products			
Fatigue limiting factors			
Type of recovery			
Advantages of the energy system			
Disadvantages of the energy system			

5.8 The significance of lactate

KEY CONCEPT Lactic acid splits into lactate and hydrogen ions. Lactate can provide fuel for energy production and reduce fatigue.

Lactate

Within muscle cells, lactic acid quickly dissociates (splits) into lactate and hydrogen ions (H^+). For many years, lactic acid and lactate were seen to be very much the same thing and the prevailing knowledge was that the accumulation of lactic acid (lactate) that resulted from anaerobic glycolysis during high-intensity exercise was the cause of local muscular fatigue.

Lactate acts as an important intermediary in numerous metabolic processes; in particular, as a mobile fuel source for aerobic metabolism.

The fate of lactate: the lactate shuttle

Lactate shuttles are the processes by which lactate is shuttled from one location to another where it is converted to glucose that can then be used to provide further energy.

Type 1 slow-twitch oxidative fibres contain large and numerous mitochondria, high levels of myoglobin and a high capillary density. They are very resistant to fatigue and have a high capacity to generate ATP by oxidative metabolism.

The **Cori cycle** is the metabolic pathway in which lactate produced by anaerobic glycolysis in the muscles moves via the bloodstream to the liver, where it is converted to blood glucose and glycogen.

Lactate can be shuttled, referred to as **lactate shuttles**, or moved intracellularly from the muscle cell cytoplasm to the mitochondria, extracellularly from one muscle fibre to a nearby adjacent muscle fibre, and between the muscle and the bloodstream where it can then be transported to other tissues and organs.

The intracellular lactate shuttle involves the movement of lactate between the muscle cell cytoplasm where it is produced and the mitochondria where it is oxidised to pyruvate, which then passes through the various stages of aerobic metabolism. In this way lactate is acting as an important intermediary fuel source for aerobic metabolism. Extracellular lactate shuttles act to move lactate between tissues and organs. Intramuscularly, most lactate moves out of active fast-twitch glycolytic fibres and into active oxidative **type 1 slow-twitch oxidative fibres** where it again acts as a fuel source for energy production during aerobic metabolism.

Some of the lactate also diffuses out of the muscle itself into the bloodstream. From there the lactate is transported to other tissues and organs, most notably the heart, respiratory muscles, brain and liver. The heart, respiratory muscles and brain are able to use lactate as an important fuel source, and in fact studies have shown that during high-intensity exercise these tissues use blood-borne lactate as their fuel source in preference to other fuels such as glucose. In the heart, for example, the uptake of lactate increases many-fold as the intensity of exercise increases, while the uptake of glucose remains unchanged. These tissues take up lactate at a fast rate to satisfy their energy needs.

Lactate in the bloodstream is also transported to the liver where it is converted to blood glucose and glycogen. This glucose can then be transported back to the muscles to act as a fuel source for further muscular contraction. This process is referred to as the **Cori cycle** (see figure 5.36).

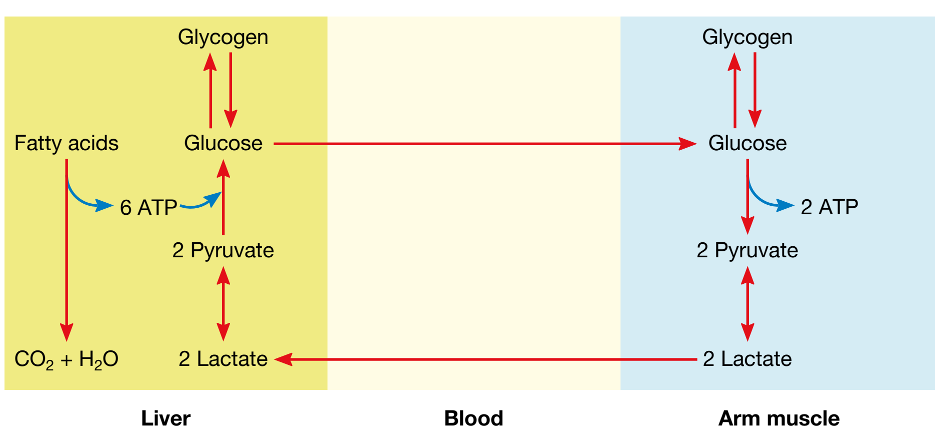


FIGURE 5.36 The Cori cycle

It is also important to note that when lactate diffuses into the bloodstream from the active muscles it takes with it some of the hydrogen ions (H^+) that are also produced as a result of anaerobic metabolism. In this way lactate helps to reduce the hydrogen ion accumulation within the muscle and so helps to delay the onset of muscle acidosis, which is implicated as a cause of muscular fatigue.

To summarise, the lactate shuttle involves the following series of events:

1. As we exercise, pyruvate is formed.
2. When insufficient oxygen is available to break down the pyruvate, lactate is produced.
3. Lactate enters the surrounding muscle cells, tissue and blood.
4. The muscle cells and tissues receiving the lactate either break down the lactate to provide energy for immediate use or use it in the creation of glycogen.
5. The glycogen then remains in the cells until energy is required.

eBookplus

eLesson
The Cori cycle
Searchlight ID: eles-2755

Lactate inflection point

Changes in the lactate concentration of blood can be determined by graphing the results of blood testing during incremental exercise (exercise that progressively increases in intensity). Figure 5.37 identifies the **lactate inflection point (LIP)** which is the last point where lactate production and removal is balanced. It marks the point on the graph where there is an exponential or non-linear increase in the lactate concentration in the blood.

It is also identified as the final exercise intensity or oxygen uptake value at which the blood lactate remains relatively stable during a maximal aerobic test.

The **lactate inflection point (LIP)** represents the highest intensity point where there is a balance between lactate production and removal from the blood.

Significance of the lactate inflection point

The LIP establishes the exercise intensity beyond which a given exercise or power output cannot be maintained for any sustained period of time. Exercise intensities beyond the LIP are associated with a shortened time to fatigue or exhaustion. The higher the exercise intensity beyond the LIP, the more rapid the onset of fatigue. This decreased time to exhaustion appears to be primarily associated with an increase in the acidosis within the muscle due to the accumulation of metabolic by-products including, but not necessarily limited to, hydrogen ions.

The LIP can also be used to determine the highest intensity of aerobic exercise an athlete can sustain without the rapid accumulation of hydrogen ions. This is because the rise in blood lactate concentration is related to rising levels of hydrogen ions within the muscle (remember, lactic acid dissociates into hydrogen ions and lactate). It appears that the LIP can serve as a reasonably good indirect marker for muscle cell metabolic conditions that increase muscle acidosis, which in turn leads to muscular fatigue.

eBookplus

eLesson
Lactate inflection point
Searchlight ID: eles-2758

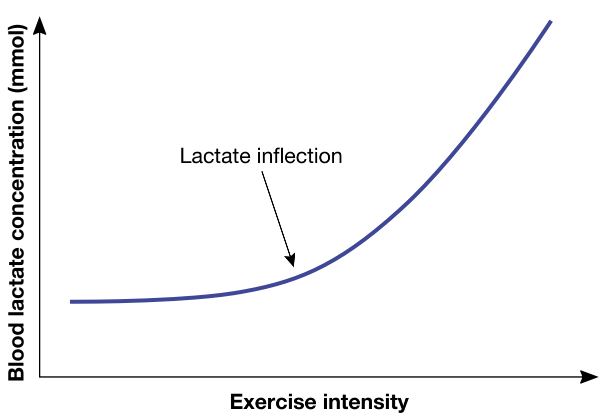


FIGURE 5.37 General representation between exercise intensity and blood lactate concentration and lactate inflection

TEST your understanding

1 What is the fate of lactate that is produced in the muscle cells as a result of anaerobic metabolism? Why do we call the processes involved *lactate shuttles*?
2 Explain in your own words the meaning and significance of LIP.

EXAM practice

3 The 400-metre sprinter will work at an exercise intensity level above their lactate inflection point. What occurs physiologically beyond this LIP point? **3 marks**

eBook*plus*

Interactivity
Lactate inflection point
Searchlight ID: int-6794

KEY SKILLS ENERGY SYSTEMS AND INTERPLAY OF ENERGY SYSTEMS

KEY SKILLS

- Participate in a variety of physical activities and describe, using appropriate terminology, the interplay and relative contribution of the energy systems
- Perform, observe, analyse and report on laboratory exercises designed to explore the relationship between the energy systems during physical activity and recovery
- Explain the fatiguing factors associated with the use of the three energy systems under varying conditions

- **yellow** identify the action word
- **pink** key terminology
- blue key concepts
- **light grey** marks/marking scheme

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- The role of ATP to produce energy and how it is resynthesised
- The role of energy fuels or substrates that are used to provide the energy required for ATP resynthesis. You may be asked how food/chemical fuels resynthesise ATP; for example, how muscle glycogen can resynthesise ADP to ATP.
- ATP can be resynthesised via three energy pathways: ATP–CP, anaerobic glycolysis and aerobic energy systems
- Understand, in specific detail, the characteristics of the three energy systems including fuel sources, rate of ATP, yield of ATP, dominant time period and type of event, fatigue and recovery
- Relationship between intensity of exercise and rate of ATP
- Relationship between duration of exercise and yield of ATP
- Fatiguing factors such as CP stores could deplete, and hydrogen ions and lactate levels could increase to a level that changes energy systems
- Each physical activity has a dominant energy system
- Interplay of the three energy systems
- Many factors contributing to fatigue
- Recovery strategies used to return to pre-exercise conditions

PRACTICE QUESTION

Brooke, a 20-year-old high-level female 1500 m runner, is preparing for the Australian Track and Field Championships. Her current personal best time is 4 minutes 30 seconds.

Describe the energy system interplay in a 1500 m track event of a similar time to Brooke's. *(6 marks)*

STRATEGIES TO DECODE THE QUESTION

- **Identify the action word:** **Describe** — provide a detailed account of interplay of energy systems
- **Key terminology:** 1500 m runner, duration of 4 minutes and 30 seconds
- **Key concept:** Energy system interplay — understanding how the energy systems operate together
- **Marking scheme:** *6 marks* — always check marking scheme for the depth of response required, linking to key information highlighted in the question

SAMPLE RESPONSE

At the start of the 1500-metre race, all energy systems contribute to the supply of ATP with one system being dominant. As the athlete explodes away from the starting blocks, all energy systems contribute, however the ATP–CP is the predominant energy system due to the maximal intensity and the need to replenish ATP quickly (3.6 moles/min) for the first 6 to 10 seconds. As limited PC stores quickly deplete and there continues to be a need to supply ATP at a fast rate, anaerobic glycolysis becomes the predominate energy system for the next 30 to 45 seconds as exercise intensity is maintained. ATP is resynthesised at a fast rate (1.6 moles/min) with muscle glycogen broken down without oxygen available. Any increases of intensity during the race, sprint to finish line, may see an increased contribution from the anaerobic glycolysis system. As the duration of the race continues beyond 60 seconds, the aerobic energy system becomes the dominant energy system for the rest of the race. The aerobic ES begins to have a greater contribution (duration is 4.5 minutes) to resynthesising ATP, at a slower rate (1.0 moles/min) but with a greater yield (38 moles of ATP) as the body is able to supply oxygen to the working muscles.

HOW THE MARKS ARE AWARDED

- **1 mark:** stating all energy systems contribute
- **1 mark:** stating ATP–CP system utilised at the explosive start
- **1 mark:** CP stores depleting
- **1 mark:** to maintain intensity, anaerobic glycolysis is utilised
- **1 mark:** aerobic system is dominant due to the duration being greater than 60 seconds
- **1 mark:** aerobic ES resynthesises ATP with the greatest yield as oxygen is able to break down glycogen

CHAPTER SUMMARY

ATP: The body's energy currency

- The energy for physical activity is released by the catabolism (breaking down) of adenosine triphosphate (ATP). This energy source is stored in only very limited quantities within muscles and must be constantly replenished or resynthesised in order for muscular contractions to continue.
- ATP breaks down to ADP and Pi. ATP can be resynthesised from ADP and Pi but energy is required in order to do this.
- The energy required to resynthesise ATP from ADP and Pi is produced via three energy pathways: the ATP–CP (or phosphate) energy system, the anaerobic glycolysis system and the aerobic system.

Energy fuels

- The fuels or substrates that are used by the body's three energy systems include creatine phosphate, carbohydrates, fats and protein. The energy systems break down these fuels to provide the energy to resynthesise ATP.
- Creatine phosphate is a chemical compound which, like ATP, is stored in limited quantities within muscle cells.
- Also like ATP, creatine phosphate is a high-energy substance capable of storing and releasing energy via the high-energy bond that binds the creatine and phosphate parts of it together. When this bond is broken, energy is released that enables ATP to be resynthesised from ADP and Pi.
- Carbohydrate is broken down into glucose. Glucose is stored as glycogen in the muscles and liver. Any excess is stored as fat in adipose tissue around the body.
- Fats provide more energy per gram than the other fuels, but the body prefers carbohydrate as an energy source during exercise because it is easier to break down and produces energy at a faster rate.
- Protein is used as an energy source only when carbohydrate and fats are depleted; for example, in extreme conditions such as in ultra-endurance events.

Energy systems and pathways

- The ATP–CP system uses creatine phosphate to create new ATP supplies without using oxygen. The ATP–CP energy system can create ATP very quickly, and is the predominant energy contributor to maximal intensity, short-duration activities of up to 6–10 seconds' duration.
- The anaerobic glycolysis system involves the metabolism of glycogen stores within the muscle without oxygen needing to be present. The anaerobic glycolysis system takes longer to create ATP than the ATP–CP system, and it is the major contributor to high-level exertions of 10–60 seconds' duration. This system creates lactate and hydrogen ions as by-products.
- The aerobic energy system can use glycogen and fats (and protein under extreme conditions) to provide energy for ATP resynthesis, but oxygen must be present for the chemical reactions involved in aerobic metabolism to take place.
- The aerobic system is the major contributor to energy production during rest and low- to moderate-intensity activity. It becomes the primary energy contributor to sustained maximal activity after approximately 60 seconds.
- Aerobic metabolism occurs primarily within specialised cell structures known as mitochondria, which can be considered the 'power houses' of the cell.
- Tables 5.5 and 5.6 summarise the main information that has been presented in this chapter.

TABLE 5.5 Summary: the conversion of food to energy

Characteristics	Carbohydrates	Fats	Proteins
Conversion and storage	• Transported in the blood as glucose • Stored in muscle cells as muscle glycogen • Stored in liver as glycogen • Excess carbohydrates stored as fat in adipose tissue	• Free fatty acids in blood • Stored as triglycerides in muscle • Stored as fat in adipose tissue	• Broken down through digestion into amino acids • These amino acids stored in muscles as muscle amino acids • Excess amino acids stored as fat in adipose tissue
Major role and function	• The most readily available source of energy to fuel working muscles during exercise performance (moderate- to high-intensity exercise)	• The most concentrated form of energy, but a secondary source of energy during moderate- to high-intensity exercise • Primarily used as a source of energy during rest and low-intensity exercise	• Help the formation, growth and repair of body tissue • Help in the production of red blood cells and enzymes • Provide an emergency fuel source for energy during prolonged exercise, when carbohydrate and fat stores are depleted
Use	• At rest and during low-intensity exercise provide about one-third of the energy required • During moderate- and high-intensity exercise are used as the primary energy source • Carbohydrates as fuel can last for up to 90–120 minutes of continuous exercise	• At rest provide approximately two-thirds of the energy needs of the body • As exercise intensity increases, the percentage of fats being used as an energy source decreases • Fats as an energy source become increasingly important when stores of carbohydrates become depleted during endurance exercise (usually after 90–120 minutes of continuous activity)	• Generally only occurs in extreme situations such as starvation and ultra-endurance events such as the Hawaii triathlon
Percentage of total daily intake	• Average person: 55–60 per cent • Athletes in training: 60 per cent or greater, or 7–10 grams of carbohydrate per kilogram body mass	• Average person: 20–25 per cent • Endurance athletes in training: 20–30 per cent	• Average person: 15 per cent • Athletes in training: strength athletes may require slightly more protein in their diets
Common food sources	**Foods with low glycaemic index:** • Those carbohydrate-rich foods that take longer to digest and release glucose at a slower but more sustained rate • Include bread, cereals, pasta, lentils and baked beans **Foods with high glycaemic index:** • Those carbohydrate-rich foods that are digested rapidly and release glucose at a fast rate • Include sugar, honey, bananas, potatoes, jelly beans, soft drinks and sports drinks	**Saturated fats:** • Found in animal foods such as milk, cheese and meat products • This type of fat contains cholesterol (implicated in cardiovascular disease) **Unsaturated fats:** • Two groups of unsaturated fats: polyunsaturated and mono-unsaturated. • Polyunsaturated fats are found in most vegetable oils (e.g. sunflower oil) and oily fish (e.g. tuna) • Mono-unsaturated fats are found in olive oil, avocados and nuts • Both types of unsaturated fats help lower total cholesterol levels	• Animal foods such as meat, poultry, fish, eggs and dairy products are rich in protein and contain all the essential amino acids • Plant foods such as cereals, grains, lentils, beans and peas are also good sources of protein, although they do not contain all of the essential amino acids

TABLE 5.6 Summary: characteristics of the three energy systems

Characteristics	ATP–CP system	Anaerobic glycolysis system	Aerobic system
Alternative name or names	• Phosphagen system • ATP–PC system • Creatine phosphate system • Phosphate system		
Aerobic or anaerobic	• Anaerobic	• Anaerobic	• Aerobic
Fuel or fuels used	• **Creatine phosphate** (also known as phosphocreatine) — stored in small quantities within muscle cells	• **Carbohydrates** — stored as **glycogen** within muscle cells and the liver	• **Carbohydrates** — preferred fuel during exercise • **Fats** — stored as triglycerides in muscle cells and the liver. Used predominantly when body at rest, and during lower-intensity exercise (up to about 50–65 per cent of maximum oxygen uptake) • **Proteins** — only in extreme circumstances such as starvation or ultra-endurance events
Maximal rate of energy production	• **Fastest** rate of energy release for resynthesis of ATP from ADP and Pi • **3.6** moles per minute • This is because this system is the least complicated of the three energy systems (fewer chemical steps), and because creatine phosphate is found within the muscle cells themselves	• Provides energy for ATP resynthesis **rapidly**, but not as quickly as the ATP–CP system • **1.6** moles per minute • This is due to a more complex series of chemical reactions that results in glycogen breaking down to glucose and then to pyruvic acid and then eventually to lactic acid	• **Slowest** system to provide energy for ATP resynthesis due to complex nature of its chemical reactions, and the fact that sufficient oxygen has to be made available to the muscle cells • **1.0** mole per minute
Maximum ATP production (yield) per mole of fuel source	• Small amounts of ATP produced • Less than 1 mole of ATP per mole of phosphocreatine	• Approximately twice as much ATP produced as the ATP–CP system • Approximately 2 moles of ATP per mole of glycogen	• Vastly greater amounts of ATP produced compared with the two anaerobic systems • **38** moles of ATP from 1 mole of glucose • Over **100** moles of ATP from 1 mole of fat (but more oxygen required)
Duration and intensity of peak energy production	• Activated at the beginning of maximal-intensity exercise • Predominant energy supplier within the first 6 seconds of high-intensity exercise, but its capacity is depleted after 6–10 seconds of maximal intensity exercise	• Also activated at the beginning of high-intensity activity • Predominant energy contributor for ATP resynthesis from the time when the phosphagen system is rapidly depleting up until about 30–60 seconds during high-intensity exercise • May also become predominant producer of energy for ATP resynthesis during repeated short-duration maximal intensity efforts that have insufficient recovery time to allow for full replenishment of creatine phosphate stores	• Also activated at the start of high-intensity exercise and will become the predominant supplier of energy for ATP resynthesis during continuous submaximal intensity exercise that exceeds 1–2 minutes in duration • In a maximal effort lasting 75 seconds, equal energy is derived from the aerobic and anaerobic systems • Predominant supplier of energy for ATP resynthesis when at rest and during submaximal activity • As event duration increases and intensity decreases, the contribution of the aerobic system to energy production increases while that of the anaerobic systems diminishes

Characteristics	ATP–CP system	Anaerobic glycolysis system	Aerobic system
Specific examples	• Athletic field events (e.g. high jump, shot put) • Short sprints (50- to 100-metre) • Tennis serve • Gymnastics vault • Golf drive	• 400-metre athletic event • 50-metre swim • High-intensity tennis rally of 15–30 seconds' duration	• 10 000-metre athletic event • Marathon • 2000-metre rowing event • Mid-field players in many team sports (e.g. Australian Rules, soccer)
Fatigue limiting factors	• Depletion of creatine phosphate stores	• Changes in the intra-muscular environment due to the accumulation of hydrogen ions (H^+)	• Depletion of glycogen stores
Type of recovery	• Passive	• Active	• Active
Metabolic by-products	• Inorganic phosphates (Pi) • ADP	• Lactic acid — lactate and hydrogen ions (H^+) • ADP	• Carbon dioxide (CO_2) • Water (H_2O) • Heat • ADP
Links to fitness components	• Muscular strength • Muscular power • Anaerobic power • Speed and agility • Reaction time	• Anaerobic capacity • Local muscular endurance • Speed and agility • Muscular power	• Relevant to all fitness components because it provides the basis for recovery in anaerobic-type tasks as well as the bulk of energy production for submaximal activities

Fatigue

- Fatigue is the inability to continue functioning at the level of one's normal physical abilities, and usually manifests itself as local muscular fatigue.
- Muscular fatigue is a highly complex phenomenon that consists of numerous factors acting at multiple sites within the contracting muscles themselves.
- The causal mechanisms of local muscular fatigue depend on the type, duration and intensity of the exercise being performed, as well as other factors such as the fibre-type composition of the involved muscle or muscles, the fitness and training status of the athlete, the nutritional state of the athlete, and even the athlete's mental state.
- Fatigue may result from fuel depletion, the accumulation of metabolic by-products and/or impaired muscle excitability. Whatever the causal mechanism, the muscular fatigue that results manifests itself as the eventual lack of ability of a single muscle or local group of muscles to do work at a given intensity.

Recovery

- Recovery can be defined as the overcoming or reversal of fatigue experienced as a result of training or some form of exercise.
- In general terms, the recovery process encompasses active recovery or passive recovery immediately post-exercise.
- Active recovery is at a lower intensity and is used to:
  - reduce heart rate to resting levels
  - replenish oxygen levels in the blood, body fluids and myoglobin
  - increase blood flow to the working muscles
  - remove higher lactate concentration levels
  - accelerate oxidation as this boosts the clearance rate of lactate
  - resynthesise high-energy phosphates
  - support the small energy cost to maintain elevated circulation and ventilation
  - remove metabolites after exercise.
- Passive recovery is used to replenish ATP and creatine phosphate stores at the fastest rate.

eBook*plus*

Interactivity
Energy systems and interplay of energy systems quiz
Searchlight ID: int-6795

studyon

Sit VCAA exam

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 State the energy rate and yield associated with the ATP–CP system.
(A) Rate is 0.7 moles per minute and yield is 3.6 moles per mole of fuel substrate
(B) Rate is 1.6 moles per minute and yield is 1.0 moles per mole of fuel substrate
(C) Rate is 3.6 moles per minute and yield is 0.7 moles per mole of fuel substrate
(D) Rate is 3.6 moles per minute and yield is 38.0 moles per mole of fuel substrate

2 List the metabolic by-products of the aerobic energy system.
(A) Carbon dioxide, hydrogen ions and ADP
(B) ADP, water and heat
(C) Lactate and inorganic phosphates
(D) Carbon dioxide, water and heat

3 Complete the following diagram outlining the metabolism of lactic acid.
Lactic acid + oxygen → _____________ + _________________
(A) Lactate and hydrogen ions
(B) Inorganic phosphates and carbon dioxide
(C) Carbon dioxide and water
(D) Lactate and water

4 In which energy system or systems are hydrogen ions a metabolic by-product of the chemical process?
(A) Anaerobic glycolysis
(B) ATP–CP
(C) Aerobic glycolysis
(D) Aerobic lipolysis

5 State an advantage of using creatine phosphate as a fuel.
(A) Readily available in the liver
(B) Breaks down slowly with oxygen
(C) Provides a large yield of ATP at a rapid rate
(D) Breaks down rapidly without oxygen

6 State which factors significantly influence the causes of fatigue.
(A) Nutritional and training status of the athlete, type, intensity and duration of exercise
(B) Intensity and duration of exercise
(C) Nutritional and training status of the athlete
(D) Type of exercise

7 Lactic acid is a by-product of
(A) aerobic lipolysis.
(B) aerobic glycolysis.
(C) anaerobic glycolysis.
(D) lactate.

8 ‘Hitting the wall’ is a term used to describe a condition caused by
(A) the depletion of fat stores.
(B) the depletion of glycogen stores.
(C) the depletion of creatine phosphate stores.
(D) an increase in lactate.

9 The point just before hydrogen ions increase exponentially is known as
(A) pyruvate inflection point.
(B) lactic acid inflection point.
(C) lactate inflection point.
(D) lactate transition point (LT1).

10 The goalie and wing player in hockey would possibly complete the following recovery activities.
(A) Passive recovery (wing player) and active recovery (goalie)
(B) Passive recovery (wing player) and passive recovery (goalie)
(C) Active recovery (wing player) and active recovery (goalie)
(D) Passive recovery (goalie) and active recovery (wing player)

TRIAL EXAM QUESTIONS

Question 1 **(adapted from ACHPER Trial Exam 2015, question 2)**

Wayde van Niekerk from South Africa is the current Olympic champion in the 400 m track event. Van Niekerk won this event in Rio in a time of 43.03 seconds. Mo Farah from Great Britain is the current Olympic champion in the 10 000 m track event. He won his gold medal in a time of 27 minutes 5 seconds.

List the predominant energy system used to complete their specific event.

2 marks

Wayde van Niekerk (400 m) ______________________________

Mo Farah (10 000 m) ______________________________

Question 2 **(ACHPER Trial Exam 2015, question 8)**

Passive and active recovery strategies can both be effective. Identify the best time to engage in each recovery strategy and provide a suitable example for each.

	Passive recovery strategy	**Active recovery strategy**
Best utilised		
Example		

4 marks

Question 3 **(ACHPER Trial Exam 2015, question 11d)**

Discuss the predominant fuels required for resynthesis of ATP in race walking compared to the High Jump event. **4 marks**

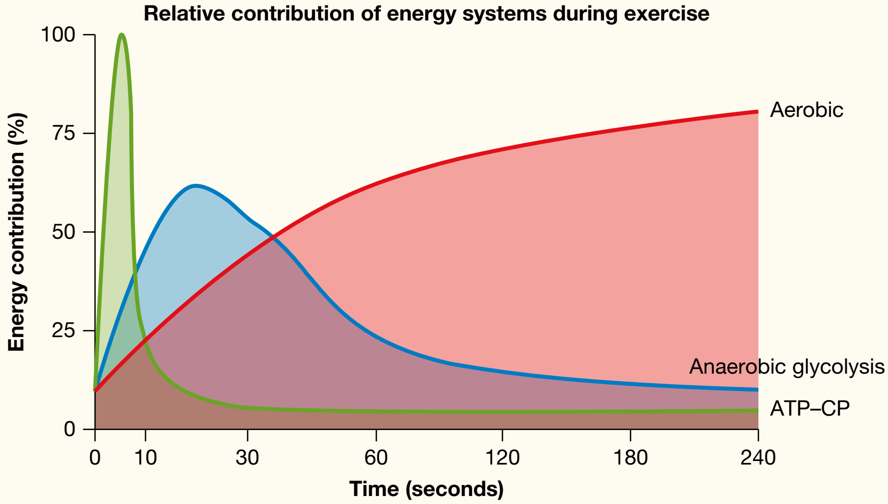
Question 4 **(ACHPER Trial Exam 2014, question 8b part iii)**

Jana Pittman is a Australian athlete. Prior to 2013 she represented Australia in the 400 m hurdles at the summer Olympics and World Championships. Her fastest time was 53.82 seconds and she won the World Championships twice. She represented Australia in the two-person Bobsled at the 2014 Sochi Winter Olympics. Jana is the 'brakeperson' which involves pushing a sleigh (with her partner in unison) on ice for approximately 50 metres in 6 seconds before loading into the bobsled to ride to the finish line.

Jana would incorporate recovery techniques into her training. Active and passive recovery are better suited to certain events. Identify the type of recovery best suited to each of Jana's events and justify your selection. **4 marks**

	400 m Hurdles	**Bobsled**
Type of recovery		
Justification		

Question 5 **(ACHPER Trial Exam 2014, question 10)**



a. Describe the relationship between the three energy systems as shown in the graph. **2 marks**

b. At what time does the anaerobic glycolysis system become predominant? **1 mark**

c. Explain why there is a delay before the aerobic energy system becomes predominant and what occurs in the interim. **2 marks**

d. Why does the ATP–CP energy system predominantly contribute to energy production for only a short period of time? **1 mark**

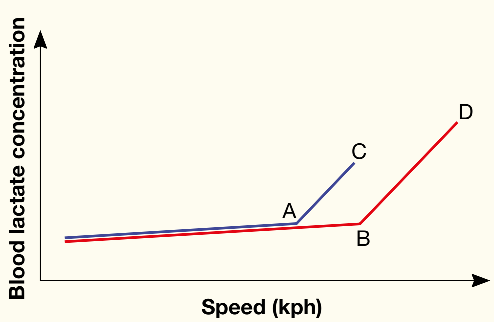
Question 6 **(ACHPER Trial Exam 2013, question 11b)**

Brooke, a 20-year-old high-level female 1500-m runner, is preparing for the Australian Track and Field Championships. Her current personal best time is 4 minutes 30 seconds.

In various periods throughout the race, Brooke exercises above her VO_2 maximum. Outline how the body enables this increase in intensity to happen. **2 marks**

Question 7 **(ACHPER Trial Exam 2014, question 12a, d)**

The graph below shows a recreational runner's blood lactate concentration during two different running treadmill tests until they reach exhaustion. The second test was completed four months later, after the runner had undertaken a regular training program.

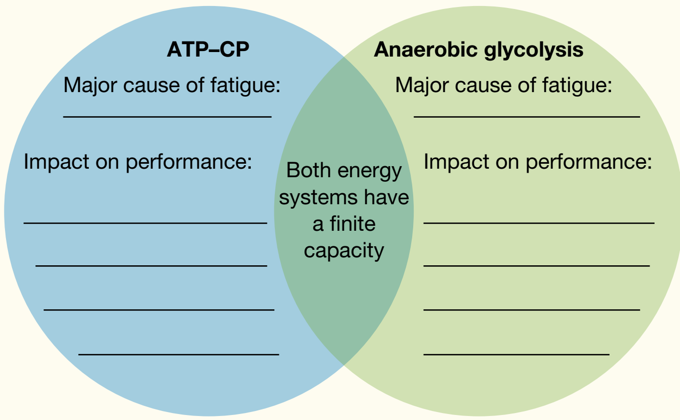


a. Identify what the points labelled A and B represent. **1 mark**

b. The test is completed when the runner is unable to continue, due to fatigue. What is the most likely cause of this fatigue? **1 mark**

Question 8 **(ACHPER Trial Exam 2013, question 13)**

The anaerobic energy systems (ATP–CP and anaerobic glycolysis) have a finite capacity, which ultimately impacts on performance. Outline the major fatiguing factors for the ATP–CP and anaerobic glycolysis energy systems, and their impact on performance in the diagram below. **4 marks**



Question 9 **(ACHPER Trial Exam 2008, question 16)**

Bryan Clay (USA) won the Gold Medal in the decathlon at the Beijing Olympics in 2008. He competes in 10 different events over a 48-hour period. Three of these events and his results are shown below.
Use this information to complete the table below. **7 marks**

Event and result	**Major fuel/s used for this event**	**Predominant energy system used in this event**	**One characteristic of this energy system that makes it suitable for the event**
400-metre run 48.92 secs	i.	ii.	iii.
Shot put 16.27 m	Phosphocreatine	iv.	v.
1500-metre run 5 min 06.59 secs	vi.	Aerobic energy system	vii.

INQUIRY QUESTION
Which acute body system responses may occur as a result of the movement depicted in this image?

CHAPTER

6 Acute physiological responses to exercise

Whenever an individual engages in exercise, the body responds physiologically to meet the increased energy demands of the activity. These immediate short-term responses that last only for the duration of the activity are referred to as acute responses. This chapter examines the cardiovascular, respiratory and muscular systems and the roles of each in supplying oxygen and energy to the working muscles.

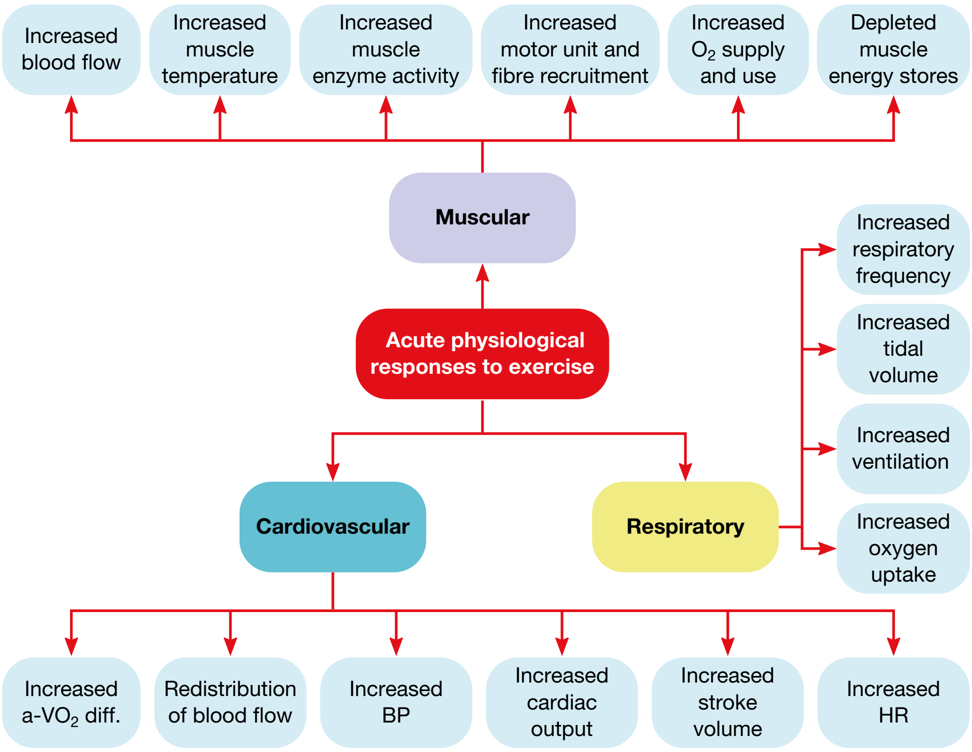
KEY KNOWLEDGE

- Oxygen uptake at rest, during exercise and recovery, including oxygen deficit, steady state, and excess post-exercise oxygen consumption
- Acute physiological responses to exercise in the cardiovascular, respiratory and muscular systems

KEY SKILLS

- Explain the changes in oxygen demand and supply at rest, during submaximal and maximal activity
- Participate in physical activities to collect and analyse data on the range of acute effects that physical activity has on the cardiovascular, respiratory and muscular systems of the body

CHAPTER PREVIEW



6.1 Acute responses of the cardiovascular system: heart rate, stroke volume and cardiac output

KEY CONCEPT When we engage in exercise, certain changes occur immediately within the cardiovascular system to meet the increased energy demands imposed on the body by the activity being undertaken. These are referred to as acute responses.

Acute responses are the body's immediate, short-term responses that last only for the duration of the training or exercise session and for a short time period (recovery) afterwards.

Numerous cardiovascular (heart, blood and blood vessels) responses occur when we start exercising. All are designed to facilitate the rapid and efficient delivery of increased amounts of oxygen to the working muscles in order to meet the body's increased demand for energy. **Acute responses** of the cardiovascular system to exercise include:

- increased heart rate
- increased stroke volume
- increased cardiac output
- increased blood pressure
- redistribution of blood flow to working muscles
- increased arteriovenous oxygen difference.

This subtopic considers the first three of these cardiovascular responses as they all relate directly to the heart itself.

Increased heart rate

Heart rate (HR) is the number of times the heart contracts or beats per minute.

Resting heart rate (RHR) refers to the number of heartbeats per minute while the body is at rest — usually an average of 70 beats per minute for an adult.

Heart rate (HR) refers to the number of times the heart contracts or beats per minute (bpm). **Resting heart rate (RHR)** refers to the number of heartbeats per minute while the body is at rest and for an adult is usually somewhere between 60 and 80 beats per minute, with 70 beats per minute being about average. Once an individual begins to exercise, their heart rate increases as a response to the extra energy required by the body. The increase in heart rate helps to increase oxygen delivery to the working muscles and aids in the removal of waste products from the muscles and body.

The heart rate increases directly in proportion (linearly) with increases in exercise intensity until near-maximal intensity is reached. The greater the intensity of exercise, the greater the increase in heart rate. For example, light or low-intensity exercise tends to produce heart rates of 100–140 beats per minute, while moderate intensity exercise typically results in heart rates of 140–160 beats per minute. High-intensity exercise produces even higher heart rates (see figure 6.1), although there is a maximum (ceiling) to which the heart rate can increase. This is referred to as the **maximum heart rate (MHR)** and it can be defined as 'the highest heart rate value achieved in an all-out effort to the point of exhaustion' (Wilmore et al. 2008).

Maximum heart rate (MHR) is the highest heart rate value achieved in an all-out effort to the point of exhaustion.

An estimation of maximum heart rate can be calculated by subtracting the age of the individual from 220 (maximum heart rate = 220 − age in years). For example, a 17-year-old VCE student would have a maximum heart rate of 220 − 17 = 203 beats per minute. However, it should be stressed that this method provides only a very rough estimation of an individual's maximum heart rate, and that considerable individual variation exists.

eBook*plus*

Interactivity
Maximum heart rate calculator
Searchlight ID: int-6796

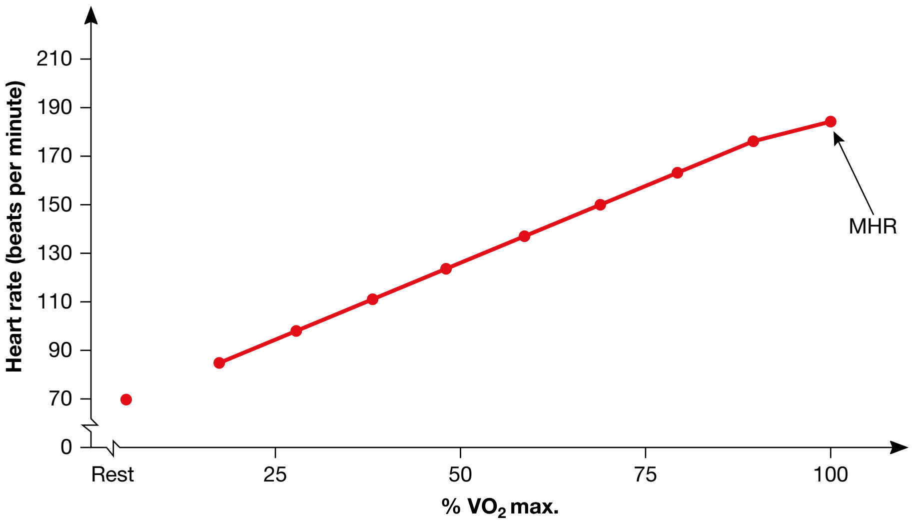
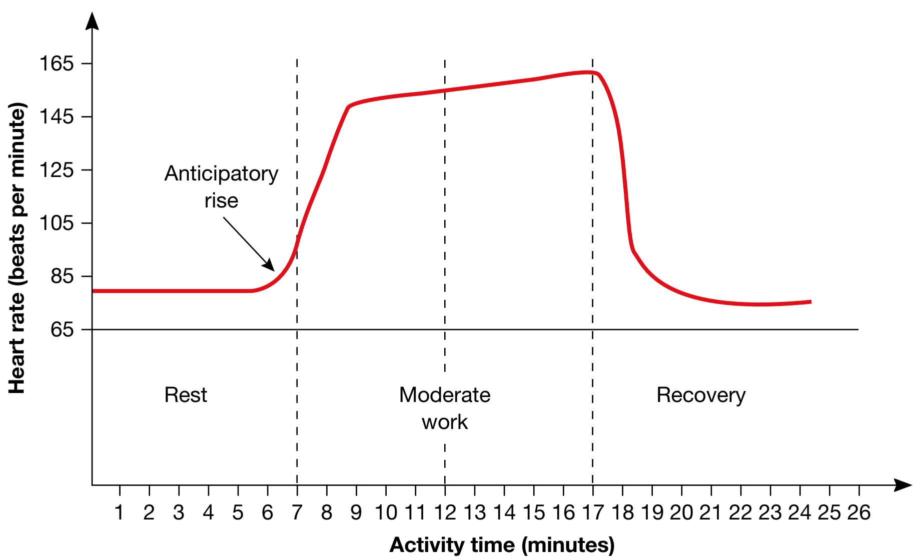


FIGURE 6.1 The heart rate increases directly in proportion (linearly) with increases in exercise intensity.

Source: Reprinted with permission, Wilmore, Costill & Kenney 2008.

Trained athletes have lower heart rates at rest and during all exercise intensities compared with untrained individuals. The heart rate actually rises above resting values just before the start of exercise. This is called an **anticipatory response**. The anticipatory increase in heart rate that occurs prior to beginning exercise is largely due to the release of epinephrine (adrenaline). Figure 6.2 depicts the heart rate response to exercise before, during and after moderate-intensity exercise.

Anticipatory response is when the heart rate rises above resting values just before the start of exercise.



eBook*plus*

eLesson
Heart rate response
Searchlight ID: eles-2760

FIGURE 6.2 Heart rate response to exercise before, during and after moderate-intensity exercise

Increased stroke volume

Stroke volume (SV) is defined as the amount of blood ejected from the left ventricle with each beat (contraction) of the heart. Stroke volume increases during exercise; however, most researchers agree that while stroke volume increases with increasing exercise intensities, it does so only up to exercise intensities, for untrained athletes, somewhere between 40 and 60 per cent of maximal capacity (see figure 6.3). In untrained individuals stroke volume at rest is about 60–80 millilitres per beat. During exercise, stroke volume increases to average maximal values ranging from 110 to 130 millilitres per beat. At this point, stroke volume typically plateaus and

Stroke volume (SV) is the amount of blood ejected from the left ventricle with each beat (contraction) of the heart.

remains unchanged despite increases in exercise intensity. In elite trained athletes, stroke volume may increase from 80 to 110 millilitres per beat at rest up to 160 to 200 millilitres per beat during maximal exercise (see table 6.1).

TABLE 6.1 Stroke volumes for untrained and trained athletes

Subjects	SV at rest (ml)	SV max. (ml)
Untrained	60–80	110–130
Trained	70–90	110–150
Highly trained	80–110	160–220

- Females tend to have lower stroke volumes than males, both at rest and during exercise, as a result of their smaller heart size.
- Trained athletes (both male and female) have larger stroke volumes compared with their untrained counterparts.
- Some researchers have reported that stroke volume continues to rise with increasing exercise intensities, up to the point of exhaustion, although these studies mainly involve highly trained elite athletes.

Mechanisms responsible for increase in stroke volume

During exercise, there is an increase in venous blood return to the heart. As a result, the ventricle stretches as it fills more fully with blood, and subsequently contracts more forcefully as a result of the greater elastic recoil. The ventricle's force of contraction is further enhanced by an increase in neural stimulation.

Vasodilation is the process whereby blood vessels increase their internal diameter as a response to an increased demand for oxygen delivery to muscle tissue.

There is a decrease in peripheral resistance as a result of **vasodilation** of the vessels supplying blood to the exercising skeletal muscles. This decrease in resistance facilitates a greater emptying of the blood from the ventricle.

As to why stroke volume tends not to increase further at exercise intensities beyond 40–60 per cent of maximal capacity, the most likely explanation for this is the reduced amount of time available for the ventricle to fill. As heart rate increases with increasing exercise intensity, the filling time is reduced significantly, thereby limiting the amount of blood within the ventricle. Studies have shown that the filling time may be reduced from 500–700 ms (milliseconds) at rest to as little as 150 ms at higher heart rates.

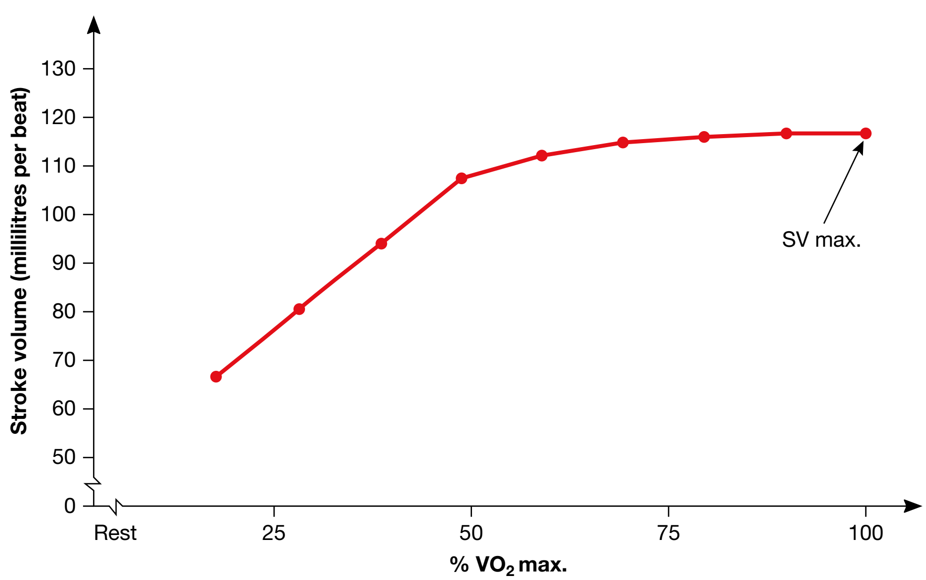


FIGURE 6.3 Stroke volume responses to exercise. The stroke volume increases as exercise intensity increases up to approximately 40–60 per cent of VO_2 max. then plateaus and remains essentially unchanged despite increases in exercise intensity.

Source: Reprinted with permission, Wilmore, Costill & Kenney 2008

Increased cardiac output

Cardiac output ($\dot{Q}$) usually refers to the amount of blood ejected from the left ventricle of the heart per minute. It is the product of heart rate multiplied by stroke volume:

$$\dot{Q} = \text{heart rate (HR)} \times \text{stroke volume (SV)}$$
$$\dot{Q} = \text{HR} \times \text{SV}$$

Cardiac output ($\dot{Q}$) is the amount of blood ejected from the left ventricle of the heart per minute. $\dot{Q}$ = heart rate (HR) × stroke volume (SV).

Given this, cardiac output predictably increases during exercise. Under resting conditions the average adult male's cardiac output is about 4–6 litres per minute; but this varies in proportion to the size of the individual. During exercise, cardiac output increases as a result of increases in both heart rate and stroke volume. This increase in cardiac output is designed to bring about an increase in oxygen delivery to the working muscles and heart. During maximal exercise intensities, average cardiac output can be 20–25 litres per minute, although among highly trained endurance athletes cardiac output may be as high as 35–40 litres per minute, giving these athletes a major physiological advantage (see figure 6.4).

eBook*plus*

Interactivity
Cardiac output calculator
Searchlight ID: int-6797

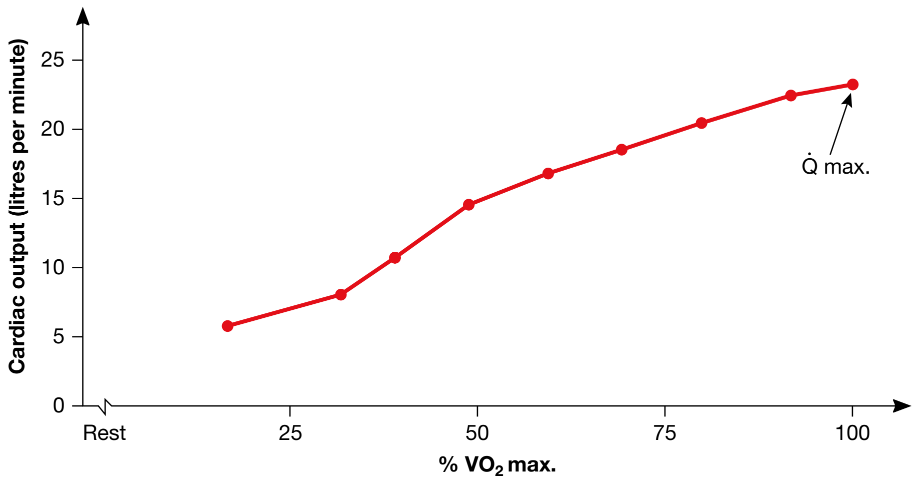


FIGURE 6.4 Cardiac output responses to exercise: cardiac output increases in direct proportion to increasing exercise intensity.

Source: Reprinted with permission, Wilmore, Costill & Kenney 2008

The integrated cardiac response to exercise

To summarise the cardiac response to exercise, let us consider how heart rate, stroke volume and cardiac output vary as an individual (average adult male aged 20) transitions from rest to exercise of increasing intensities.

At rest, the individual's heart rate will be around 70 beats per minute, with their stroke volume approximately 70 millilitres per beat. This gives them a cardiac output (HR × SV) of roughly 5 litres per minute (70 beats per minute × 70 millilitres per beat = 4900 millilitres per minute).

As they transition from rest to walking, their heart rate will increase to about 90 beats per minute, and their stroke volume will also increase, resulting in an increase in cardiac output.

Moderate-paced jogging will see their heart rate increase to approximately 140 beats per minute, with stroke volume peaking at about 120 millilitres per beat, giving them a cardiac output of approximately 16–17 litres per minute.

Fast-paced running will see heart rate reach maximal values of near 200 beats per minute. During high-intensity exercise, it will be this increase in heart rate that contributes primarily to the further increases in cardiac output, since stroke volume tends to plateau when exercise intensity reaches around 40–60 per cent of the individual's maximal exercise capacity.

TABLE 6.2 Heart rate, stroke volume and cardiac output at rest, during moderate exercise and during strenuous exercise

Intensity	Heart rate (beats per minute)	Stroke volume (millilitres per beat)	Cardiac output (litres/minute)
Rest	70	70	4.9
Submaximal	140	120	16.8
Maximal	200	120	24.0

TEST your understanding

1 Explain what is meant by *acute responses to exercise*.
2 Define what is meant by the terms *heart rate*, *stroke volume* and *cardiac output*.
3 Outline the method for estimating the maximum attainable heart rate.
4 Explain why females tend to have lower stroke volumes than males.
5 (a) Explain the mechanisms that are responsible for the increase in stroke volume that accompanies exercise.
(b) Explain why stroke volume plateaus at exercise intensities approaching 40–60 per cent of maximum exertion levels. Discuss why this might not be the case with highly trained athletes.
6 (a) Calculate the cardiac output of an individual who has a heart rate of 80 beats per minute and a stroke volume of 75 millilitres per beat.
(b) Calculate the heart rate of an individual who has a cardiac output of 12 litres per minute and a stroke volume of 120 millilitres per beat.
7 **Heart rate and stroke volume responses to exercise**
Refer to figures 6.1 and 6.3 and answer the following questions:
(a) Figure 6.1 shows a linear relationship between heart rate and exercise intensity, as indicated by the straight line. Explain what is meant by a linear relationship between heart rate and exercise intensity.
(b) At what intensity of exercise does stroke volume reach maximum levels? Explain your answer.
(c) Explain why trained athletes have higher stroke volumes than untrained individuals.

APPLY your understanding

8 **Practical activity: laboratory test on heart rate responses to exercise**
In pairs, measure and record your and your partner's resting heart rate. Your teacher will show you how to do this manually or with a heart rate monitor. Then perform the following physical activities with your partner, taking and recording your and your partner's heart rate immediately after you both complete each activity. Allow your heart rates to return to their resting values before undertaking the next activity.
- Walking for 2 minutes
- Jogging for 2 minutes
- Performing stepups on a bench for 2 minutes
- Performing bent-knee situps for 2 minutes

(a) Graph the results you obtained for both yourself and your partner.
(b) Identify the exercise that resulted in the highest heart rate. How do you account for this?
(c) Discuss the relationship between your heart rate and the intensity of the exercise.

EXAM practice

9 Describe how heart rate, stroke volume and cardiac output respond during exercise of increasing intensity. Ensure that you explain how these three variables are interrelated. **3 marks**

6.2 Acute responses of the cardiovascular system: blood pressure, redistribution of blood flow, arteriovenous oxygen difference

KEY CONCEPT In addition to the acute cardiac responses to exercise, other acute cardiovascular responses occur in relation to changes in blood pressure, distribution of blood flow and the arteriovenous oxygen difference.

Increased blood pressure

Blood pressure is the pressure exerted by the blood against the arterial walls as it is forced through the circulatory system by the action of the heart. It has two components: **systolic blood pressure** and **diastolic blood pressure**. Systolic blood pressure is the pressure recorded as blood is ejected during the contraction phase of the heart beat. Diastolic blood pressure is the value recorded during relaxation of the heart.

Blood pressure is usually expressed as:

$$\text{Blood pressure} = \frac{\text{systolic}}{\text{diastolic}}\ \text{mmHg}$$

$$\text{Normal blood pressure} = \frac{120}{80}\ \text{mmHg}$$

During dynamic whole-body exercise such as jogging or cycling, blood is pumped more forcefully and quickly out of the heart, increasing pressure on the artery walls. This results in an increase in systolic blood pressure — it may reach levels as high as 180–200 mmHg during the heaviest workloads (see figure 6.5) — although the decrease in peripheral resistance caused by vasodilation of the blood vessels of the exercising muscles offsets or buffers this rise in systolic pressure. Diastolic blood pressure changes little during exercise, with increases of more than 10 mmHg considered abnormal. The minimal change in diastolic blood pressure is accounted for by the decrease in peripheral resistance.

Blood pressure (BP) is the pressure exerted by the blood against the arterial walls as it is forced through the circulatory system by the action of the heart. It has two components: systolic blood pressure and diastolic blood pressure.

Systolic blood pressure is the blood pressure recorded as blood is ejected during the contraction phase of the heart cycle. It is the higher of the two blood-pressure values.

Diastolic blood pressure is the blood pressure recorded during the relaxation phase of the heart cycle. It is the lower of the two blood-pressure values.

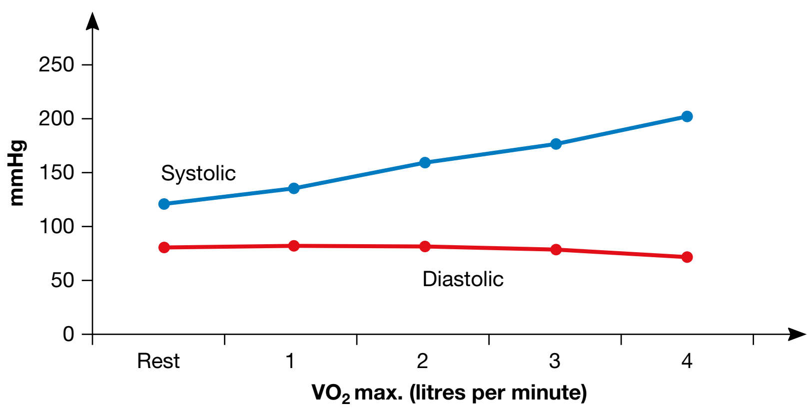


FIGURE 6.5 Blood pressure responses to progressive endurance exercise

Source: Reprinted with permission, Hoffman J 2002.

During resistance-type exercise (e.g. lifting weights), large increases in both systolic and diastolic blood pressure are evident. With high-intensity resistance training, blood pressure can reach values as high as 480 over 350 mmHg. This increase is the result of a compression of the vasculature within the contracting muscles and the use of a **Valsalva manoeuvre** during the performance of the exercise. The Valsalva manoeuvre occurs when an individual attempts to exhale while the mouth, nose and glottis (part of the larynx) are closed. This results in a large increase in the intrathoracic (chest cavity) pressure, which in turn results in an increase in both systolic and diastolic blood pressure as the body attempts to overcome the high internal pressure created during the Valsalva manoeuvre. The Valsalva manoeuvre is considered dangerous and should be avoided.

The **Valsalva manoeuvre** occurs when an individual attempts to exhale while the mouth, nose and glottis (part of the larynx) are closed.

eBook*plus*

Interactivity
Systemic blood flow
Searchlight ID: int-6640

Systemic blood flow is the blood flow around the body. Blood leaves the left ventricle of the heart via the aorta, and then travels via the arteries and capillaries to the body, returning to the right atrium of the heart via the superior and inferior vena cava.

Vasoconstriction is the process where blood vessels narrow or constrict as a response to a decreased demand for oxygen delivery to muscle tissue.

Redistribution of blood flow to working muscles

Under resting conditions only about 15–20 per cent of total **systemic blood flow** is directed to the skeletal muscles. The majority of the remaining 80–85 per cent is distributed to the organs (e.g. heart, liver, kidneys, intestines, brain) of the body. However, under exercise conditions the majority of the blood (80–90 per cent) may be redirected to the working muscles (see figure 6.6). This is achieved by the capillaries and arterioles supplying the working muscles expanding in diameter (a process known as vasodilation). At the same time, blood flow to the organs of the body is reduced by the **vasoconstriction** (narrowing) of the capillaries and arterioles that supply blood to these organs.

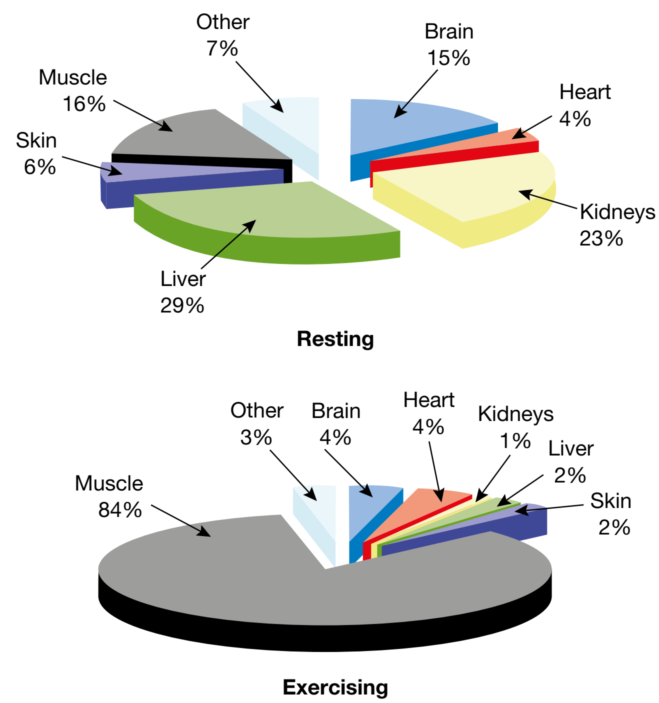


FIGURE 6.6 Distribution of cardiac output while resting and exercising

Source: Reprinted with permission, Hoffman J 2002.

eBook*plus*

Interactivity
Redistribution of blood flow during exercise
Searchlight ID: int-6798

Arteriovenous oxygen difference (a-VO_2 diff.) is a measure of the difference in the concentration of oxygen in the arterial blood and the concentration of oxygen in the venous blood.

Increased arteriovenous oxygen difference

The **arteriovenous oxygen difference (a-VO_2 diff.)** is a measure of the difference in the concentration of oxygen in the arterial blood and the concentration of oxygen in the venous blood. This is measured in millilitres per 100 millilitres of blood. At rest, the arteries contain an oxygen concentration of approximately 20 millilitres per 100 millilitres of blood (200 millilitres of oxygen per litre of blood), while at rest the veins typically contain about 15 millilitres per 100 millilitres. Thus the arteriovenous oxygen difference at rest is about 5 millilitres per 100 millilitres of blood.

$$\text{a-VO}_2\text{ diff.} = \frac{20\text{ mL}}{100\text{ mL}} - \frac{15\text{ mL}}{100\text{ mL}}$$

$$\text{a-VO}_2\text{ diff.} = \frac{5\text{ mL}}{100\text{ mL}}$$

The amount of oxygen extracted from the arterial blood at rest is therefore about 25 per cent. However, during exercise working muscles extract much more of the available oxygen from the blood that passes through them (as much as 75 per cent of the available oxygen is extracted). As a result, the arteriovenous oxygen difference increases and can be as high as 15–18 millilitres per 100 millilitres of blood — almost a threefold increase over the value at rest (see figure 6.7).

eBook*plus*

Weblink
a-VO_2 diff.

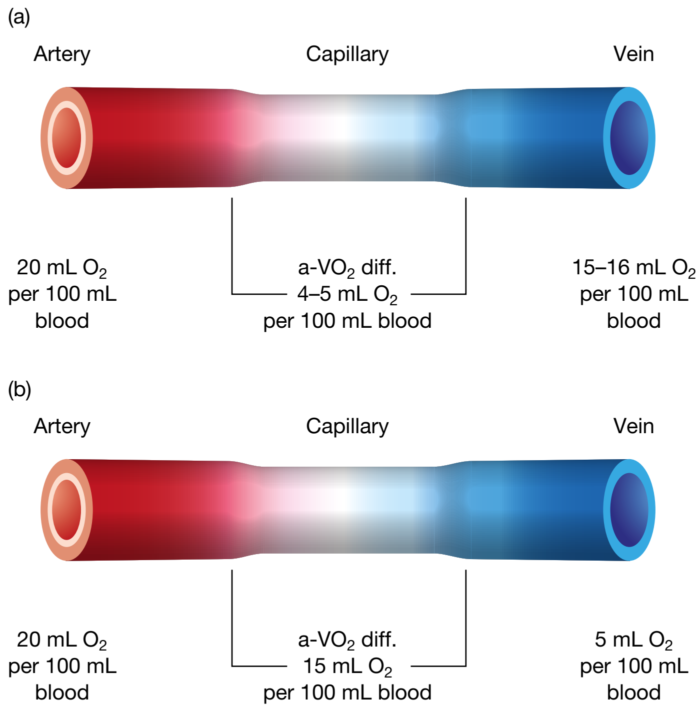


FIGURE 6.7 The arteriovenous oxygen difference (a) at rest and (b) during intense aerobic exercise

eBook*plus*

Interactivity
Arteriovenous oxygen difference at rest and during intense exercise
Searchlight ID: int-6799

studyon

Unit 3 | AOS 2 | Topic 2 | Concept 1

Changes in oxygen uptake
Summary screen and practice questions

studyon

Unit 3 | AOS 2 | Topic 2 | Concept 2

Cardiovascular system
Summary screen and practice questions

TEST your understanding

1. State the component of blood pressure that is most affected by exercise. Explain why this is the case.
2. Explain the difference between vasodilation and vasoconstriction. Explain how these processes result in increased blood flow and oxygen delivery to working muscles.
3. Explain what is meant by the arteriovenous oxygen difference. Explain why this increases during exercise.

APPLY your understanding

4. **Practical activity: laboratory test on measuring blood pressure**
   Working in small groups of three or four, measure and record the blood pressure of one member of your group while they undertake the activities listed below. Record the blood pressure each minute (i.e. at 1 minute, 2 minutes, 3 minutes).
   - Sitting at rest
   - Standing at rest
   - Lying at rest
   - Cycling for 10 minutes on an exercise bike at a moderate intensity

   In order to complete this laboratory test you will need to be proficient in the use of either a sphygmomanometer or a digital blood pressure reader. Your teacher will show you how to use this equipment to measure blood pressure.
   (a) Graph the blood pressure data you obtained. Make sure both systolic and diastolic values are shown on the one graph.
   (b) What effect did different body positions have on blood pressure when the participant was at rest? Explain how you account for any differences observed.
   (c) What happened to the participant's blood pressure during exercise? At what point in the exercise bout did blood pressure reach its maximum value? Did blood pressure plateau at any point?
   (d) Did the changes in the participant's blood pressure during exercise match what you expected to happen based on your understanding of blood pressure responses to exercise? Explain.
   (e) Explain what might happen to the participant's blood pressure if they had been asked to perform a maximum bench press test? How would this blood pressure response differ to that experienced during the 10 minutes of moderate-intensity cycling? Explain why this difference occurs.

EXAM practice

5. Anna Meares won the 2015 Women's Keirin in France at the Track Cycling World Championship. The Keirin consists of eight laps around a 250-metre velodrome: a total of 2000 metres. State an acute cardiovascular response and explain how this response assisted with Anna's performance. **2 marks**

6.3 Acute responses of the respiratory system

KEY CONCEPT When we engage in exercise, certain changes occur immediately within the respiratory system. These acute responses are designed to meet the increased energy demands imposed on the body by the activity being undertaken.

Acute responses of the respiratory system to exercise are designed to facilitate an increase in the availability of oxygen and the removal of carbon dioxide. These responses include:

- increased respiratory frequency (breathing rate)
- increased tidal volume
- increased ventilation
- increased pulmonary diffusion
- increased oxygen uptake.

Increased respiratory frequency (breathing rate)

Respiratory frequency (RF) is the number of breaths taken per minute.

Respiratory frequency (RF) or breathing rate refers to the number of breaths taken per minute. At rest, the average respiratory frequency is around 12 breaths per minute. When exercise begins, breathing rates rise sharply and can increase to as high as 35–50 breaths per minute. This increase in respiratory frequency is triggered by the increase in carbon dioxide concentrations in the blood, which stimulates the respiratory control centre in the brain.

Increased tidal volume

Tidal volume (TV) is the amount of air breathed in and out in one breath.

The depth of breathing (**tidal volume (TV)**) increases from around 0.5 litres per breath at rest to as high as 3–5 litres per breath at maximal workloads.

Increased ventilation

Ventilation is the amount of air inspired or expired per minute by the lungs. Ventilation (V) = respiratory frequency × tidal volume.

Ventilation is the amount of air inspired or expired per minute by the lungs. It is a product of respiratory frequency multiplied by tidal volume.

$$\text{Ventilation (V)} = \text{respiratory frequency} \times \text{tidal volume}$$

At rest, ventilation is around 5–6 litres per minute. During maximal exercise, it may increase beyond 180 and 130 litres per minute (for males and females respectively). This is 25 to 35 times as great as resting values. It should be noted that both tidal volume and ventilation for males are generally greater because of larger lung volumes in males.

TABLE 6.3 Comparison of respiratory frequency, tidal volume and ventilation at rest and during exercise

	Respiratory rate (breaths/minute)	Tidal volume (L/breath)	Ventilation (L/min)
Rest	12	0.5	6
Submaximal exercise	30	2.5	75
Maximal exercise	45	4.0	180

Increased pulmonary diffusion

Pulmonary diffusion is where gaseous exchange takes place within the lungs. Pulmonary diffusion has two major functions:

- to replenish oxygen supply through diffusion from alveolar to pulmonary capillaries
- to remove carbon dioxide from returning venous blood.

At rest, the oxygen diffusion capacity is about 21 mL of oxygen per minute. During maximal exercise, the oxygen diffusion capacity may increase by up to three times the resting rate.

Pulmonary diffusion is the process whereby oxygen is taken in via the lungs to the blood, and carbon dioxide is diffused from the blood to the lungs.

Mechanisms responsible for increased ventilation

Because of its rapid onset, the initial ventilation adjustment to the increased oxygen demands of exercise is without doubt neural in nature, controlled by respiratory control centres in the brain, although neural input can also be provided by receptors within the exercising muscles. As exercise progresses, further adjustments in ventilation are controlled primarily by changes in the chemical status of arterial blood. Increased muscle metabolism due to exercise results in the production of greater levels of carbon dioxide and hydrogen ions. The increased levels of carbon dioxide and hydrogen ions within the blood are sensed by chemoreceptors located in the brain and lungs, which in turn stimulate the respiratory control centres resulting in an increase in both the rate and depth of breathing (in other words, an increase in ventilation).

Increased oxygen uptake

Oxygen uptake (VO_2) refers to the amount of oxygen transported to, taken up by and used by the body for energy production. At rest, the body consumes oxygen at a rate of approximately 0.25 litres per minute. When exercise begins, oxygen uptake increases as the working muscles use more of the oxygen made available by the combined efforts of the circulatory and respiratory systems. In fact, there is a linear relationship between oxygen uptake and exercise intensity (see figure 6.8), similar to that between heart rate and exercise intensity. That is, as exercise intensity increases, oxygen uptake increases in direct proportion because the body requires more oxygen to perform at higher intensities. This linear increase continues until a maximum level of oxygen uptake is attained — the **maximum oxygen uptake (VO_2 max.)**. No further increase in oxygen uptake can be achieved beyond this maximal value, which is usually around 2–3.5 (absolute value) litres per minute.

Oxygen uptake (VO_2) is the amount of oxygen transported to, taken up by and used by the body for energy production.

Maximum oxygen uptake (VO_2 max.) is the maximum amount of oxygen per minute that can be transported to, taken up by and used by the body for energy production.

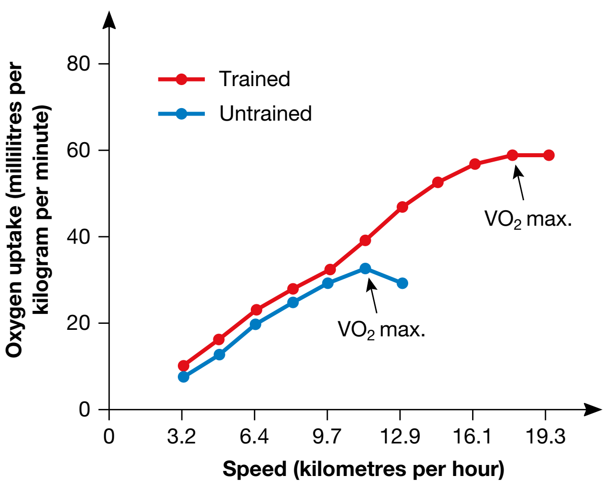


FIGURE 6.8 The relationship between exercise intensity and oxygen uptake

Source: Reprinted with permission, Wilmore, Costill & Kenney 2008.

TEST your understanding

1 Define the terms *respiratory frequency*, *tidal volume*, *ventilation*, *pulmonary diffusion*, *oxygen uptake*, *maximum oxygen uptake*.

2 An individual sets out on a 3-kilometre run. Indicate the likely respiratory system responses to this exercise bout.

3 Using your prior knowledge of the respiratory system, explain the mechanics of inspiration (inhalation) and expiration (exhalation), and how gases diffuse into and out of the lungs and blood vessels.

4 Calculate the ventilation of an individual who has a respiratory frequency of 15 breaths per minute and a tidal volume of 0.5 litres per breath.

APPLY your understanding

5 **Practical activity: laboratory test on acute respiratory responses to exercise**

Measure your resting respiratory frequency by counting the number of breaths you take in 1 minute. Then perform the following activities, measuring your respiratory frequency for 10 seconds immediately after you complete each activity. Allow your breathing rate to return to your resting value before undertaking the next activity.

- Standing still for 2 minutes
- Lying down for 2 minutes
- Walking for 2 minutes
- Jogging for 2 minutes
- Performing stepups on a bench for 2 minutes
- Resting for 1 minute after the bout of stepups
- Resting for 2 minutes after the bout of stepups
- Performing bent-knee situps for 2 minutes

(a) Record and graph your results. To determine your respiratory frequency immediately after each activity, multiply the 10-second breathing-rate measurement by 6 to calculate your respiratory frequency per minute.

(b) Which activity resulted in the highest respiratory frequency? How do you account for this?

(c) Did standing still or lying down result in the highest respiratory frequency? Explain.

(d) Explain why respiratory frequency increases so much during exercise.

(e) Explain why your respiratory frequency remains elevated above normal resting values for a period after the cessation of strenuous exercise.

EXAM practice

6 List two acute respiratory responses to exercise and explain how they assist with the performance of the athlete. **3 marks**

6.4 Maximum oxygen uptake

KEY CONCEPT Maximum oxygen uptake refers to the maximum capacity for oxygen consumption by the body during maximum exertion.

Maximum oxygen uptake or VO_2 max. represents the maximum amount of oxygen able to be taken up by, transported to and used by the body for energy production. This value is commonly used to determine an athlete's capacity to perform in aerobic (endurance) activities.

Around 3.5 litres of oxygen per minute is the average maximum oxygen uptake for males. This figure is lower for females, who have an average oxygen uptake of around 2.3 litres per minute.

Factors affecting maximum oxygen uptake

Maximum oxygen uptake is affected by a number of factors including body size, gender, genetics, age and training status (aerobic or cardiorespiratory fitness levels).

Body size

Oxygen uptake is related to body size — a larger, heavier person requires more oxygen than a smaller person. It is for this reason that VO_2 max. is usually expressed relative to body size in mL/kg/min — so that individuals can be compared, particularly in relation to their aerobic fitness levels, irrespective of differences in body size.

FIGURE 6.9 Oxygen uptake is related to body size.

Gender

Females tend to have lower oxygen uptake values compared with males of similar age and athleticism. Maximum oxygen uptake values for untrained female individuals can be as great as 20–25 per cent lower than for untrained male individuals. However, when comparing trained athletes, the gap tends to close to about 10 per cent.

Several factors contribute to females having a lower maximum oxygen uptake than males, including:

- Females typically have a higher percentage of body fat and lower percentage of muscle mass. Body fat does not consume oxygen, unlike muscle tissue.
- Females have lower blood volumes and lower levels of red blood cells and haemoglobin compared with males. This reduces the oxygen-carrying capacity of females as compared with males, as oxygen binds to haemoglobin when being transported around the body.
- Females typically have a smaller lung size and volume and a smaller heart size and volume (due to their on-average smaller body size) than males, thereby reducing their oxygen intake and transport capacity.

FIGURE 6.10 Females generally have a lower maximum oxygen uptake than males.

Genetics

There is significant evidence to suggest that aerobic capacity is largely genetically determined, with some studies suggesting that heredity may account for up to 25–50 per cent of the variance seen between individuals. Training, however, can result in substantial improvement in maximum oxygen uptake values.

Age

Maximum oxygen uptake tends to decline with increasing age. It peaks during late adolescence and early adulthood and then declines from that point. The average rate of decline is generally accepted to be about 1 per cent per year or 10 per cent per decade after the age of 25. However, training and/or maintaining a physically active lifestyle can both increase maximum values as well as decrease the rate of decline that occurs with increasing age. Usually, the age-related decline in maximum oxygen uptake can be accounted for by a reduction in maximum heart rate, maximal stoke volume and maximal a-VO_2 difference.

FIGURE 6.11 Maximum oxygen uptake declines with age.

Training status (aerobic or cardiorespiratory fitness level)

Aerobic training can substantially increase maximum oxygen uptake values for both males and females. Average maximum oxygen uptake relative values for untrained male and female adults aged 20–29 are 43–52 mL/kg/min and 33–42 mL/kg/min respectively. Trained endurance athletes on the other hand may have values as high as 60–85 mL/kg/min for male athletes and 50–70 mL/kg/min for female athletes. Table 6.4 presents a range of maximum oxygen uptake values for various population groups.

The extent to which maximum oxygen uptake can improve also appears to be dependent on the initial fitness level (starting point) of the individual. The greater the level of an individual's fitness to begin with, the less potential there is for further increases. There also seems to be a genetic upper limit beyond which further increases in either intensity or volume of training have no effect on increasing maximum oxygen uptake, although other benefits may be gained from such training; for example, an improvement in the athlete's capacity to perform at a higher percentage of their maximum oxygen uptake for longer periods of time.

studyon

Unit 3 | AOS 2 | Topic 2 | Concept 3

Respiratory system
Summary screen and practice questions

FIGURE 6.12 Oxygen uptake levels can be increased in an individual through aerobic training.

The highest ever recorded and documented maximum oxygen uptake values are 94 mL/kg/min for a male and 77 mL/kg/min for a female. Both were elite-level cross-country skiers.

TABLE 6.4 Maximum oxygen uptake values (mL/kg/min) for various population groups

Group	Age	Males	Females
Non-athletes	10–19 20–29 30–39 40–49 50–59 60–69 70–79	47–56 43–52 39–48 36–44 34–41 31–38 28–35	38–46 33–42 30–38 26–35 24–33 22–30 20–27
Baseball/softball	18–32	48–56	52–57
Basketball	18–30	40–60	43–60
Bicycling	18–26	62–74	47–57
Canoeing	22–28	55–67	48–52
Gymnastics	18–22	52–58	36–50
Racquetball	20–35	55–62	50–60
Rowing	20–35	60–72	58–65
Skiing, alpine	18–30	57–68	50–55
Skiing, Nordic	20–28	65–94	60–75
Soccer	22–28	54–64	50–60
Speed skating	18–24	56–73	44–55
Swimming	10–25	50–70	40–60
Track and field, discus	22–30	42–55	—
Track and field, running	18–39 40–75	60–85 40–60	50–75 35–60
Track and field, shot put	22–30	40–46	—
Volleyball	18–22	—	40–56
Weight-lifting	20–30	38–52	—

Source: Reprinted with permission, Wilmore, Costill & Kenney 2008.

TEST your understanding

1 Define the term *maximum oxygen uptake*. Explain why it is best expressed relative to body weight.
2 List and briefly summarise the factors that can affect maximum oxygen uptake.
3 Discuss the relationship between oxygen uptake (consumption) and energy production.
4 Explain why Nordic (cross-country) skiers would have higher maximum oxygen uptake values than weight-lifters of a similar age (see table 6.4).

APPLY your understanding

5 **Practical activity: estimating maximum oxygen uptake**
As a class, undertake a test designed to provide an estimation of VO_2 max.
After completing the test, obtain the results for all members of the class and calculate the average estimated VO_2 max. for males and females. Graph these results alongside your own personal results and then answer the following questions.
(a) How did your personal result compare with the group average result? (If you are a male student compare your result with the male class average; if you are a female student compare your result with the female class average.)
(b) How would you account for your performance relative to the class average? Think about your activity levels and the sports and activities you participate in.
(c) Which group obtained the higher group average — males or females? How do you account for this?
(d) Explain the influence of genetics and training status on maximum oxygen uptake.

6 **Practical activity: laboratory testing of VO_2 max.**
As a class, visit an organisation that conducts laboratory testing of VO_2 max. A number of universities and other organisations offer such facilities to school groups (your teacher will have details).
After attending and witnessing a laboratory VO_2 max. test, complete the following questions.
(a) Outline the basic protocols involved in a laboratory test of VO_2 max.
(b) Why are laboratory tests more accurate than field tests designed to measure VO_2 max.?
(c) What are the disadvantages of laboratory testing of VO_2 max. as compared with field tests?

EXAM practice

7 Australia's Michael Shelley, 31 years of age, powered to victory in the men's marathon at the Glasgow 2014 Commonwealth Games in a time of 2 hours, 11 minutes and 15 seconds.
(a) Estimate the VO_2 max. result of an international level male marathon runner such as Michael Shelley. **1 mark**
(b) Estimate the VO_2 max. result of a 31-year-old female competing in the local marathon. Explain your reasons. **3 marks**

eBook*plus*

eLesson
VO_2 test
Searchlight ID: int-0820

6.5 Oxygen uptake at rest, oxygen deficit, steady state and excess post-exercise oxygen consumption

KEY CONCEPT Oxygen uptake at rest, oxygen deficit, steady state and excess post-exercise oxygen consumption are important factors in the efficient delivery of oxygen to working muscles during exercise performance.

Oxygen uptake at rest

When at rest, the body's need for ATP is relatively small, requiring minimal oxygen consumption. At rest the average person consumes about 0.3 L of oxygen per minute and will usually utilise a mixture of carbohydrates and fats for energy. The body stores minimal amounts of oxygen. This means that the amount of oxygen entering your bloodstream is directly proportional to the amount used by your tissues for oxidative metabolism. As exercise intensity increases, the consumption of oxygen increases to allow greater levels of ATP to be produced at the muscle level.

Oxygen deficit

As we have discovered in the previous sections, when exercise begins, oxygen uptake increases as the body attempts to meet the increased oxygen demand of the working muscles that results from their need to produce more energy for ATP resynthesis. The respiratory and cardiovascular systems play the major role when increasing oxygen uptake and transport to the working muscles.

However, during the transition from rest to exercise, particularly high-intensity exercise, and at any time during exercise performance when exercise intensity increases, there is a period of time where there is a discrepancy between the amount of oxygen required for a given exercise intensity and the amount actually supplied and used. This discrepancy is referred to as the **oxygen deficit** (see figure 6.13). Because of this discrepancy (shortfall) between supply and demand, anaerobic sources must be involved in providing energy during these periods of time.

The oxygen deficit occurs because the respiratory and circulatory systems take some time to adjust to the new oxygen demand (even at low exercise intensities) and, consequently, the amount supplied lags behind the amount needed until these systems make the necessary adjustments required to increase oxygen supply. These adjustments involve such things as:

- increased respiratory frequency (breaths per minute)
- increased tidal volume (depth of breathing)
- increased heart rate (number of times the heart beats per minute)
- increased stroke volume (amount of blood ejected from the heart per beat).

eBook*plus*
eLesson
Oxygen deficit
Searchlight ID: eles-2759

Oxygen deficit is the state in which there is a discrepancy (shortfall) between oxygen supply and demand and the oxygen needed to meet the energy requirements of the activity. Under these conditions the anaerobic pathways must supplement the energy demands of the activity. The size of oxygen deficit can be reduced by decreasing intensity, completing a warm-up and completing aerobic training.

Steady state

It may take anywhere between a few seconds and 1 minute or more, depending on the intensity of the exercise, for oxygen supply or uptake to have increased sufficiently to meet the oxygen demands of the exercise. If and when oxygen supply does equal the oxygen demand of the exercise, an aerobic **steady state** (see figure 6.13) has been attained. Steady state occurs when virtually all of the required ATP to maintain the current exercise intensity is being supplied aerobically, so that there is no need for further increases in oxygen uptake and there is little reliance on the anaerobic pathways to supply energy for ATP resynthesis. This steady state in oxygen uptake also coincides with a plateau in heart rate and ventilation.

However, if the exercise intensity increases again, the demand for ATP resynthesis and oxygen also increases. Once again, during the short delay before oxygen uptake increases sufficiently for supply to equal demand, the anaerobic pathways must

Steady state is the state in which oxygen supply equals oxygen demand so that virtually all of the required ATP to maintain the current exercise intensity is being supplied aerobically.

supplement the energy supply. As the oxygen uptake increases to the required level, a second aerobic steady state is achieved. The process of increasing oxygen uptake and reaching a new steady state can only occur when lactate removal is greater than production. A steady state can only be held up to and including the lactate inflection point. It should be noted that in trained endurance (aerobic) athletes, the oxygen deficit is reduced due to these athletes attaining steady state sooner than untrained individuals.

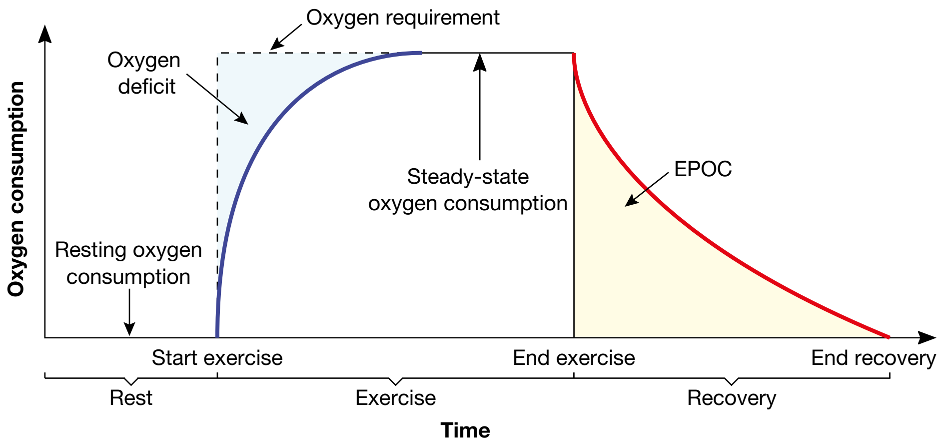


FIGURE 6.13 Oxygen deficit, steady state and EPOC

Source: Reprinted with permission, Wilmore, Costill & Kenney, 2008.

Excess post-exercise oxygen consumption (EPOC)

eBook*plus*

Interactivity
Oxygen deficit, steady state and EPOC
Searchlight ID: int-6800

Oxygen can be viewed as the 'currency' the body uses in order to 'purchase' (resynthesise) ATP. In other words, oxygen must be used in order for ATP to be produced. During the time period where an oxygen-deficit condition prevails, the muscles are able to continue contracting by obtaining the required energy for ATP resynthesis via the two anaerobic pathways (i.e. without sufficient oxygen).

Even though these two anaerobic systems do not rely directly on oxygen, they should not be viewed as producing 'free' ATP. After the cessation of exercise, oxygen uptake or consumption does not immediately return to resting levels, despite the fact that the demand for ATP resynthesis decreases dramatically. Rather, oxygen consumption remains temporarily elevated. This elevated oxygen consumption, which exceeds that normally experienced at rest, is referred to as **excess post-exercise oxygen consumption (EPOC)** (see figure 6.13).

Excess post-exercise oxygen consumption (EPOC) is the amount of oxygen consumed during the recovery period after the cessation of an exercise bout that is over and above the amount usually required during rest.

Factors responsible for elevated EPOC

There are a number of factors associated with EPOC and they can only be understood by focusing on how the chemical and physical changes occur in muscle cells during exercise. Chemical and physical changes occurring in contracting muscle cells that increase levels of oxygen consumption and ATP will continue for some time after exercise has ceased. These changes continue into the recovery phase as oxygen consumption remains elevated.

The factors associated with EPOC include the following.

- Temperature is the most important factor. Elevated muscle temperature after exercise is closely associated with elevated levels of EPOC and accounts for the slow component of oxygen consumption.
- Increased mitochondrial respiration during exercise to produce aerobic energy. Mitochondria are the site of aerobic energy production. Calcium ions stimulate mitochondrial respiration, influencing EPOC levels.

- Elevated concentration levels of catecholamine, which stimulate energy-requiring processes in cells.
- Changes in sodium (Na^+), potassium (K^+) and hormone levels interact to change EPOC levels.
- Lipolysis and release of fatty acids increases EPOC after exercise.
- If previous exercise was primarily aerobic, EPOC recovery would be completed within several minutes (fast component).
- Increased use of mitochondria, which may be controlled by concentrations of ADP, ATP, inorganic phosphates and creatine phosphate.
- Resynthesising creatine phosphates after exercise exhibiting a fast and slow recovery component.
- The size of EPOC is determined by re-phosphorylation of creatine and ADP.
- Increased ATP production.
- If previous exercise was strenuous, where lactate and body temperature have increased considerably, EPOC recovery would be slow (slow component). EPOC recovery may take several hours, depending on intensity and duration, before returning to pre-exercise oxygen consumption levels.

TEST your understanding

1 Explain why an oxygen deficit accrues at the beginning of any exercise bout.

2 Discuss the factors that could determine the size of the oxygen deficit that accrues.

3 When is a steady state achieved during an exercise bout? What does this signify in terms of energy supply to the working muscles?

4 Explain the factors responsible for the elevated levels of EPOC.

5 Explain what is meant by the expression 'oxygen is the body's exercise currency'.

6 Explain the changes in oxygen demand and supply during submaximal exercise.

EXAM practice

7 A female VCE PE student completes a 3-km cross-country course in 12 minutes on a 20 °C day. She wears a heart rate monitor and holds a steady pace until the final minute where she increases her pace until she crosses the finish line.

She notices that her heart rate reaches a plateau after about three minutes from the start. She also notices that her heart rate returns to pre-race levels about four minutes after her race is completed.

Draw and label a graph that illustrates oxygen uptake for the female student for the 12 minutes of the race and 4 minutes of recovery.

(a) On your graph, label and include:

(i) any periods of rest **1 mark**

(ii) any periods of oxygen deficit **1 mark**

(iii) any periods of steady state **1 mark**

(iv) any periods of EPOC. **1 mark**

(b) Explain why the heart rate plateaued at the three-minute mark. **2 marks**

6.6 Acute responses of the muscular system

KEY CONCEPT When we engage in exercise, acute responses also occur in the muscles themselves as the body responds to the increased energy demands imposed by the activity undertaken.

Acute muscular system responses to exercise are those that occur in the working muscles themselves. These responses vary according to the type, intensity and duration of the exercise performed, and may differ according to the type of muscle fibre recruited (fast-twitch as opposed to slow-twitch fibres). However, basically these responses include:

- increased motor unit and muscle fibre recruitment
- increased blood flow to the muscles
- increased arteriovenous oxygen difference
- increased muscle temperature
- increased muscle enzyme activity
- increased oxygen supply and use
- decreased muscle substrate levels (ATP, creatine phosphate, glycogen and triglycerides).

Increased motor unit and muscle fibre recruitment

When an individual engages in any physical activity there is a need for muscular contractions to take place. When exercise begins, an increase in motor unit recruitment must take place so that more muscle fibres are activated to contract. The greater the force or effort required, the greater the number of motor units recruited and the greater the number of muscle fibres activated.

Increased blood flow to the muscles

The extra demand of the muscles for oxygen during exercise leads to vasodilation of the capillaries and redistribution of blood flow from the internal organs to the working skeletal muscles.

Increased arteriovenous oxygen difference

During exercise, working muscles extract much more of the available oxygen from the blood, via myoglobin and mitochondria. As much as 75 per cent of the available oxygen is extracted and, as a result, the arteriovenous oxygen difference increases.

Increased muscle temperature

Increased blood flow to the muscles, coupled with the heat generated as a by-product of the increased production of ATP during exercise, results in an increase in muscle temperature.

Increased muscle enzyme activity

Enzyme activity increases during exercise to produce the increased amounts of ATP required by the muscles. Enzymes are involved in all of the chemical processes that produce energy via the three energy pathways.

Increased oxygen supply and use

The muscle cells extract and use more oxygen from the blood during exercise because of the increased demand for ATP. This greater extraction and use of oxygen by the exercising muscle contributes to the increase in the arteriovenous oxygen difference that has been previously referred to.

Decreased muscle substrate levels

Muscular stores of ATP, creatine phosphate, glycogen and triglycerides begin to deplete during exercise because they are sources of fuel for the production of ATP. The depletion of these energy stores, particularly creatine phosphate and glycogen, contributes to the fatigue experienced during exercise and physical activity.

FIGURE 6.14 During high-intensity exercise, muscular stores of ATP and creatine phosphate deplete as they provide energy for the production of ATP.

studyon

Unit 3 | AOS 2 | Topic 2 | Concept 4

Muscular system
Summary screen and practice questions

TEST your understanding

1 Draw a simple diagram (using appropriate icons to represent each muscular system change) that summarises the major acute muscular system responses to exercise.

2 Using your knowledge of different types of muscle fibre, explain how each of the muscle fibre types might respond to different types of exercise (anaerobic and aerobic).

EXAM practice

3 State one acute muscular response that will occur during a 100-metre sprint and assist with performance. Explain how the stated acute response assists with performance. **2 marks**

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

STRATEGIES TO DECODE THE QUESTION

- **Identify the action word: Describe** — provide a detailed account of
- **Key terminology:** changes in oxygen demand from rest to submaximal exercise and relationship between oxygen uptake and exercise intensity
- **Key concepts:** oxygen demand and supply at various exercise intensities — understanding how oxygen demand and supply changes from rest (supply = demand) to submaximal intensity (oxygen supply > oxygen demand)
- **Marking scheme:** *4 marks* — always check marking scheme for the depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

- **1 mark:** describing that energy demand equals energy supply at rest as the oxygen uptake meets all energy requirements
- **1 mark:** describing that this is a linear relationship between oxygen uptake and exercise intensity
- **1 mark:** describing that as exercise intensity increases, there is a period where oxygen demand is greater than supply (oxygen deficit)
- **1 mark:** describing oxygen demand and supply at submaximal intensity and reaching steady state

KEY SKILLS

- Explain the changes in oxygen demand and supply at rest, during submaximal and maximal activity
- Participate in physical activities to collect and analyse data on the range of acute effects that physical activity has on cardiovascular, respiratory and muscular systems of the body

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- At rest, oxygen uptake is low as the body's need for ATP is relatively small
- As the body shifts from rest to exercise, the demand for ATP increases
- At the onset of exercise, the respiratory and cardiovascular systems are unable to immediately meet the oxygen demand of the task
- Because of this lag time, oxygen demand by the working muscles is greater than the oxygen supplied so the body incurs oxygen deficit
- Oxygen deficit occurs as soon an exercise commences
- Oxygen deficit is calculated as the difference between the oxygen required for a given rate of work and the oxygen actually supplied
- During oxygen deficit, ATP will be resynthesised using the anaerobic pathways
- During submaximal exercise intensities, steady state occurs where oxygen supply equals oxygen demand
- When exercise intensity is increased, oxygen demand will be greater than supply as the working muscles produce additional ATP through the anaerobic pathways creating a larger oxygen deficit
- After the cessation of exercise, oxygen uptake or consumption does not immediately return to resting levels. Oxygen consumption remains temporarily elevated (EPOC)
- The range of acute responses (cardiovascular, respiratory and muscular) that occur due to various exercise intensities

PRACTICE QUESTION

1 **Describe** the changes in oxygen demand and supply from rest to submaximal exercise and the relationship between oxygen uptake and exercise intensity. *(4 marks)*

SAMPLE RESPONSE

At rest, energy demand equals energy supply as the body's oxygen uptake meets all energy requirements.

When exercise begins, oxygen uptake increases as the working muscles use more of the oxygen made available by the combined efforts of the circulatory and respiratory systems. There is a linear relationship between oxygen uptake and exercise intensity.

However, from rest to exercise there is a period of time when there is a discrepancy between the amount of oxygen required for a given exercise intensity and the amount actually supplied and used. This is referred to oxygen deficit where there is a shortfall between supply and demand.

For submaximal intensities, it may take only a few seconds for oxygen supply or uptake to meet the demands of the exercise and reach steady state.

CHAPTER REVIEW ACUTE PHYSIOLOGICAL RESPONSES TO EXERCISE

CHAPTER SUMMARY

Table 6.5 summarises the acute cardiovascular, respiratory and muscular system responses to exercise that have been discussed in this chapter.

TABLE 6.5 Summary of acute responses to exercise

Body system	Acute response	Nature of response
Cardiovascular system	Increased heart rate	Increases linearly with increasing exercise intensity up to approximate maximum that is calculated by subtracting the individual's age (years) from 220
	Increased stroke volume	Maximal value reached during submaximal exercise
	Increased cardiac output	Increases from 5–6 L/min at rest to 20–25 L/min or more during maximal exercise
	Increased blood pressure	Increased systolic pressure
	Redistributed blood flow to working muscles	At rest 15–20 per cent of total blood flow directed to working muscles; during exercise 80–90 per cent of total blood flow directed to working muscles
	Increased arteriovenous oxygen difference	Increases can be almost threefold over the value at rest
Respiratory system	Increased respiratory frequency (breathing rate)	Increases from 12 breaths per minute to as many as 35–40 per minute
	Increased tidal volume	Increases from around 0.5 litres per breath at rest to as high as 5 litres per breath at maximal workloads
	Increased ventilation	Increases from around 5–6 L/min at rest to beyond 108 and 130 L/min during exercise (for males and females respectively)
	Increased oxygen uptake	Increases from 0.3–0.4 L/min at rest to maximal values of 2.0–3.5 L/min during exercise
	Increased pulmonary diffusion	Increases by up to three times the resting rate
Muscular system	Increased motor unit and muscle fibre recruitment	More motor units recruited and muscle fibres activated
	Increased blood flow in the muscles	Increases from 15–20 per cent of total blood flow at rest up to 80–90 per cent during exercise
	Increased muscle temperature	As a result of increased blood flow and ATP production
	Increased muscle enzyme activity	In order to produce the increased amounts of ATP required by the muscles during exercise
	Increased oxygen extraction and utilisation	Muscle cells extract and use more oxygen during exercise
	Decreased muscle substrate levels	ATP, creatine phosphate, glycogen and triglycerides deplete

eBook*plus*

Interactivity
Understanding acute response terms
Searchlight ID: int-6801

eBook*plus*

Interactivity
Acute responses to exercise
Searchlight ID: int-6802

eBook*plus*

Interactivity
Acute physiological responses to exercise quiz
Searchlight ID: int-6803

studyon

Sit VCAA exam

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 State the major body systems that respond immediately to the transition from rest to exercise.
(A) Cardiovascular, skeletal and muscular
(B) Respiratory, skeletal and muscular
(C) Cardiovascular, respiratory and muscular
(D) Cardiovascular, digestive and nervous

2 State which two factors, when multiplied, result in cardiac output.
(A) Heart rate and stroke volume
(B) Blood volume and heart rate
(C) Tidal volume and heart rate
(D) Stroke volume and blood volume

3 Cardiac output at rest and during maximal exercise would be approximately
(A) 1 to 2 L/min and 4 to 5 L/min respectively.
(B) 1 to 2 L/min and 40 to 45 L/min respectively.
(C) 11 to 12 L/min and 24 to 35 L/min respectively.
(D) 5 to 6 L/min and 20 to 25 L/min respectively.

4 Which two factors, when multiplied, result in ventilation?
(A) Tidal volume and maximal oxygen uptake
(B) Respiratory frequency and total lung capacity
(C) Respiratory frequency and tidal volume
(D) Residual volume and respiratory volume

5 The relationship between exercise intensity and oxygen uptake is
(A) exponential until maximal uptake is obtained.
(B) linear until maximal uptake is obtained.
(C) non-linear.
(D) non-linear until maximal uptake is obtained.

6 From rest to submaximal exercise, the arteriovenous difference
(A) increases.
(B) remains the same.
(C) decreases.
(D) is close to zero.

7 At the start of exercise, the body's oxygen transport systems do not immediately supply the required quantity of oxygen to the active muscles. This is known as
(A) steady state.
(B) oxygen debt.
(C) oxygen deficit.
(D) EPOC.

8 During exercise, capillaries and arterioles
(A) vasoconstrict to increase oxygen to the working muscles.
(B) vasodilate to decrease oxygen to the non-essential organs.
(C) remain the same to increase oxygen to the non-essential organs.
(D) vasodilate to increase oxygen to the working muscles.

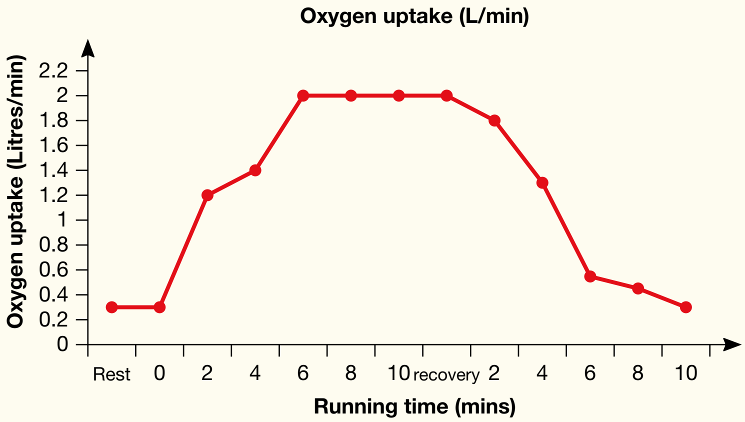
9 An elite female alpine skier would have a VO_2 max. of approximately
(A) 65 to 70 mL/kg/min.
(B) 50 to 55 mL/kg/min.
(C) 50 to 55 L/min.
(D) 50 to 55 mL/min.

10 An acute muscular response during high intensity exercise could be
(A) decreased stores of ATP and creatine phosphate.
(B) increased tidal volume.
(C) increased cardiac output.
(D) decreased muscle enzyme activity.

TRIAL EXAM QUESTIONS

Question 1 **(ACHPER Trial Exam 2009, question 8a, b, c, f, g)**

The graph shows the oxygen uptake of a male athlete running on a treadmill for 12 minutes at 22 degrees C.



a. Explain why the athlete's oxygen uptake has increased at the 2 and 4 minute marks of exercise. **1 mark**

b. State what would happen to the athlete's heart rate and stroke volume at the 2 and 4 minute marks of the exercise bout.

Heart rate: ____________________

Stroke volume: ____________________

2 marks

c. Does the athlete achieve steady state during their run? Use data from the graph to justify your answer. **2 marks**

d. On the graph, shade in the area of excess post-exercise oxygen consumption (EPOC). **1 mark**

e. Outline **three** reasons why EPOC occurs.

Reason 1: ____________________

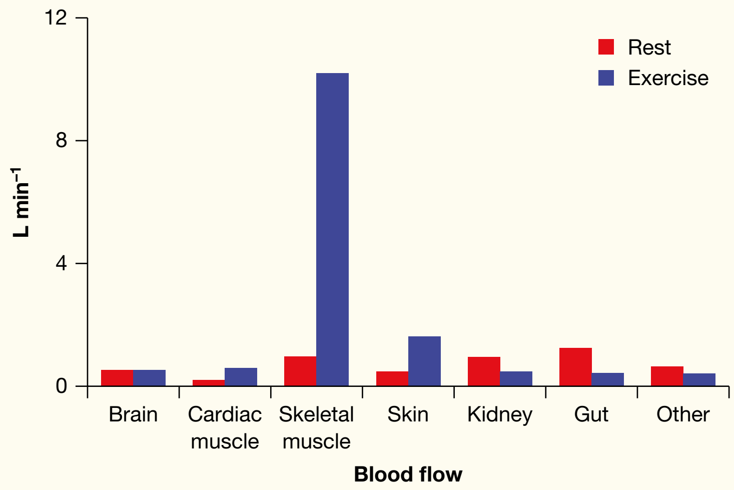
Reason 2: ____________________

Reason 3: ____________________

3 marks

Question 2 **(ACHPER Trial Exam 2009, question 12a, b, c)**

The graph below indicates blood flow to various organs of the body at rest and during exercise.



a. Approximately how much blood is redistributed to the skeletal muscles during exercise? **1 mark**

b. Other than skeletal muscle, indicate **two** areas in which blood flow increases during exercise and outline the reason for this redistribution in blood flow for each area.

Area 1: ____________________

Reason: ____________________

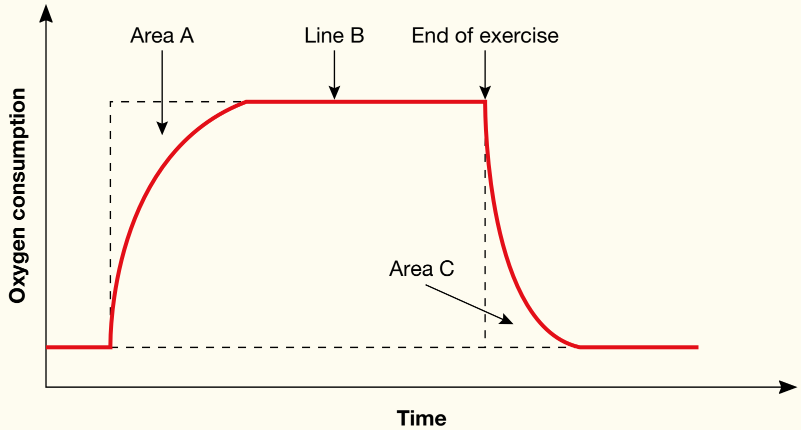
Area 2: ____________________

Reason: ____________________

2 + 2 marks

c. Explain the physiological response that allows the increase in blood flow to skeletal muscle during exercise. **2 marks**

Question 3 **(ACHPER Trial Exam 2010, question 4)**



a. What do the following areas of the graph represent?

Area A: ____________________

Line B: ____________________

Area C: ____________________

3 marks

b. Why does Area A occur at the beginning of exercise? **1 mark**

c. Describe the circumstances that allow Line B to occur. **2 marks**

d. Name one strategy that an athlete can undertake in order to reduce the size of Area A. **1 mark**

e. Explain why the strategy listed in **part d** above can reduce the size of Area A. **2 marks**

Unit 4

Training to improve performance

OUTCOME 1

Analyse data from an activity analysis and fitness tests to determine and assess the fitness components and energy system requirements of the activity

OUTCOME 2

Participate in a variety of training methods, and design and evaluate training programs to enhance specific fitness components

INQUIRY QUESTION
What is the most important step in developing a successful training program? Why is this step so important?

CHAPTER

7 Activity analysis

The more information you know about the requirements of the activity you are training for, the more specific and therefore effective your training can be.

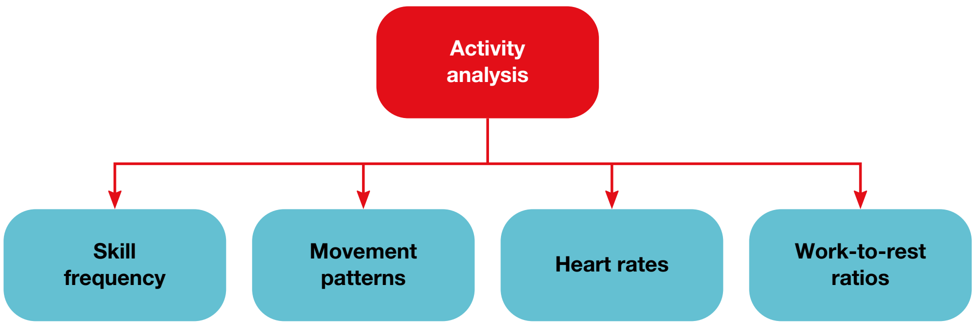
KEY KNOWLEDGE

- Activity analysis, including skill frequencies, movement patterns, heart rates and work-to-rest ratios

KEY SKILLS

- Analyse data to determine the major fitness components and the factors that affect them, and energy systems used in a variety of sporting events and physical activities

CHAPTER PREVIEW



7.1 What is activity analysis?

KEY CONCEPT Activity analysis is a vital component of creating a training program. It should be the very first step of all training programs.

Activity analysis is the recording and analysis of movement and skill data from a game, sport or activity.

Activity analysis enables coaches and performers to make the important link between training and the actual performance of an activity. It involves recording and illustrating the physical demands on the performer in the competitive setting. Elite athletes are often the ideal subjects for activity analysis as they will exhibit the movements and skills that are most likely to lead to optimal performance. These physical demands can then be translated to the training situation. The key to successful activity analysis centres on the training principle of specificity (see chapter 11); that is, quality activity analysis helps coaches and performers gain specific knowledge that can be used to design tailored training programs.

This knowledge can include:

- skill requirements
- work-to-rest patterns and ratios
- distances travelled at various speeds
- movement patterns, type and direction
- energy system requirements
- the intensity of movement and the actions performed
- muscle groups and muscle action
- team strategies
- opponents' strengths and weaknesses
- biomechanical techniques.

FIGURE 7.1 Coaches working with elite athletes gain specific knowledge and then design training programs that will enhance the athlete's performance.

Team sports and individual sports of an intermittent nature are most suited to activity analysis. For example:

- netball
- volleyball
- hockey
- squash
- water polo
- golf
- archery
- surfing.

Analysis of continuous activities such as middle-distance and long-distance running, road cycling, rowing and swimming is more limited to the measurement of heart rates and intensities.

It is important that where possible the highest level of performance is observed; for example, elite. This allows for greater accuracy in data collection as it should provide information about how to achieve optimal performance.

FIGURE 7.2 Netball and surfing are intermittent sports where activity analysis, such as skill frequency tables, can provide much insight into the physiological requirements of the sports.

Data collection

Data collection is the process of gathering information. This is the first step of activity analysis. Once the data is collected, it can be analysed.

The most common way to gather data is through observation. Observation is a practical method of data collection but has low accuracy. Digital recording can be less practical but has higher accuracy.

Data collection is the process of gathering information.

Simple direct observation

The coach or interested party views the player or team from the sideline. All gathered information is subjective and may include:

- how the athlete moves around the playing area
- where they move to
- the intensity of their sprint or playing
- the frequency of particular skill movements, such as backhand tennis shots
- the muscle groups that need strengthening
- the team plays that are in use.

There are no supportive data for observed information, as this information is simply one person's or a group's point of view.

studyon

Unit 4 | AOS 1 | Topic 1 | Concept 1

Activity analysis and data collection
Summary screen and practice questions

eBook*plus*

Weblinks
AFL recording methods

Digital recording

Statistical data can be recorded live and analysed immediately, or gathered and analysed after the event. The use of video is the preferred method to record data, because the coach and athlete can replay, slow down and freeze-frame the images. This method of activity analysis is commonly used in all top sporting teams.

Many elite teams now have access to programs that allow for immediate analysis of digital recording, reducing the burden of data collection and making the collection and analysis of data incredibly efficient.

TEST your understanding

1 Define the term *activity analysis.*
2 Identify methods of activity analysis that are best used for team sports.
3 Identify methods of activity analysis that are best suited to individual sports.
4 Outline the difference between data collection and activity analysis.

APPLY your understanding

5 Consider the **AFL recording methods** weblinks found in your eBookPLUS.
(a) Make a list of the types of recording methods that are used in AFL.
(b) What information is gained by these methods?
(c) How is the information gained used by coaching staff and players?
(d) What are the advantages and some limitations of activity analysis?

EXAM practice

6 Explain why activity analysis is the first and most important step in developing any training program. **2 marks**

7.2 Methods of activity analysis: skill frequency

KEY CONCEPT Skill frequencies provide insight into the predominant fitness components and muscles and muscle groups used in a sport. This can help ensure specific tests and training activities are included in a training program.

Skill frequency tables can be easily completed using direct observation but can also be collated using different technologies. Skill frequency tables are generally referred to as 'stats'. Tables outline the frequency, and in many cases the effectiveness, of skill execution.

The following skill frequency tables were taken over a 5-minute period during a Year 12 practical class.

TABLE 7.1 Skill frequency tables record the number of times common skills are executed during a set time frame.

Volleyball

Skill	Frequency
Block	3
Serve	6
Spike	3
Dig	4
Set	7

Netball — Centre

Skill	Frequency
Pass	18
Catch	12
Dodge	9
Sprint	11
Defend	6
Jump	4
Rebound	0
Running backwards	3

AFL

Skill	Frequency
Kick	6
Mark	3
Handball	4
Baulk	4
Sprint	7
Tackle	3

Football/soccer

Skill	Frequency
Kick	12
Dribble	8
Sprint	4
Tackle	2

Badminton

Skill	Frequency
Overhead	9
Serve	6
Forehand	5
Backhand	4
Lunge	13

Tennis

Skill	Frequency
Overhead	3
Serve	6
Forehand	13
Backhand	8
Lunge	5

eBook*plus*

Digital document
Activity analysis
Searchlight ID: doc-22226

Skill frequency tables give an indication of the predominant fitness components and muscles/muscle groups; for example, a skill frequency table that shows a high percentage of leaps or jumps would suggest the fitness component of muscular power.

To enable training programs to be specific, the analysis also needs to identify the muscle groups and movements used in performing each skill. For example, if the skill frequency table shows a high percentage of leaps or jumps, the major muscle groups would be the hamstrings, quadriceps and gluteals.

Muscle-use analysis is often neglected. It must be done in isolation from data gathering because it relies on subjective observation. In muscle-use analysis, the player is observed and notes are made about:

- the major muscles or muscle groups most used
- which main muscle groups are used early in the match, and whether they are different from those used later in the match
- whether the muscle contraction is powerful and fast, or slow and repeated
- whether muscle strength or muscle endurance is most important
- what range of motion and flexibility is exhibited.

This can then help enhance the specificity of training.

For example:

1. The skill frequency table (data collection) shows a number of chest passes for a basketballer.
2. Analysis identifies the biceps and triceps are used in an explosive manner.
3. Resistance training could be used, targeting the bicep power.
4. This could include bicep curls with a low–medium weight, fast speed and a work-to-rest ratio of 1:5.

study on

Unit 4	**Skill frequencies**
AOS 1	Summary screen and practice questions
Topic 1	
Concept 2	

TEST your understanding

1 List five skills that you would include in a skill frequency table for each of the following sports.
(a) Hockey
(b) Basketball
(c) Rugby

2 For each of the following skills, outline what major muscles/muscle groups are involved.
(a) Vertical jump
(b) Change of direction
(c) Shoulder pass
(d) Kick

APPLY your understanding

3 Learning activity: skill frequency table
Develop a skill frequency table for a sport or activity of your choice, preferably using the highest level athlete possible. Use this table to record data for an individual athlete. You may undertake the analysis at school or outside school on the weekend, and you may record the data while watching the game or make a digital recording of the game. If making a digital recording, keep the focus athlete in view at all times.

Using the results of your skill frequency table, answer the following questions.
(a) What were the most important fitness components for the athlete in this sport? Use data to support your choice.
(b) What role do each of the energy systems play for the athlete in this sport? Use data to support your choice.
(c) How should the information gathered affect the training program for this athlete?

EXAM practice

4 The following skill frequency table was taken from a Year 12 student during a 15-minute basketball game.

Skill frequency table

Movement	Frequency
Changing direction	90
Rebounds	8
Shooting	7
Passing	31
Defending with arms up	22

(a) Suggest an advantage of using elite athletes compared to Year 12 students for activity analysis. **1 mark**
(b) List the fitness components associated with each movement recorded in the table above. **2 marks**
(c) Based on the data, suggest the most important fitness component for basketball. **1 mark**

7.3 Methods of activity analysis: movement patterns

KEY CONCEPT Movement patterns, most commonly recorded through the use of GPS technology, provide highly accurate information that can help determine the predominant energy systems and fitness components required in a sport or activity.

Movement patterns reveal typical activities completed by a performer during a game or an activity. They enable the coach or athlete to determine the fitness components and energy systems that are used, and they provide (along with work-to-rest ratios and skill analysis) specific information required to develop training programs relevant to the athlete or team.

Movement patterns can be very important in helping determine the distance of efforts. Knowing the distance of sprints can determine which fitness component (aerobic power, speed or anaerobic capacity) and which energy system are predominant. Shorter sprints with recovery suggest ATP–CP system, whereas longer lower-intensity efforts suggest aerobic power.

Equipment needed to record movement patterns of a player in a competitive setting includes:

- a diagram of the playing area, either on a piece of paper or a computer screen
- a stopwatch or other device for recording time (the period of time for the movement is recorded and extrapolated to the full game or performance time period)
- a method of recording player movement; this can be a manual recording method or an electronic method (e.g. GPS tracking device)
- a list of skills to be recorded (and a code for each) that are pertinent to the activity (see table 7.3 for an example).

Movement patterns are the typical movements completed by a performer during a game or an activity.

studyon

Unit 4 | AOS 1 | Topic 1 | Concept 3

Movement patterns Summary screen and practice questions

TABLE 7.2 Example codes for various sports movements

Movement	Code	Movement	Code
Sprinting	— — —	Cruising	= = = = =
Mark	M	Tackle	T
Shepherd	S	Guarding	G
Backward movement	B	Sideway movement	SI
Running	…………	Walking	~~~~~~
Kick	K	Punch	P
Jumping	J	Shuffling	SH
Rebound	R	Jump shot	JS

eBook*plus*

Interactivity
Movement analysis
Searchlight ID: int-6805

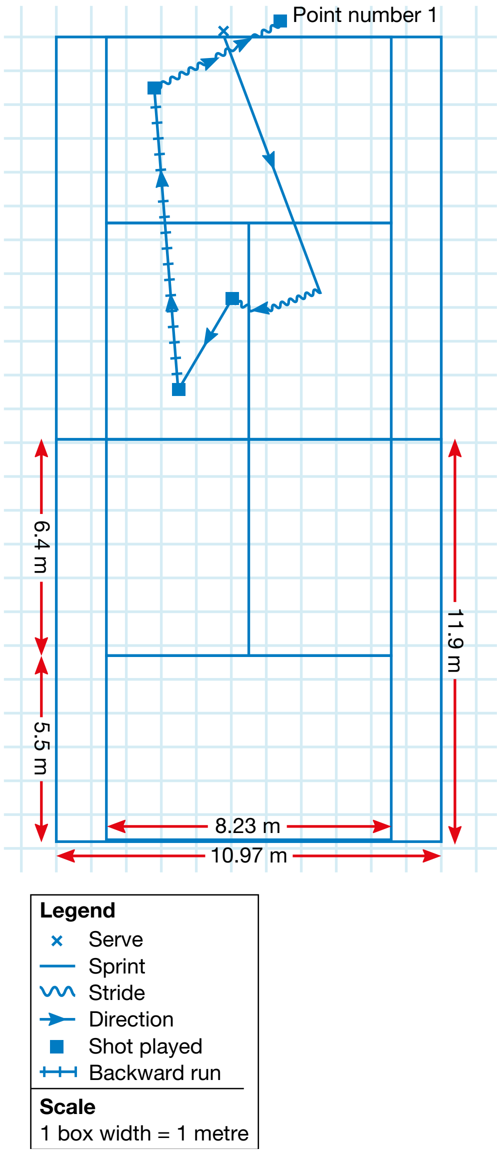


FIGURE 7.3 A typical movement pattern recorded for a tennis player at the elite level

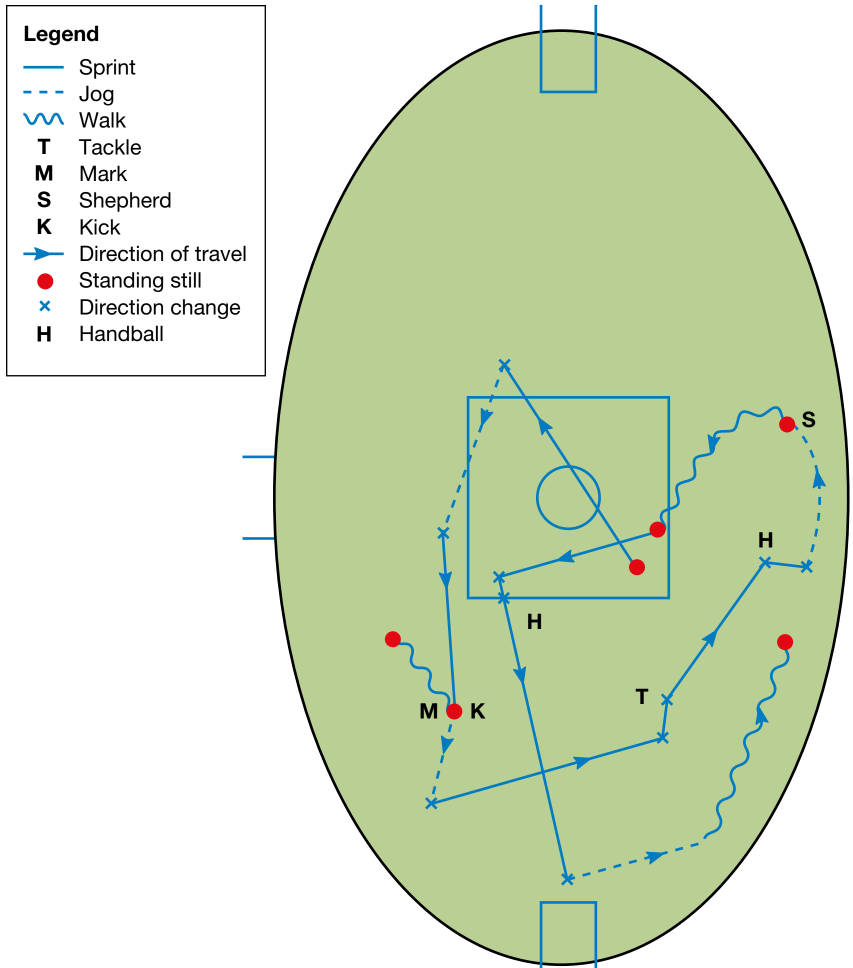


FIGURE 7.4 A typical movement pattern recorded for an 'on ball' player during 2 minutes in an AFL game

GPS Global Positioning System. A sensor is worn that uses satellites to identify position and movement. This can provide an indication of speed and distance covered.

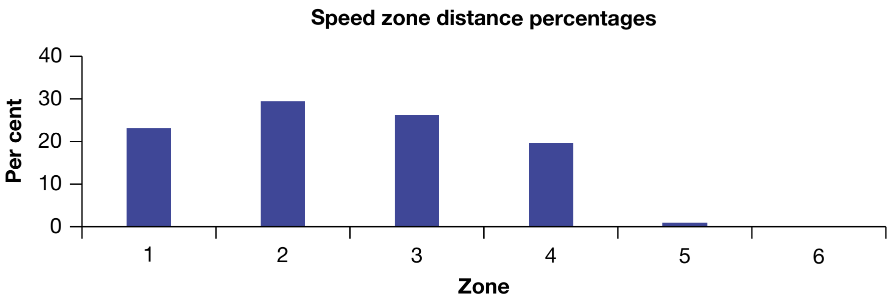
GPS tracking

GPS tracking devices are used for activity analysis at elite levels. Individual players wear these sophisticated devices, which record data indicating various movement patterns and efforts throughout the playing period.

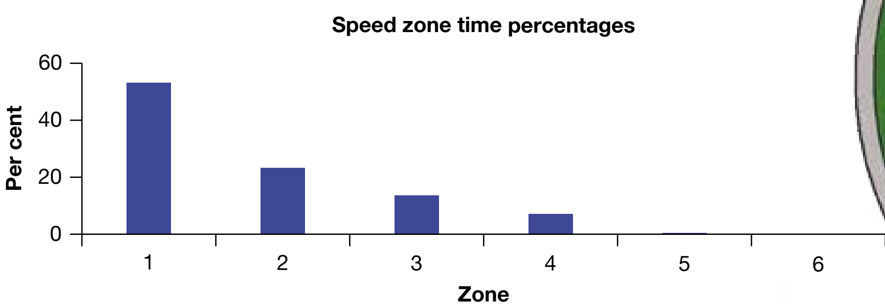
GPS trackers are a far easier and more efficient way of collecting movement patterns. They can allow multiple athletes to be recorded at the same time and data is easily stored and converted into information that can be analysed. GPS trackers can be expensive, especially for large groups. They are generally also limited to outside activity. However, as technological advances continue, GPS trackers are becoming more accessible and more accurate, even indoors.

Many activity trackers also include total distances covered in efforts. While this information can be helpful in determining predominant energy systems, GPS with movement patterns is required to determine predominant fitness components. See chapter 11 for more information.

Distance within speed zone					
Zone	**Lower**	**Upper**	**Distance (m)**	**Percentage**	**Entries**
1	0	6	932.9	23.2	108
2	6	12	1184.8	29.5	177
3	12	16	1062.8	26.5	109
4	16	25	795.4	19.8	40
5	25	30	36.9	0.9	2
6	30	35	0	0	0



Time within speed zone						
Zone	**Lower**	**Upper**	**Minutes**	**Percentage**	**Exertion**	**Entries**
1	0	6	17.6	53.9	1055	108
2	6	12	7.92	24.2	950	177
3	12	16	4.58	14	824	109
4	16	25	2.48	7.6	595	40
5	25	30	0.08	0.3	25	2
6	30	35	0	0	0	0



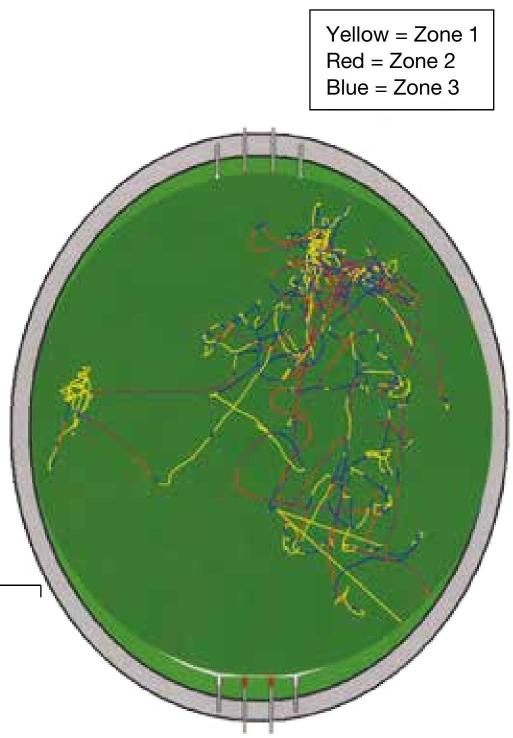


FIGURE 7.5 Collected AFL activity data from one game's quarter in 2009

Source: GPSports.

TEST your understanding

1. How are movement patterns useful in activity analysis?
2. List the equipment needed to record movement patterns.
3. Outline the information gathered from movement patterns.
4. What does GPS stand for?
5. How does movement analysis add to skill analysis to provide a more comprehensive activity analysis?

APPLY your understanding

TABLE 7.3 GPS data of a netball game

	Game time	Game time %	Distance	m/min	HIPL/min	PL/min	Low dist. (%) >8 km/h	Mod. dist. (%) >13 km/h	High dist. (%) >18 km/h	TE (no.) >26.5 km/h	TE dist. (m)	Max. speed (km/h)
Player A	47.8	75%	2612	46.5	0.4	7.0	75%	22%	0%	0	0	18.8
Player B	55.1	89%	4018	72.9	0.0	8.8	60%	37%	0%	0	0	19.9
Player C	62.8	100%	3160	50.9	0.1	6.8	68%	29%	0%	0	0	16.6
Player D	62.8	100%	3178	50.8	0.1	7.6	70%	28%	0%	0	0	17.9
Team avg	**57**	**91%**	**3242**	**55**	**0.2**	**7.6**	**68%**	**29%**	**0%**	**0**	**0**	**18.3**

RED numbers are 1 standard deviation **BELOW** the average for that measure.
BLUE numbers are 1 standard deviation **ABOVE** the average for that measure.
Metres/min (m/min) describes locomotor load. A measure of the metres covered per minute.
High intensity player load instances/min (HIPL/min) describes player physicality. A measure of the number of rapid movements/high impact incidents (jumping, bodying, tackling) a player is involved in per minute.
Player load/min (PL/min) is a summation of movement in all three planes per minute. Correlates highly to total distance as it includes the forces associated with foot strike during running.

6 The information in table 7.2 was gathered from four netballers. The positions played were Goal Keeper, Wing Defence, Goal Attack and Centre.
(a) Based on the data collected, suggest which player played Centre.
(b) Based on the data, suggest which player is most likely to need to include the following in their training program:
- longer runs
- speed work
- high impact activities.

(c) Using players A and B, discuss how this information could be used to individualise training.

eBook*plus*
Weblink
AIS netball tracking technology

EXAM PRACTICE

7 Using the data in table 7.4, answer the following questions.
(a) Identify and justify what method of activity analysis has been used. **2 marks**
(b) Outline one example of physiological information that can be gained from this type of data. **1 mark**
(c) Describe how the information could be used by a coach to plan training. **3 marks**

TABLE 7.4 GPS data of VFL game, North Ballarat Roosters Football Club

Player	Time	Game time %	Odometer	Meterage/min	Low % <8 km/h	Moderate % <13 km/h	High % <18 km/h	Max. velocity (km/h)
A	101.8	83%	12991	128.7	32%	55%	13%	28.2
B	93.9	77%	13734	146.2	29%	58%	13%	25.9
C	73.8	61%	10171	137.4	22%	62%	15%	25.2
D	95.8	78%	11331	118.2	40%	46%	13%	29.0
E	96.9	79%	12122	125.6	26%	57%	16%	26.2
F	114.3	93%	12251	107.5	34%	54%	12%	28.9
G	103.2	85%	13307	129.3	34%	50%	16%	27.9
H	114.3	93%	13155	114.9	46%	44%	8%	27.6
I	84.5	69%	10518	124.5	28%	57%	14%	27.6
J	91.2	74%	12180	133.2	34%	45%	21%	27.6
K	110.6	91%	14071	127.4	38%	48%	13%	27.2
L	88.4	72%	12705	143.7	26%	57%	17%	29.1
M	101.2	83%	13278	131.3	32%	52%	15%	30.2
N	100.9	83%	13215	131.5	33%	56%	11%	29.3
O	102.6	84%	12571	123.0	37%	48%	14%	28.2
P	100.4	82%	12070	121.7	21%	62%	17%	27.8

7.4 Methods of activity analysis: heart rates

KEY CONCEPT Heart rate has long been associated with measuring efforts in physical activity. Heart rate monitors provide important information about the intensity at which an athlete is working.

A heart rate telemeter is a device (usually a watch) that provides data on a participant's heart-rate response to physical activity. Heart rate is usually measured in bpm (beats per minute). Heart rate is typically used to estimate physical activity as energy expenditure (oxygen uptake), based on the assumption of a linear association between heart rate and energy expenditure. Heart rate monitors therefore provide important information about the role of the energy systems; for example, intensity over 85 per cent maximum heart rate would suggest the predominance of the anaerobic systems. Heart rate monitors involve reasonably low participant burden, especially now many monitors do not even require a chest strap, and can be used for most activities.

FIGURE 7.6 There is a huge range of fitness tracking devices and heart rate monitors on the market at present, a response to demand from consumers who are conscious about their health and fitness.

One major disadvantage of heart-rate monitoring is the need to calibrate the device to each individual. Another limitation is that during low-intensity exercise, the relationship between exercise intensity and heart rate is frequently not linear. At a low level of intensity, factors that affect heart rate such as stress, fear, excitement and changes in body temperature need to be considered as they may cause a false reading.

studyon

Unit 4 | AOS 1 | Topic 1 | Concept 4

Heart rates
Summary screen and practice questions

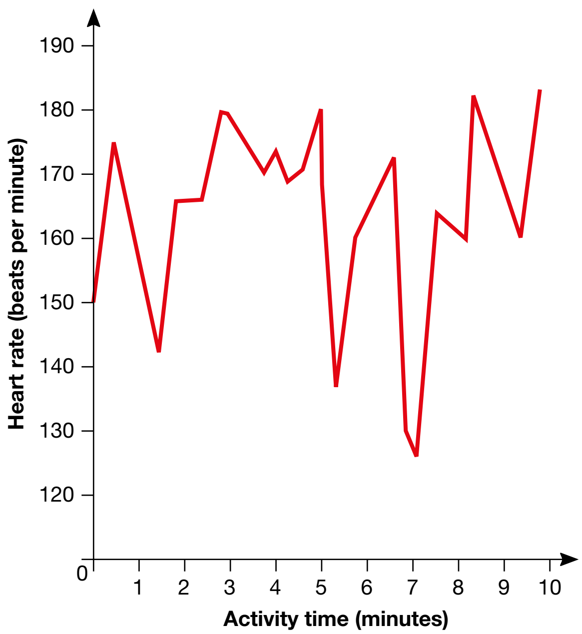
TEST your understanding

1 Describe the information that can be gathered from a heart rate monitor.
2 Provide two limitations of using heart rate monitors.
3 Suggest two activities to which heart rate monitoring would be best suited.

APPLY your understanding

4 Learning activity: tennis analysis

(a) What information does the following graph show about the game of tennis?
(b) What conclusions can be made about tennis based on the heart rate?
(c) What is most likely to have occurred between 6 minutes 30 seconds and 7 minutes 30 seconds?



5 Practical activity: heart rate monitor analysis

Complete the following activities while wearing a heart rate monitor. The heart rate monitor should be worn for the whole class.

- 800 m jog
- Team game
- Body weight circuit, 1 minute work and 30 seconds rest
  - situps
  - jumping lunges
  - pushups
  - plank
  - squats
  - tricep dips

Compare your heart rate data for each of the activities.

(a) When was your heart rate highest? Why?
(b) When was your heart rate lowest? Why?
(c) Compare your heart rate data to that of other students in your class. How would a coach use this information?

EXAM practice

6 **ACHPER Trial Exam 2015, question 13c**

Sharon and Katherine decided that the Cooper 12-minute run test was a specific test to assess their aerobic capacity before undertaking their training program. They both completed the test to the best of their ability.

During the Cooper 12-minute run test, the students' heart rate data (measured in beats per minute) were collected and are presented in the table below.

Refer to the table below to answer questions 6(a) and (b).

	Heart rate: Sharon	**Heart rate: Katherine**
Resting heart rate	72	61
Immediately before run	96	98
At the conclusion of 1st minute	160	170
At the conclusion of 2nd minute	170	171
At the conclusion of 3rd minute	171	170
At the conclusion of 4th minute	170	171
At the conclusion of 5th minute	170	172
At the conclusion of 6th minute	171	171
At the conclusion of 7th minute	172	172
At the conclusion of 8th minute	172	172
At the conclusion of 9th minute	172	172
At the conclusion of 10th minute	172	171
At the conclusion of 11th minute	185	188
At the conclusion of 12th minute	200	198
1 minute following run	185	172
2 minutes following run	171	161
3 minutes following run	165	133

(a) Which energy pathways are likely to be used during the first minute of the test by both girls? Justify your selection. **2 marks**

(b) Discuss two limitations of using heart rate monitors as the only method of data collection. **2 marks**

(c) Identify and justify, using the data, if steady state was reached for Sharon. **2 marks**

7.5 Methods of activity analysis: work-to-rest ratios

KEY CONCEPT All sporting events include times when the performer is resting and times in which they are working. The ratios between each state and the relative exertion levels between each are essential parts of activity analysis.

Work-to-rest ratio is a summary of the time an athlete spends physically working compared to the time spent resting or recovering.

The **work-to-rest ratio** is used to assess, during competition, the time spent physically working compared to the time spent resting or recovering. Data about work and rest periods are vital in determining an athlete's energy systems and intensity of effort. Activity analysis calculates work-to-rest ratios (also known as work–rest ratios), which provide information that should underpin decisions about methods of training, work intervals and rest intervals.

To determine work-to-rest ratios, standing still, walking and slow jogging may be classified as rest, while all other movements are classified as work. To record work-to-rest ratios manually, record all work efforts on one stopwatch and all rest periods on another. Once the activity is complete, you have a work-to-rest ratio; for example, for 5 minutes' total work and 20 minutes' total rest, the ratio is 5:20 or 1:4. The intensity of the work efforts should also be noted because this information is important in determining energy system requirements. Ideally, you could use a heartrate monitor to determine the intensity of each effort or work period, expressing the recorded heart rate as a percentage of the athlete's maximum heart rate (MHR).

When analysing work and rest data, determine the following information:

- total work time and total rest time
- average work time per effort and average rest time
- longest work time and longest rest time
- the work-to-rest ratio.

TABLE 7.5 Work-to-rest ratios associated with each energy system

Work-to-rest ratio	Energy system
1:5 and above (rest significantly higher than work)	ATP–CP
1:3–1:4 (rest higher than work)	Anaerobic glycolysis
1:1–1:2 or 2:1 or above (work similar to rest OR work higher than rest)	Aerobic

Work-to-rest ratios can be very useful for intermittent sports such as team games.

It can, however, be very time consuming and difficult to collect and analyse the information. Many computer programs and apps are making this easier. While they only provide information about the role of the energy systems, this can be vital information to replicate during training to ensure specificity for all athletes.

TABLE 7.6 Work-to-rest ratio throughout a 2-minute time sample during a game of basketball

W	R	W	R	W	R	W	R
10	21	5	10	6	10	4	9

The above work-to-rest ratio (W:R) was manually calculated using observation and a stopwatch during a Year 12 PE class of basketball. The W:R above is equal to 25:50 which can be simplified to 1:2. This suggests that, for this passage of play for this player, the aerobic energy system was predominant.

TEST your understanding

1 Define the term *work-to-rest ratio*.
2 Outline two limitations of using the work-to-rest ratio.
3 Identify what energy system is associated with the following work-to-rest ratios:
1:4
1:6
3:1

APPLY your understanding

4 Observe (directly or digitally) a sport of your choice for three two-minute blocks.
(a) Record the work and rest times for each two-minute block.
(b) Calculate the W:R.
(c) Which energy system does this W:R suggest is predominant?
(d) Are the W:R and energy system the same for each two-minute block? Why or why not?

EXAM practice

5 A recent analysis of a game of grass-court tennis played between two competitors provided the following data:
- average rally time — 5.3 seconds
- average rest between rallies — 17.5 seconds
- length of the match in total — 3.5 hours
- length of time the ball was in play — 19 minutes, 20 seconds
- time spent changing ends and between games — 73 minutes.

(a) Explain why is it important to undertake an analysis before developing a fitness program for an athlete. **2 marks**
(b) Justify the role of each energy system in tennis using the data above. **3 marks**
(c) Calculate the work-to-rest ratio from this data set. **1 mark**

studyon
Unit 4
AOS 1
Topic 1
Concept 5
Work-to-rest ratios
Summary screen and practice questions

7.6 Netball case study

KEY CONCEPT Netball is a team sport that has seven very different positions. Each position has significantly different physiological requirements. Completing an activity analysis can help a coach ensure that each player, no matter what position they play, can achieve optimal results from training.

Data collection

The first step of activity analysis is data collection.

The following data was collected during an A-grade netball game from a 20-year-old playing Centre. GPS and heart rate were recorded using digital recording (stored in electronic devices). Movement patterns, work-to-rest ratios and skill frequency table were collected using direct observation.

GPS data

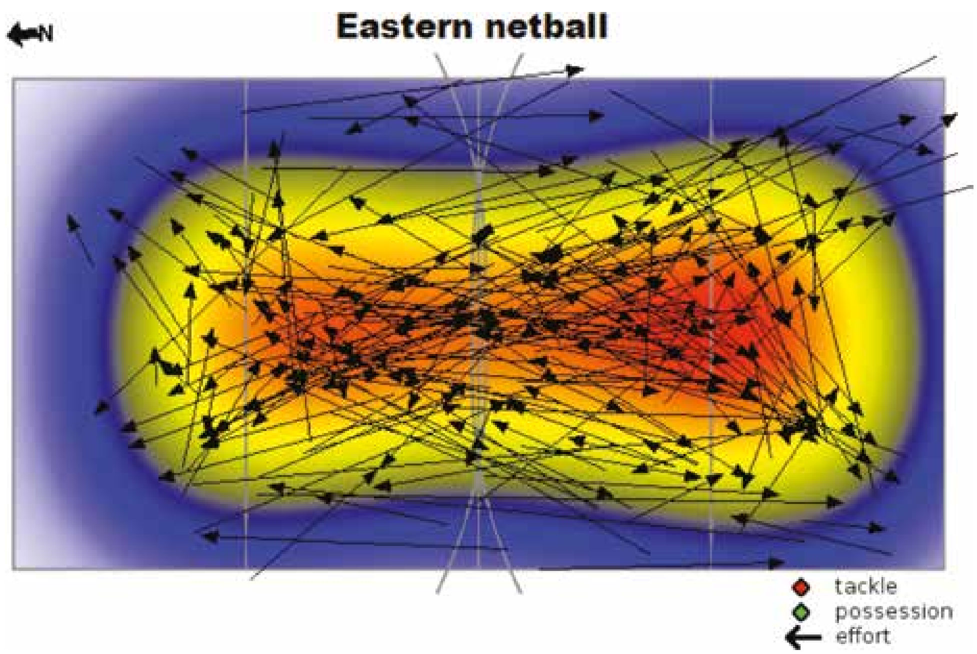


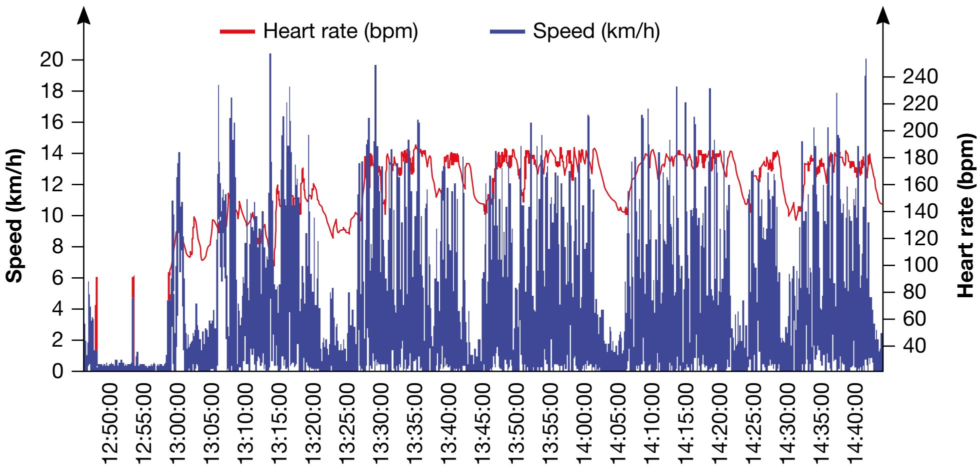
FIGURE 7.7 The movement patterns of the Centre during a game of netball.

TABLE 7.7 GPS data for netball Centre

	Game time	Game time %	Distance	m/min	HIPL/ min	PL/min	Low dist. (%) >8 km/h	Mod. dist. (%) >13 km/h	High dist. (%) >18 km/h	TE (no.) >26.5 km/h	TE dist (m)	Max speed (km/h)
Centre	55.1	89%	4018	72.9	0.0	8.8	60%	37%	0%	0	0	19.9

Red numbers are 1 standard deviation **BELOW** the average for that measure.
Blue numbers are 1 standard deviation **ABOVE** the average for that measure.
Metres/min (m/min) describes locomotor load. A measure of the metres covered per minute.
High intensity player load instances/min (HIPL/min) describes player physicality. A measure of the number of rapid movements/high impact incidents (jumping, bodying, tackling) a player is involved in per minute.
Player load/min (PL/min) is a summation of movement in all three planes per minute. Correlates highly to total distance as it includes the forces associated with foot strike during running.

Heart rate with GPS



Work-to-rest ratio

Taken from second quarter.

- Work: anything above walking pace.
- Rest: walking and standing still.

TABLE 7.8 Work-to-rest ratio for netball Centre

	Mean work period (seconds)	Mean rest period (seconds)	Mean work–rest ratio	Max. work duration (seconds)	Max. rest duration (seconds)	Max. work-to-rest ratio
Centre	2	4	1:2	9	69	1:8

Skill frequency table

Taken from the first quarter (15 minutes).

TABLE 7.9

Skill	Frequency
Pass	45
Catch	34
Dodge	23
Sprint	28
Defend	10
Jump	14
Walk	24
Run backwards	17

Data analysis

After the data has been collected, it needs to be analysed. The more data you can collect, the more accurate your analysis is likely to be.

- Total distance covered (4018 m) suggests aerobic power and aerobic energy system are important.
- Max speed was 19.9 km/h, which suggests speed is important.

- GPS movement patterns show that the total distance is made up of many shorter and repeated efforts, suggesting anaerobic capacity is important.
- Much of the game time is spent in the aerobic training zone (70–85 per cent MHR), suggesting aerobic power is important.
- LIP is important as the athlete works a significant amount of time around 85 per cent MHR.
- Speed varies greatly and suggests repeated high-intensity efforts with little recovery, therefore anaerobic capacity is important.
- The duration of the match suggests aerobic power is important.
- Mean W:R suggests aerobic energy system is important.
- The high number of passes in the skill frequency table suggests upper body muscular power is important.
- The high number of catches in the skill frequency table suggests hand–eye coordination is important.
- The high number of dodges in the skill frequency table suggests agility is important.
- The high number of sprints in the skill frequency table suggests speed is important.

Planning a training program

Once the analysis is completed, the information can be used to help plan a specific training program. It is important to note that the above process should be completed for all positions in a sport. While there may be similarities within sports, different positions often require different fitness components, energy systems and muscle movements.

Based on the data provided, the following should be considered when planning a program for a netball Centre.

Fitness components

Based on the data analysis, the important fitness components for a netball Centre are:

- aerobic power
- anaerobic capacity
- speed
- agility
- upper body power
- hand–eye coordination.

Energy systems

Based on the data analysis, the most important energy system for a netball Centre is the aerobic energy system. The ATP–CP system would assist in allowing the athlete to sprint and pass. Given that there is a lot of opportunity for recovery, the anaerobic glycolysis system is only likely to be predominant if the sprints and passes are repeated with insufficient recovery.

Muscles and muscle groups

- Upper body (deltoid, pectorals, bicep, tricep, flexors and extensors)
- Lower body (quadriceps, hamstrings, gastrocnemius, soleus, gluteals)
- Core muscles to allow efficiency in running and changing direction (abdominals, obliques)

Fitness testing (see chapter 9 for more details)

The following tests would be best used as they replicate the requirements (muscles and movements) of netball.

- Aerobic power: a test that mimics the change of intensity, stop and start nature, e.g. yo-yo test

- Anaerobic capacity: a test that has repeated sprint efforts, e.g. phosphate recovery test
- Speed: a test that is not longer than 20 m, e.g. 20 m sprint
- Agility: tests that either involve 'weaving' or short sharp changes of direction, e.g. Illinois agility test or 5-0-5 agility test
- Upper body power: tests that involve the upper body muscles, e.g. basketball throw

Training methods (see chapter 11 for more details)

- Aerobic power: fartlek or long-interval training to replicate the change in intensity and stop and start nature
- Anaerobic capacity: short interval to replicate the distances typically covered (no more than 20 m)
- Speed: short interval to replicate the distances typically covered (no more than 20 m)
- Agility: short interval with changes of direction, e.g. shuttle runs, to replicate the movements and distances covered
- Upper body power: upper body plyometrics, e.g. medicine ball slams, to replicate the muscles and muscle groups used in passing

TEST your understanding

1 List the different types of activity analysis used in the netball case study.
2 For each method of activity analysis listed in question 1, outline what information can be gained from this method.
3 Identify an advantage and a disadvantage of using digital recording.

APPLY your understanding

4 Watch a game of netball (preferably elite netball).
   (a) Discuss whether the same fitness tests and training methods would be used for a Goal Keeper (GK) and Goal Attack (GA). Use specific examples to justify your response.
5 Complete an activity analysis for a sport of your choice.
   (a) Collect at least three pieces of data.
   (b) Analyse the data to identify and justify the predominant fitness components, energy systems and muscles.

EXAM practice

6 **ACHPER Trial Exam 2014, question 4a–c**
Melissa is a 'centre' player for her secondary school netball team. The following data about Melissa were collected by her coach from the first quarter of a netball match. The match consisted of 4 × 10 minute quarters.

Work-to-rest ratio	
Work/Rest periods	**Time (seconds)**
Shortest work period	0.61
Longest work period	11.09
Shortest rest period	1.37
Longest rest period	31.21

	Work (seconds)	**Rest (seconds)**
Total	186.99	444.6
	1	2.378
Ratio (approx.)	1	2

Skills and their frequency	
Skill	**Frequency**
Chest pass	9
Overhead pass	15
Catch	18
Jump	13
Guard	8
Defend	13
Leap forwards	15
Leap sideways	7
Change of direction	55
Centre pass	5

Locomotor patterns

Loco-motion	Intensity	0–5 metres	6–10 metres	11–15 metres	16+ metres	Total (count)	Distance metres	% Total	Average metres
Walk	Low	12	7	3	2	24	111	26	4.6
Jog	Low-medium	12	7	1	1	21	147	35	7.0
Sprint	High	11	9	1	0	21	127	30	4.8
Shuffle	Very high	18	4	0	0	22	36	9	1.6
Totals		**53**	**27**	**5**	**3**		**421**	**100%**	

(a) Data were collected by the coach to ensure accurate application of which training principle? **1 mark**

(b) Identify two fitness components that Melissa would require to be a successful centre player. **2 marks**

(c) Using the data provided, justify your choices in **part b** above. **4 marks**

KEY SKILLS ACTIVITY ANALYSIS

KEY SKILLS

- Analyse data to determine the major fitness components and the factors that affect them, and energy systems used in a variety of sporting events and physical activities

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:
- The purpose of activity analysis is to determine the predominant energy systems, fitness components and muscle groups to ensure specificity in the training programs (tests and methods used, as well as the individual sessions)
- Characteristics of the energy systems including duration and intensity

PRACTICE QUESTION

1 **ACHPER Trial Exam 2013, question 10**

The following data were collected from a 15-minute quarter of a Netball game for a Centre player.

Table 1
Skill frequency

Skill	Frequency
Lob pass	0
Bounce pass	1
Chest pass	23
Receive ball	9
Defend	22

Table 2
Average percentage of game time for each activity during the quarter

Standing	14.3
Walk forward	24.5
Walk backwards	8.8
Shuffle	4.0
Jog	18.3
Stride	24.8
Sprint	9.3

(a) **Identify** one way in which this data could have been collected. *1 mark*
(b) **Outline** two reasons for the collection of data. *2 marks*

SAMPLE RESPONSE

a. Direct observation (skill) OR GPS (movement patterns) OR skill frequency table
b. This would be collected to help determine the predominant fitness components and energy systems required for successful performance. This can then help develop a specific training program.

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Identify — determine the key characteristics or features
  Outline — general description but not in detail
- **Key terminology:**
  One way — only one required, pick best one
  Reasons — why collect data, role in training program
- **Key concepts:** Data collection — data collection plays a very important role in ensuring the training program is specific
- **Marking scheme:**
  3 marks — always check marking scheme for the depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

a. **1 mark:** for identifying GPS, direct observation or skill frequency table as the method of data collection

b. **1 mark:** for each of two reasons for the collection of data. Two different reasons required to receive full marks.

Possible answers include:
To establish the major muscle groups involved in the activity.
OR
To determine energy system usage.
OR
To determine the major fitness components of the activity.
OR
To establish the major skills required in the activity.
OR
To develop a more specific training program based on the information collected.

CHAPTER SUMMARY

- Activity analysis is a key technique that can be used to determine the physiological requirements of a sport. It uses movement patterns, heart rates, GPS, skill frequency tables and work-to-rest ratios to determine the predominant energy systems, fitness components and muscles.
  - Heart rate is typically used to estimate physical activity as energy expenditure (oxygen uptake), based on the assumption of a linear association between heart rate and energy expenditure.
  - Movement patterns are the typical movements completed by a performer during a game or an activity.
  - Skill frequency tables are generally referred to as 'stats'. Tables outline the frequency, and in many cases the effectiveness, of skill execution.
  - Work-to-rest ratio is a summary of the time an athlete spends physically working compared to the time spent resting or recovering.
- Observation is a practical method of data collection but has low accuracy. Digital recording can be less practical but has higher accuracy.
- Data collection is the first step of activity analysis. This is followed by activity analysis. The findings of this analysis should then shape the fitness testing that is prescribed.
- A player's training methods and activities should always be based on the findings of such analysis.

TABLE 7.10 The what, who and how of the different methods of activity analysis

Method of activity analysis	What sports/ activities it is best used for	What information can be determined	How it can be used
Skill frequency table	Intermittent activities (e.g. tennis, gymnastics)	Major muscle groups Major fitness components	To ensure that training replicates the requirements (energy system/fitness components/major muscle groups)
Movement patterns, including GPS data	Team sports on larger playing areas (e.g. AFL, hockey) Continuous activities (average speed, e.g. Tour de France, triathlon)	Predominant energy systems Fitness components (aerobic power vs anaerobic capacity)	Example: A high percentage of long duration lower speed/ intensity in GPS/movement patterns data suggests aerobic energy system is predominant; therefore this system should be a focus in training.
Heart rate	Continuous activities (e.g. 1500 m running, 3 km cycling)	Predominant energy systems	Example: A high percentage of jumps in volleyball skill frequency table suggests gluteus, quads and gastrocnemius muscles are important; therefore the coach would create a program that focuses on the power of these muscles.
W:R (intensity charts)	Intermittent activities (e.g. rugby, badminton)	Predominant energy systems	

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 Which of the following is not a purpose of activity analysis?
(A) To determine predominant strengths and weaknesses
(B) To determine predominant fitness components
(C) To determine predominant energy systems
(D) To determine predominant muscles and muscle groups

2 A very short high-intensity effort on GPS data is most likely to require which fitness component?
(A) Power
(B) Strength
(C) Aerobic power
(D) Muscular endurance

3 A high percentage of time spent under 85 per cent MHR suggests which energy system is important?
(A) ATP–CP
(B) Anaerobic glycolysis
(C) Anaerobic system
(D) Aerobic

4 Recording a large number of changes in direction in a skill frequency table suggests which fitness component is important?
(A) Power
(B) Speed
(C) Agility
(D) Balance

5 Which form of activity analysis can best determine important muscles and muscle groups?
(A) Heart rate telemetry
(B) GPS
(C) Movement patterns
(D) Skill frequency table

6 A work-to-rest ratio that shows the anaerobic glycolysis system being predominant is
(A) 1:4
(B) 1:6
(C) 2:1
(D) 6:1

7 The most important muscle groups required to complete a pass are
(A) abdominals and hamstrings.
(B) flexors, extensors.
(C) bicep and tricep.
(D) abdominals and pectorals.

8 Which of the following is not a limitation of heart rate telemetry?
(A) It can be affected by nerves
(B) It can be affected by body temperature
(C) It provides information about energy systems and some fitness components
(D) Heart rate monitors can be expensive

9 In order to gather information about fitness components and energy systems, the best forms of activity analysis to use would be
(A) skill frequency table and GPS.
(B) heart rate telemetry and work-to-rest ratio.
(C) GPS and movement patterns.
(D) movement patterns and heart rate telemetry.

10 The best method of activity analysis for a triathlete would be
(A) movement patterns.
(B) skill frequency table.
(C) heart rate telemetry.
(D) work-to-rest ratio.

eBook*plus*
Interactivity
Activity analysis quiz
Searchlight ID: int-6804

studyon
Sit VCAA exam

TRIAL EXAM QUESTIONS

Question 1

Table 1 Korfball games analysis taken from Player 1 throughout the first half

Passes	99
Catches	67
Dodges	103
Side steps	87
Intercepts	8
Shots	16
Lunges	110
Balancing on one foot	23
Defending stance	88
Holding position	45

Table 2 Work-to-rest ratio from Player 1 throughout the second half (2 minute time sample)

W	R	W	R	W	R	W	R	W	R
17	20	15	10	8	10	13	9	9	9

a. Using data from above, justify an important fitness component required to be successful in Korfball. **2 marks**

b. Using the data above, justify the most important energy system. **2 marks**

Question 2 (ACHPER Trial Exam 2015, question 13)

Two Year 12 students, Katherine and Sharon, undertook an activity analysis in order to assess the requirements of training for, and then competing in, a 10 km Fun Run event. The girls also analysed the heart rate data of an elite 10 km runner as part of their data collection to determine the requirements of successfully completing the event.

a. Why is it important to analyse the performance data of an elite 10 km athlete rather than that of a novice runner? **2 marks**

b. Other than using a heart rate monitor, state **one** form of data collection that could be used as part of an activity analysis for a 10 km Fun Run event. **1 mark**

Question 3 (ACHPER Trial Exam 2014, question 7)

Daniel is a Year 12 student who trained to compete in an 8 km Fun Run. The race was held on a flat course that comprised 2 × 4 km laps. On the night of the race the air temperature was 33 degrees Celsius.

During the race the following data were collected via a heart rate monitor and GPS:

Distance	Time (minutes)	Average heart rate
1 km	4:09	166 bpm
2 km	4:13	172 bpm
3 km	4:26	173 bpm
4 km	4:23	173 bpm
5 km	4:38	175 bpm
6 km	4:37	175 bpm
7 km	4:38	176 bpm
8 km	4:13	180 bpm

a. What was the predominant energy system that Daniel would have utilised during this event? **1 mark**

b. Complete the table below. **2 marks**

Method of data collection	Data collected
GPS	
Heart rate monitor	

INQUIRY QUESTION
What does being 'fit' mean to you and what affects your fitness?

CHAPTER

8 Fitness components

The term 'fitness' is used in a variety of ways. In order to describe fitness accurately, the fitness components should be referred to. The fitness components help us to understand the specific physical requirements required to successfully perform an activity.

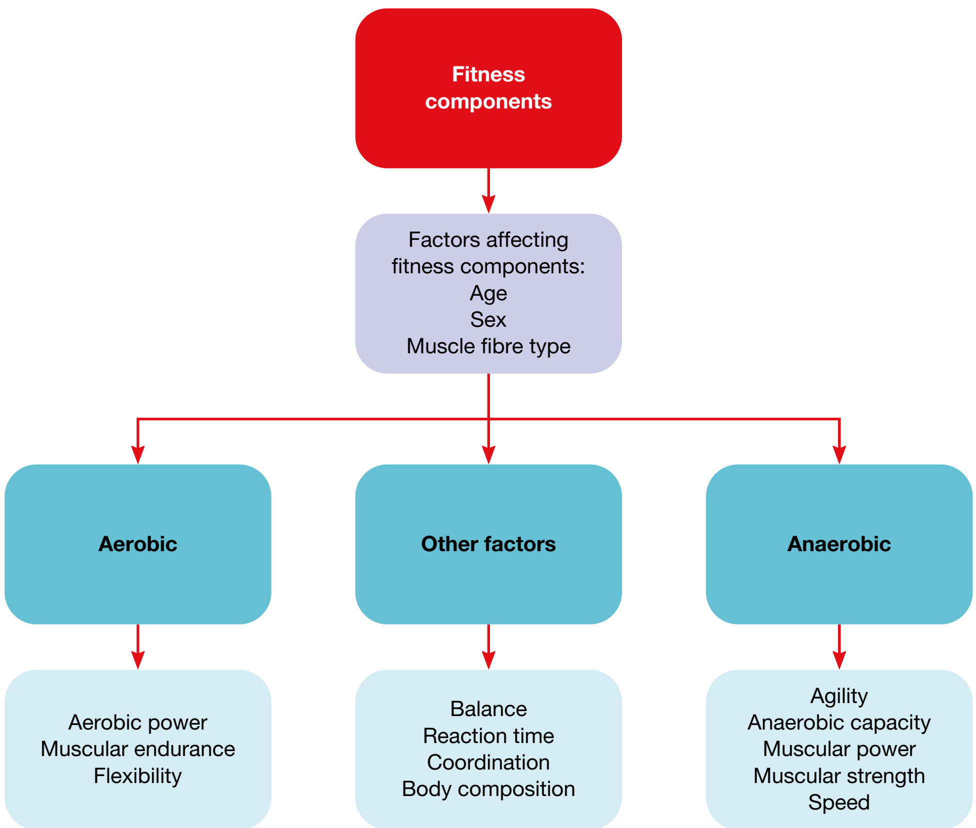
KEY KNOWLEDGE

- Fitness components: definitions and factors affecting aerobic power, agility, anaerobic capacity, balance, body composition, coordination, flexibility, muscular endurance, power and strength, reaction time and speed

KEY SKILL

- Analyse data to determine the major fitness components and the factors that affect them, and energy systems used in a variety of sporting events and physical activities

CHAPTER PREVIEW



8.1 Aerobic power and anaerobic capacity

KEY CONCEPT Aerobic power and anaerobic capacity are the building blocks for all other fitness components and are generally what people refer to when discussing general fitness.

Aerobic power is the maximum rate of energy production from the aerobic energy system (i.e. energy produced in the presence of oxygen).

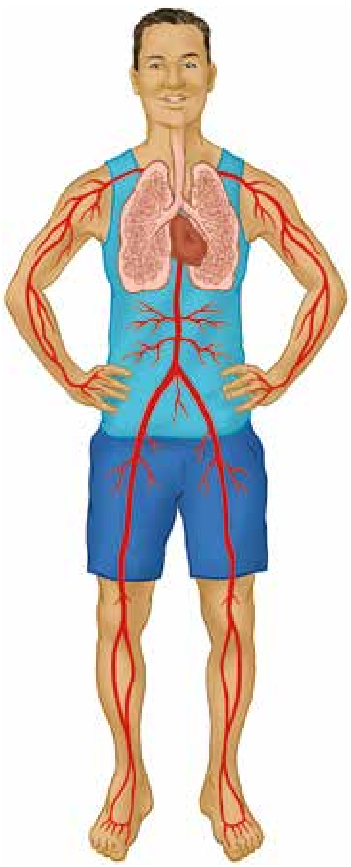


FIGURE 8.1 Aerobic power relies on the cardiovascular and respiratory systems working together.

Aerobic power

Aerobic power is the maximum rate of energy production from the aerobic energy system (i.e. energy produced in the presence of oxygen). The cardiovascular and respiratory systems work together to deliver oxygen to the working muscles for any physical exertion that requires aerobic power.

If the cardiovascular and respiratory systems are highly trained, the athlete will be better able to produce ATP for the working muscles under aerobic conditions (at a higher intensity for longer), and they will have increased capacity for efficiently replenishing the anaerobic systems during and/or after an extended performance in a sports event or physical activity.

Aerobic power is of high importance in:

- extended athletic events such as marathons, triathlons and cross-country skiing
- team sports requiring repeated efforts over a longer period of time
- racquet sports such as tennis and squash
- team games such as netball, football, hockey, soccer, volleyball, water polo, basketball, lacrosse and rugby.

FIGURE 8.2 Long-distance cyclists require the highest levels of aerobic power in order to work at higher intensities for long periods of time, often for a number of days in a row.

Factors affecting power

TABLE 8.1 Factors affecting aerobic power

Factor	Effect on aerobic power
Age	*Aerobic power (VO_2 max.) peaks in the mid 20s and then decreases as age increases.* This is due to decreased elasticity of the lungs (decreased oxygen uptake), decreased haemoglobin (decreased oxygen transport) and decreased muscle mass and therefore mitochondria (decreased oxygen utilisation).
Sex	*Males generally have a higher aerobic power (VO_2 max.) than females.* This is due to greater size of the lungs (increased oxygen uptake), increased haemoglobin levels (increased oxygen transport) and increased muscle mass and therefore mitochondria (increased oxygen utilisation).
Muscle fibre type	*A greater percentage of slow-twitch fibres will increase aerobic power (VO_2 max.)* Slow-twitch fibres work aerobically, therefore the greater number of slow-twitch fibres, the greater ability to work aerobically.

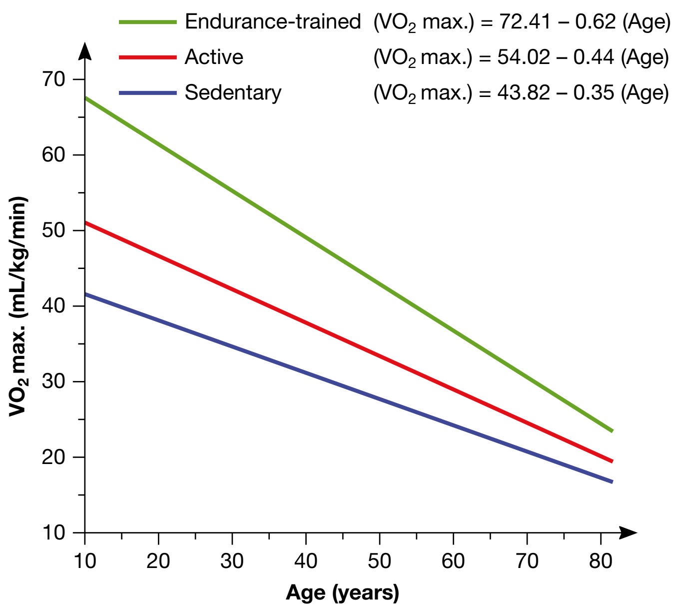


FIGURE 8.3 As age increases, aerobic power, measured by VO_2 max., decreases.

Some common ways to test aerobic power include:

- multi-stage fitness test
- yo-yo test
- Cooper 12-minute run test
- 2.4 kilometre run test
- Rockport 1.6 kilometre walking test
- VO_2 max. Astrand-Ryhming cycle ergometer test
- VO_2 max. treadmill test
- Harvard step-test. (See chapter 9 for more details.)

The most appropriate training methods to develop aerobic power are continuous, fartlek, long-interval, HIIT and circuit training (see chapter 11 for more details).

Anaerobic capacity

Anaerobic capacity is the total amount of energy obtainable from the anaerobic energy systems (the combined capacity of the ATP–CP system and anaerobic glycolysis system).

Anaerobic capacity is generally measured over a maximal effort up to one minute. As discussed in chapter 5, during a maximal effort up to one minute the ATP–CP system will play a major role at the beginning and then the anaerobic glycolysis system will be predominant. The longer and more efficiently these systems can contribute significantly to performance, the greater an individual's anaerobic capacity will be.

High anaerobic capacity can allow an athlete to complete longer maximal intensity efforts (for example, an elite 400-metre sprint), but also repeat more maximal intensity efforts with limited recovery (for example, basketball rebounds).

Anaerobic capacity is the total amount of energy obtainable from the anaerobic energy systems (the combined capacity of the ATP–CP system and anaerobic glycolysis system).

FIGURE 8.4 400-metre hurdlers require very high anaerobic capacity in order to sprint 400 metres and jump 10 hurdles along the way.

Anaerobic capacity is of high importance in:

- an elite-level, 100-metre sprint
- athletic field events, such as the long jump, high jump, shot put, javelin, discus, pole vault and hammer throw
- basketball rebounds and blocks
- netball sprints to position
- an elite level 400-metre run
- a 50-metre sprint in swimming
- an uphill cycle for 30–60 seconds in a triathlon.

Factors affecting anaerobic capacity

TABLE 8.2 Factors affecting anaerobic capacity

Factor	Effect on anaerobic capacity
Age	*Anaerobic capacity peaks in the 20s and then decreases as age increases.*
Sex	*Males generally have a higher anaerobic capacity than females.* This is due to greater muscle mass, therefore more places to store CP and anaerobic enzymes, therefore increased ability to work anaerobically.
Muscle fibre type	*A greater percentage of fast-twitch fibres will increase anaerobic capacity.* Fast-twitch fibres work anaerobically, therefore the more fast-twitch fibres, the greater the ability to work anaerobically.
Lactate tolerance	*The greater the lactate tolerance, the greater the anaerobic capacity.* The more metabolic by-products that can be tolerated, the more high-intensity efforts / longer high-intensity efforts can be made.

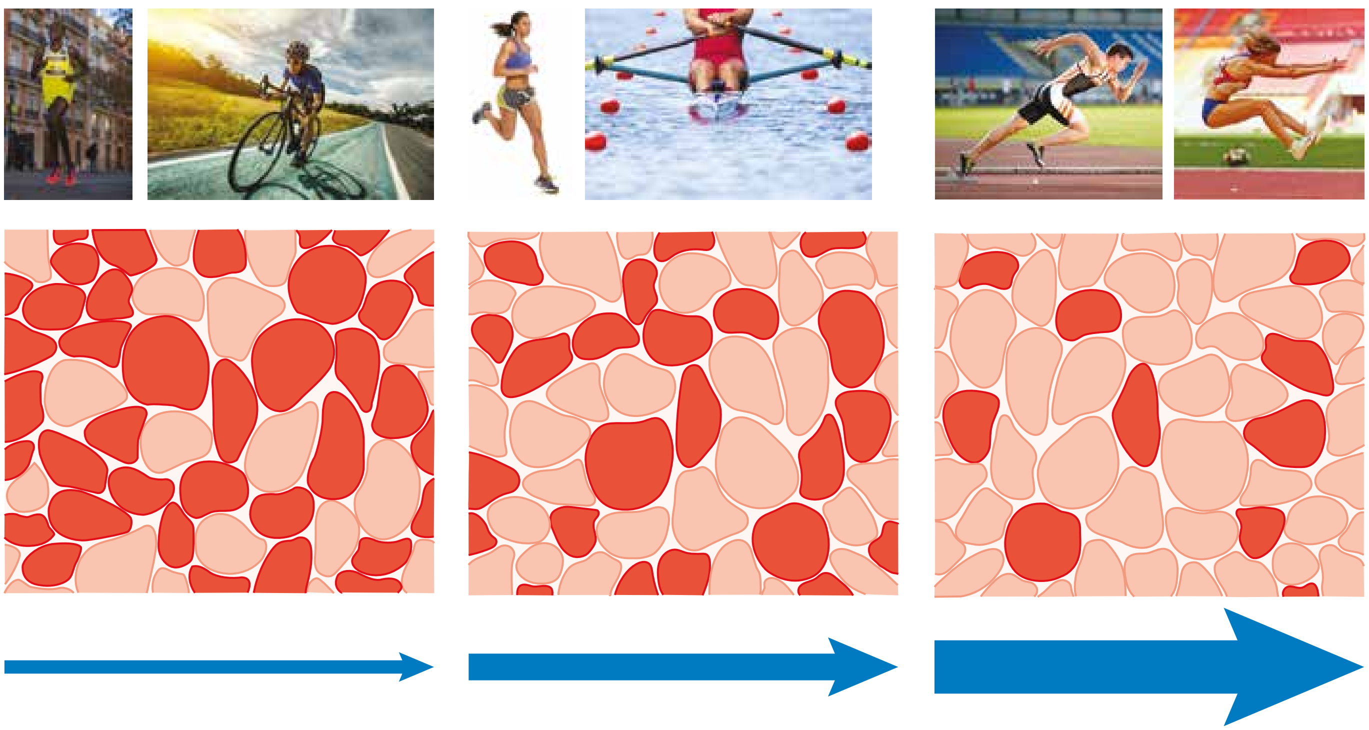


FIGURE 8.5 The percentage of slow (red)- and fast (light pink)-twitch fibres is a significant factor affecting an individual's anaerobic capacity.

The greater the percentage of fast-twitch fibres, the greater one's ability to generate anaerobic energy and therefore the greater the anaerobic capacity. Sprinters and jumpers require high anaerobic capacity.

Some common ways to test anaerobic capacity are:

- phosphate recovery test
- 30-second Wingate test
- Repco peak power test. (See chapter 9 for more details.)

The most appropriate training methods to develop anaerobic capacity are short and intermediate interval training (see chapter 11 for more details).

studyon

Unit 4 | AOS 1 | Topic 2 | Concept 1

Aerobic power and anaerobic capacity
Summary screen and practice questions

TEST your understanding

1. Define *aerobic power*.
2. List five sports or activities that you have played that require aerobic power.
3. Define *anaerobic capacity*.
4. List five sports or activities that you have played that require anaerobic capacity.
5. Outline the role of the three energy systems in producing aerobic power and anaerobic capacity.

APPLY your understanding

6. Explain the main differences between aerobic power and anaerobic capacity.
7. Discuss a time when aerobic power and anaerobic capacity are predominant during a triathlon.
8. Discuss when you would use aerobic power and when you would use anaerobic capacity during a team game such as basketball.

9 Practical activity: laboratory tests for aerobic power

As a class, thoroughly warm-up and stretch, then undertake the multi-stage fitness test (page 292, chapter 9) to predict each student's aerobic power. Then select different students to also undertake the Harvard step-test (page 298, chapter 9).

(a) Explain the correlation between students' aerobic power and their main sport.
(b) Outline the correlation between the different aerobic power tests.
(c) What variables may affect results? Explain how each test is specific to a sport when considering muscle groups/actions and energy system contribution.
(d) Explain the role of each energy system in achieving level 12 on the multi-stage fitness test.
(e) Explain how having good anaerobic capacity, as well as high aerobic power, may lead to success in these tests.
(f) Compare your results with those of two other students. Discuss what factors may have affected these results.

EXAM practice

10 Use figure 8.3 to answer the following questions.

(a) Identify the trends in the graph. **2 marks**
(b) Explain a reason for each trend. **4 marks**

11 Examine figure 8.5 and answer the following questions.

(a) Fast-twitch fibres are light pink and slow-twitch fibres are red. Using your understanding of the characteristics of fast- and slow-twitch fibres, discuss why this may be so. **2 marks**
(b) Justify the predominance of fast-twitch fibres for weightlifters. **2 marks**

8.2 Muscular strength, muscular power and muscular endurance

KEY CONCEPT Strength, power and muscular endurance all require a high force contraction for high-intensity efforts. While there are many similarities, including heavy reliance on the anaerobic energy pathways, it is important to understand the difference between these fitness components.

Muscular strength

Strength is the peak force that a muscle can develop. Apart from weightlifting, this peak force strength movement is used infrequently in competitive or recreational sport. However, it is not difficult to imagine muscles creating near-peak force during sports participation.

Strength is the peak force that a muscle can develop.

Muscular strength is of high importance in:

- pushing with seven team mates against eight opponents in a Rugby Union scrum
- gripping a hockey stick while making a powerful shot at goal
- attempting a static or submission hold against an opponent in wrestling
- leaning out to try to keep a boat upright while sailing.

FIGURE 8.6 Pushing against your team mates and against the opposition is an example of muscular strength.

Factors affecting strength

TABLE 8.3 Factors affecting muscular strength in the individual

Factor	Effect on strength
Speed of muscle contraction	*The more slowly a muscle contracts, the more force it can create (figure 8.7).* Compare an isometric contraction with a powerful, isotonic contraction. A **1 RM** weight lift is performed much more slowly than 12 RM movements, because it requires more strength.
Length of muscle fibre	*If the muscle is slightly stretched, it is in the best position to create its maximum force.* This is demonstrated when long jumpers lower their centre of gravity just before take-off — a movement that stretches the quadriceps just before they contract to achieve the powerful leap. Performers need to account for this fact along with the best 'joint angle' specific to the particular joint around which the movement is centred.

(continued)

1 RM (1 repetition maximum) is the maximum amount of force that can be generated in one maximal contraction. This is commonly used to measure strength.

TABLE 8.3 *(continued)*

Factor	Effect on strength
Age of the performer	*Strength peaks in performers aged 20–30 years, then decreases with the body's diminishing ability to process protein*. Regular exercise can slow this process.
Warm-up	*Warmed-up muscles have a greater ability to create strength than muscles that are not warmed up.*
Fibre type	*Fast-twitch (or light pink) fibres are capable of greater strength output than that of slow-twitch (or red) fibres.*
Cross-sectional area	*The larger the muscle, the greater the strength potential (figure 8.8)*. But this relates to the muscle mass, not the total body area in which the muscle is found. The diameter of the biceps, for example, may include both muscle and fat.
Sex of the performer	*Males generally have greater muscle mass, so they have greater absolute strength*. Relative to the cross-sectional area of muscle, there is no difference in the strength available to males and females (see figure 8.8).
Joint angle around the muscle	*For each joint angle in movement there is an optimal angle for the creation of strength* (figure 8.9).

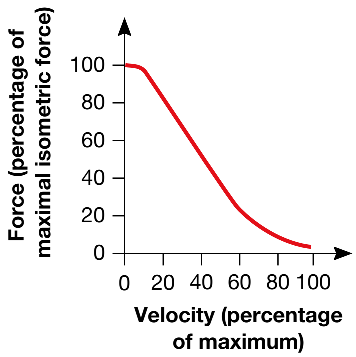


FIGURE 8.7 As speed of contraction increases, the amount of force created decreases.

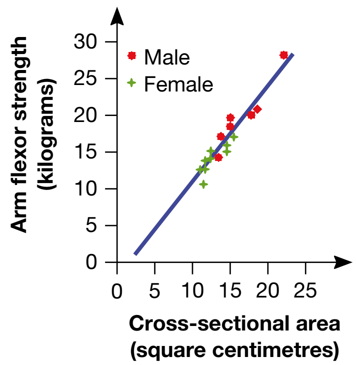


FIGURE 8.8 As the cross-sectional area of muscle increases, the strength potential also rises.

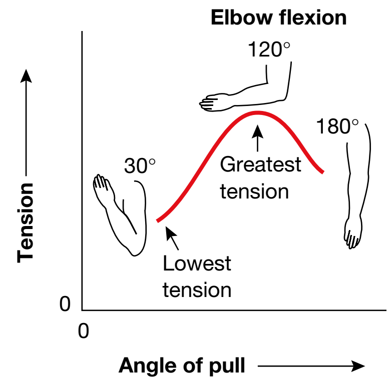


FIGURE 8.9 The strength available as a joint moves depends on the angle of the joint.

Some common ways to test muscular strength include:

- the 1 RM (bench press, back squat, leg press)
- grip strength dynamometer
- push-pull dynamometer
- seven-stage abdominal strength test (see chapter 9 for more details).

The most appropriate training method to develop muscular strength is resistance training (see chapter 11 for more details).

Muscular power

Muscular power is the ability of a muscle or group of muscles to exert a maximum amount of force in the shortest period of time. Muscular power is a combination of strength and speed. A powerful movement is at a fast rate, with great force production and power output.

Muscular power is central to successful performance in most sports where distance, height or any quick generation of force is important. It is difficult to think of many sports or recreational activities for which muscular power is not needed.

Muscular power is the ability of a muscle or group of muscles to exert a maximum amount of force in the shortest period of time.

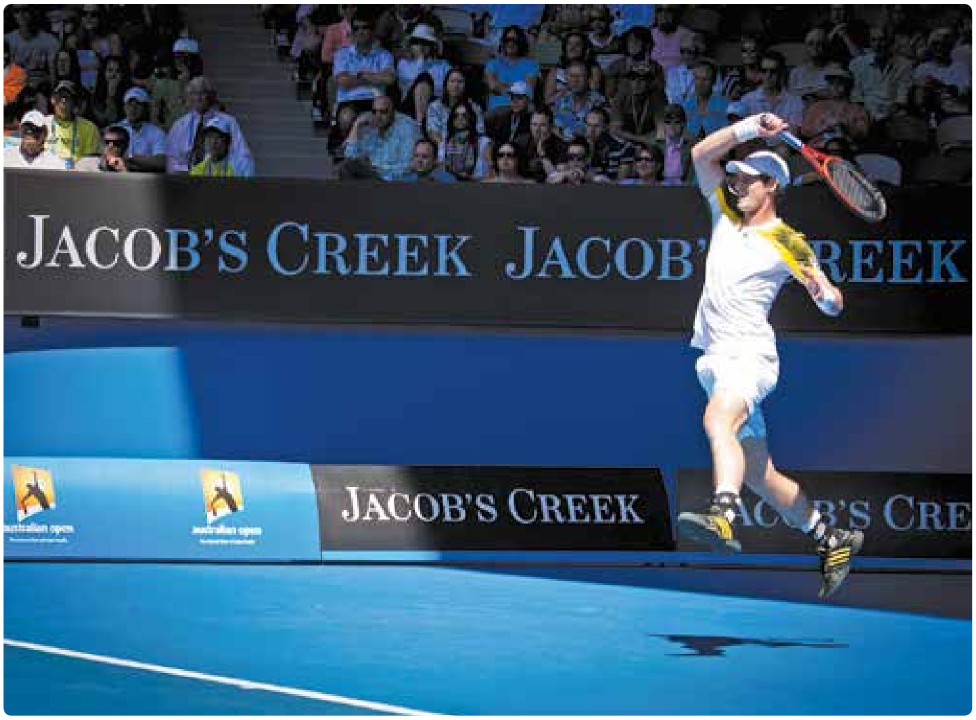


FIGURE 8.10 Andy Murray powerfully returns the ball at the Australian Open

Muscular power is important in:

- field events such as shot put, discus, javelin, high jump, long jump and hammer throw
- Rugby League or Rugby Union tackles
- volleyball spikes
- netball or basketball when the player leaps to intercept the ball
- hockey when the player performs a defensive clearance
- golf when the golfer drives the ball
- the legs in a sprint
- the arms in a tennis serve
- the legs and arms in a gymnastics floor routine.

Factors affecting muscular power

The factors affecting power are the same as those affecting muscular strength, as power combines strength and speed (see table 8.3).

Some common ways to test power are:

- vertical jump
- standing long jump
- Magaria Kalamen power test
- the basketball throw. (See chapter 9 for more details.)

The most appropriate training method to develop muscular power is plyometrics training. Resistance training with fast contractions and appropriate recovery between repetitions is also commonly used to develop power (see chapter 11 for more details).

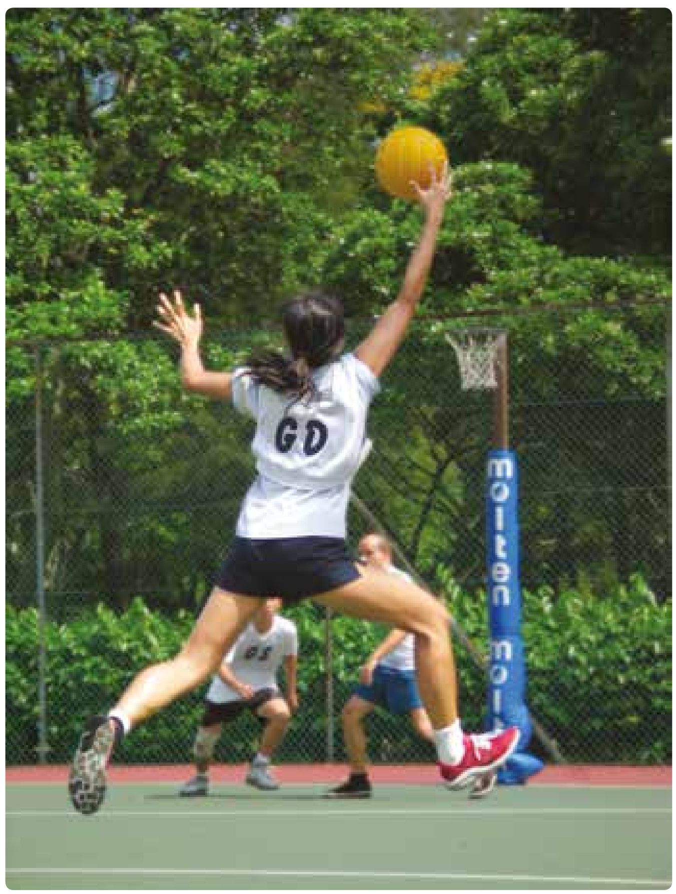


FIGURE 8.11 Netballers require muscular power for a number of actions in netball, including muscular power of the legs to jump and defend.

Muscular endurance

Muscular endurance is the ability of a muscle or group of muscles to sustain repeated contractions against a resistance for an extended period of time.

Muscular endurance is the ability of a muscle or group of muscles to sustain repeated contractions against a resistance for an extended period of time.

FIGURE 8.12 These kayakers, on the 2016 Olympic course, would require muscular endurance of the upper body to maintain high-intensity efforts for the duration of the race.

FIGURE 8.13 While a fun run is predominantly aerobic in nature, it requires muscular endurance of the legs.

Muscular endurance is often controlled by the body's tolerance of the increasing levels of lactate, which is a by-product of the glycolytic energy pathways. Heavy arms or legs during any high-intensity effort of around 60 seconds are a direct result of the body's ability to tolerate building levels of lactate and are an indicator of the person's muscular endurance. Muscular endurance is also important in endurance events, which may be aerobic in nature but require repeated efforts from a muscle or muscle group.

Muscular endurance is of high importance for:

- the arms, legs and abdominals in a 200-metre swim
- the abdominals, hip muscles and legs in a marathon
- the arms, legs and abdominals in a 2000-metre rowing race
- the arms, legs and abdominals in most team games.

Factors affecting endurance

TABLE 8.4 Factors affecting muscular endurance

Factor	Effect on muscular endurance
Sex	*Males generally have greater muscular endurance than females.* Males have increased aerobic capacity and muscular strength, therefore increased endurance compared to females.
Muscle fibre type	*A greater percentage of slow-twitch fibres will increase muscular endurance.* Slow-twitch fibres work aerobically, therefore the greater the number of slow-twitch fibres, the greater the ability to work aerobically and contract repeatedly over a longer period of time. Slow-twitch fibres have greater resistance to fatigue than fast-twitch.
Lactate tolerance	*The greater the lactate tolerance, the greater the anaerobic capacity.* The more metabolic by-products that can be tolerated, the more high-intensity efforts / longer high-intensity efforts can be made.

Some common ways to test muscular endurance are:

- 60-second pushup test
- 30-second situp test
- curlup (crunch) test
- pullup/modified pullup test
- flexed arm hang test. (See chapter 9 for more details.)

The most appropriate training methods to develop muscular endurance where the anaerobic energy system is predominant are resistance (with high repetitions and little recovery) and intermediate interval training.

For muscular endurance where the aerobic system is predominant, the most appropriate training methods would be the same as those used to develop aerobic power (see chapter 11 for more details).

studyon

Unit 4
AOS 1
Topic 2
Concept 2

Muscular endurance, power and strength
Summary screen and practice questions

TEST your understanding

1 Define the term *muscular strength.*
2 Define the term *muscular power.*
3 Define the term *muscular endurance*.
4 Apart from those listed in muscular power, list five sporting actions that exemplify muscular power.

APPLY your understanding

5 Outline the differences between muscular strength, muscular endurance and muscular power. Use sporting examples in your response.
6 Identify and justify the following movements as muscular strength, power or endurance:
   - 1 RM leg press
   - 1 minute of step ups.

7 **Practical activity: muscle endurance test**
   As a class, thoroughly warm-up and stretch, then undertake one of the following muscle endurance tests, recording the results:
   - number of pushups in 60 seconds
   - number of bench jumps in 60 seconds
   - number of situps in 60 seconds.

   (a) Present the collected data in tables and graphs.
   (b) Examine the varying results and explain possible reasons for at least two differences in results.

eBook*plus*

Weblink
Fly game

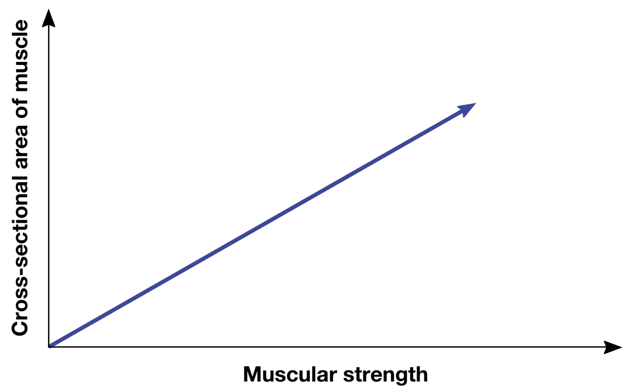
8 Practical activity: Fly game
Use the **Fly game** weblink in your eBookPLUS to learn how to play the game of Fly.
(a) Collect six stick-like objects.
(b) Spread sticks out 1 metre apart.
(c) Line up.
(d) Each person takes a turn to run through the sticks placing one foot between each stick, making sure they do not touch the stick with their feet.
(e) The last person in line takes an extra leap from the last step.
(f) Move the last stick to the back of the last jumper's foot so the gap between the fifth and sixth sticks is now bigger.
(g) Repeat the process from this end. The first step should now be bigger.
(h) Last jumper jumps and last stick is moved.
(i) Keep going until there is only one person left who can jump between the increasing gaps in one step and not touch the sticks.

A modification is that you allow the last jumper to move any stick.

After you have completed the learning activity, explain how increased muscular power increases the chance of success in the game of Fly.

EXAM practice

9 **ACHPER Trial Exam 2014, question 5 a and b**



(a) Describe the trend shown by the graph. **1 mark**
(b) Explain how an increase in cross-sectional size of muscle produces increased muscular strength. **2 marks**

8.3 Speed and agility

KEY CONCEPT Speed is very important in many sports but it is arguably more important, especially in team sports, to have the ability to change direction at speed: agility.

Speed

Speed is the rate of motion (distance/time). For sporting performance, speed is defined as the ability to move the body or part of the body from one point to another as quickly as possible.

Speed is the rate of motion (distance/time).

FIGURE 8.14 Sprint cycling requires full-body speed.

FIGURE 8.15 Table tennis players require part-body speed to react and return the ball.

Speed is important in:

- undertaking any sprint event in athletics
- accelerating to create space or evade an opponent in team games
- releasing a javelin or discus
- racquet and club speed in striking sports.

Factors affecting speed

TABLE 8.5 Factors affecting speed

Factor	Effect on speed
Muscle fibre type	*A greater percentage of fast-twitch fibres will increase speed.* Fast-twitch fibres generate increased force production and power output, therefore increase speed.
Reaction time	*The faster the reaction time, the greater the speed.*
Sex	*Males generally have greater speed than females.* Males have increased levels of testosterone therefore increased muscle mass, providing the capacity to generate more force and therefore increased speed.
Age	*As age increases, speed decreases (negative linear relationship).* This is due to decreased ability to use protein (protein synthesis) and decreased muscle mass, therefore decreased speed.
Flexibility	*The greater the flexibility/stride/stroke length, the greater the speed.* Increased range of motion, due to increased flexibility, means an athlete can get further in each stroke/stride, making them more efficient in technique and increasing speed.

FIGURE 8.16 Usain Bolt is significantly taller than many of his opponents and has a greater stride length.

Some common ways to test speed include:

- 20-metre sprint test
- 35-metre sprint test
- 50-metre sprint test. (See chapter 9 for more details.)

The most appropriate way to develop speed is by using short-interval training (see chapter 11 for more details).

Agility

Agility combines speed with flexibility and dynamic balance, allowing the performer to change direction with maximal speed and control.

Agility is a combination of flexibility and speed, which allows the performer to change direction with maximal speed and control.

In sports such as gymnastics, planned agility is required. Most sports, such as team sports, require reactive agility where players are required to change direction in response to a stimulus.

Agility is of high importance in:

- evading an opponent in soccer or rugby
- reacting to an opponent's baulk in hockey
- dribbling the ball around opponents in soccer or basketball
- changing direction during a dance, gymnastics or aerobics sequence
- moving to make a play in squash while avoiding an opponent.

FIGURE 8.17 Basketballers require agility to move around and past opponents and team mates.

FIGURE 8.18 In order to change direction and go up and over the bar, a pole vaulter requires high levels of agility as Australia's Henry Brown, demonstrates.

The factors affecting agility are similar to those affecting speed as agility requires speed (see table 8.5).

Some common ways to test agility are:

- Semo agility test
- 5-0-5 agility test
- Illinois agility test. (See chapter 9 for more details.)

The most appropriate training method to develop agility is short-interval training, ideally with changes of direction; for example, shuttle run sprints. (See chapter 11 for more details.)

TEST your understanding

1 Define the term *speed*.
2 Explain the difference between full-body speed and part-body speed.
3 Apart from those given in this subtopic, list five sports or sporting actions where whole body speed is required, and five where part-body speed is required.
4 Define the term *agility*.
5 Identify the three fitness components that comprise agility.

APPLY your understanding

6 **Learning activity: self-designed agility test**
Select a team sport and design an agility test that mimics the movement patterns required in the game.
For example:
- Netball: a centre player's first five seconds of movement following a centre pass
- Australian Rules Football: an on-baller's first five seconds of movement following a centre bounce
- Hockey: the inside-right's movement as the team makes an attacking break from defence.

7 **Class activity: the need for speed**
Rank the following actions or activities in order of importance with respect to speed. Rank them from 1 (very important) to 11 (not very important).
- Multi-stage fitness test (or beep test)
- 50-metre running sprint test
- Javelin throw
- Marathon
- Tennis serve
- Shane Warne's spin bowling
- Basketball free-throw
- Skipping with a skipping rope
- Netball centre pass
- Lead from a full forward in AFL
- Water polo 5-metre penalty throw

8 **Practical activity: team sport**
As a class, participate in any team sports game. Discuss whether speed or agility would be more desirable in the team game played and justify your response.

EXAM practice

9 Speed and agility are vital in a successful gymnastics floor routine. Explain the role each of these fitness components would play, using specific examples.
4 marks

studyon
Unit 4
AOS 1
Topic 2
Concept 3
Speed and agility
Summary screen and practice questions

8.4 Flexibility and balance

KEY CONCEPT Flexibility and balance are important when considering injury prevention. However, they have a significant impact on skill execution and, ultimately, successful skill and sports performance.

Flexibility

Flexibility is the range of movement around a joint. It is the interaction between the body's skeletal and muscular systems to allow a full and unimpeded range of joint movement to muscle actions.

Flexibility is the range of movement around a joint.

Flexibility is of high importance when:

- performing gymnastics routines on the Roman rings, uneven bars, parallel bars, floor, pommel horse and beam
- goalkeeping in hockey
- performing competitive aerobics
- catching in short-stop or catcher positions in softball or baseball.

Flexibility is essential to all sports and recreational activities, therefore it must be an integral part of all fitness training programs. It is specific to the sport or activity, because some sports require more flexibility of more body parts than do others. Flexibility may be dynamic (moving) or static (stationary). Generally, it needs to be dynamic, and it is often combined with speed to create agility.

FIGURE 8.19 Olympic champion Simone Biles of the United States demonstrates (a) dynamic flexibility and (b) static flexibility on the balance beam in the women's all-around gymnastics at the Rio 2016 Olympic Games.

Factors affecting flexibility

TABLE 8.6 Factors affecting flexibility

Factor	Effect on flexibility
Specific sport and joint flexibility	*Flexibility importance differs from one sport to the next — for example, gymnastics requires much more all-round flexibility than does rowing.*
Somatotype	*Endomorphs with their extra bulk (from extra adipose tissue) have limited flexibility*. Mesomorphs also may have limited flexibility because they have trained with a limited range of movement or because they have extra muscle tissue. Ectomorphs generally have quite good flexibility because they have lower amounts of body tissue.
Skin resistance	*Skin has lower elasticity than that of ligaments and tendons, so it can restrict higher ranges of movement.*
Sex	*Hormonal differences mean that females are generally more flexible than males.*

(continued)

TABLE 8.6 ***(continued)***

Factor	Effect on flexibility
Type of joint	*Specific joints are designed for either strength or mobility, or a combination of each.* The shoulder has great mobility but is prone to dislocation in contact sports. The hip joint has high stability, but less mobility than that of the shoulder.
Resting length of ligaments and joint capsule	*Stretching these surrounding structures in training may increase a joint's flexibility.*
Age	*Increasing age decreases flexibility.*
Warm-up	*Warm-up routines generally increase the temperature of both the muscles and the structures within the joints, increasing flexibility.*
Length of muscles at rest	*If muscles at rest are shortened, then flexibility is limited.* This may happen if the individual has too much sedentary work (which chronically shortens the hamstrings). If weight-training exercises are not performed through the full range of motion, then the muscles will shorten.
Bone	*Depending on the joint, the bone type and structure will vary and thus have different effects on the actual flexibility of the joint.*

Some common ways to test for flexibility include:
- trunk flexion (sit-and-reach) test
- trunk rotation test
- groin flexibility test
- shoulder and wrist elevation test
- trunk and neck extension test
- ankle extension/dorsiflexion test
- shoulder rotation test. (See chapter 9 for more details.)

The most appropriate training method to develop flexibility is specialised flexibility training (stretching) (see chapter 11 for more details).

Balance

Balance is the ability of the body to remain in a state of equilibrium while performing a desired task.

Balance is the ability of the body to remain in a state of equilibrium while performing a desired task.

There are two recognised types:
1. dynamic balance, which involves keeping the body's balance under control while moving
2. static balance, which involves keeping the body's balance under control while not moving.

FIGURE 8.20 Sailing and aerobics often require high levels of balance.

Balance is a fitness component that is central to all physical activity and is often the discriminating factor between excellent and average performance. For example, consider a 200-metre sprint in athletics, especially as the runners come around the bend. The sprinters run at varying distances from the inside line of their lanes, and their accompanying control of style, balance and speed ultimately contributes to their success at the finish.

Balance is of high importance when:

- running around a bend in a 200-metre athletic race
- performing a 60-second aerobics routine
- performing a handstand in a gymnastics routine
- standing on one foot while shooting a goal in netball.

Factors affecting balance

Factors that affect balance include the mass of the object, the centre of gravity, the base of support and the line of gravity (as discussed in chapter 2).

Other issues that can affect one's balance include:

- any issues with the ears
- decreased muscle mass, often associated with ageing.

The stork stand test is a common way to test balance but many sports will have sports-specific balance tests.

Balance can be developed using resistance training of the core muscles (see chapter 11 for more details).

studyon

Unit 4 | AOS 1 | Topic 2 | Concept 4

Flexibility and balance
Summary screen and practice questions

TEST your understanding

1 Define the term flexibility.
2 Name the two body systems that work together to achieve flexibility.
3 Apart from those given in this section, list five sports or sporting actions that exemplify flexibility.
4 Define the terms *static balance* and *dynamic balance*.

APPLY your understanding

5 Select three different sporting or outdoor activities. Make a list of the skills needed for each activity and assess whether they require static or dynamic balance, or a combination of the two.
6 Outline why flexibility is essential to every sports training session.
7 Study the factors that affect flexibility (table 8.6). Select your favourite sport and examine how each of the factors influences the level of achievement of an elite performer in this sport.
8 Using examples of dynamic and static flexibility in sporting situations, illustrate the differences between the two types of flexibility.
9 In groups of three or four, arrange to visit a training session of one of your school's sports teams.
(a) List the flexibility work done by the team during the session.
(b) Discuss the purpose of the flexibility work completed.
10 **Practical activity: group fitness**
Complete a group fitness class such as pilates, Body Balance or yoga.
(a) Justify how classes like this can help improve flexibility and balance.
(b) Many AFL footballers include at least one session a week of pilates, Body Balance or yoga. Explain how this may improve performance in AFL.

EXAM practice

11 Explain how gender and age affect flexibility. **2 marks**

8.5 Body composition, coordination and reaction time

KEY CONCEPT Body composition, coordination and reaction time are considered fitness components, as they can impact performance. While they can be harder to test and train for specifically, they can still have a significant influence on performance.

Body composition refers to the relative proportions of bone, muscle and fat within the body.

Body composition

Body composition refers to the relative proportions of bone, muscle and fat within the body. Lean tissue is composed of muscle, bone and organs. Fat tissue is composed of essential and storage fats (both necessary for the body to function), and non-essential fat.

Interest in body composition mostly centres on how to measure lean body mass compared with body fat content. The accepted ranges of body fat considered safe for good health are:

- 5–18 per cent for males
- 12–25 per cent for females.

There is little evidence of any sporting performance or health benefits when males drop under 8 per cent body fat and women drop under 14 per cent body fat.

Factors affecting body composition

TABLE 8.7 Factors affecting body composition

Factor	Effect on body composition
Age	*As age increases (until mid 50s–60s), there is an increased likelihood of higher body fat content and decreased muscle mass.*
Sex	*Males are more likely to be obese than females but females are less likely to have high levels of muscle mass.*
Genetics	*Likely to be similar body composition to parents.*
Diet and physical activity levels	*Positive energy balance, where energy input is greater than energy output, will result in increased body fat.*

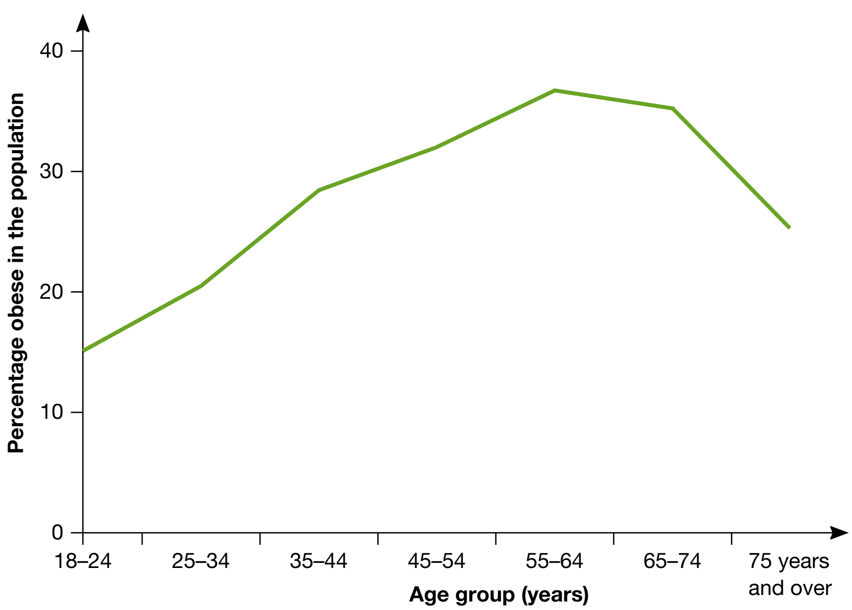


FIGURE 8.21 As age increases from 18 years old, the percentage of obese persons increases until approximately 55 years of age. (Data shown from 2011–12)

Body composition can be tested by:
- body mass index
- waist circumference
- skinfold measurements
- hydrodensitometry (underwater) weighing
- bioelectrical impedance and DEXA and TOBEC scans.

Underwater weighing is a sophisticated process that requires specialist, expensive equipment and complex calculations. However, it is considered 'the gold standard' (the most accurate) for body composition assessment. The process of hydrodensitometry requires the participant to be completely submerged within the weighing tank and to exhale all air possible while underwater. This type of assessment is for those with an invested interest in their body composition (see chapter 9 for more details).

In order to improve body composition, a variety of training methods can be used. Generally, aerobic training will help decrease fat and anaerobic training can help build muscle.

Coordination

Coordination is the ability to use different parts of the body together smoothly and efficiently.

It comes from the interaction of the neural, muscular and skeletal body systems. Coordination is a complex fitness component that requires sound levels of other fitness components such as strength, balance and agility. In sport, someone who appears well coordinated may also be described as having good timing.

Some sports require hand-eye coordination, some require foot-eye coordination and many require a combination of both.

Coordination is the ability to use different parts of the body together smoothly and efficiently.

FIGURE 8.22 Hockey requires excellent hand-eye coordination whereas soccer mainly relies on foot-eye coordination.

Coordination is of high importance when:
- performing dance, aerobics and ballet movements
- casting the shot in shotput
- hitting a cover drive for four runs in cricket
- scoring from a netball shot
- spiking in volleyball
- performing all routines in gymnastics.

If you have poor vision and hearing, it can affect your coordination. Experience and stage of development can also slightly affect coordination.

Reaction time

Reaction time is the time between a stimulus and the first response.

Reaction time is the time between a stimulus and the first response. The average reaction time is 0.2 seconds. Reaction time is the ability of the brain to react to various outside input sources, process them, select a response, then activate the expected muscular response.

A performer with better reaction time is usually the dominant player who appears controlled and rarely flustered and is usually able to impart maximum force to a desired movement. Faster reaction times allow the performer to be well positioned at the critical moments. Performers can improve their reaction time with specific training.

Reaction time is of high importance when:

- catching in the slips in cricket
- reacting to the starter's gun in a sprint race
- deciding which player is in the best position to receive a pass in basketball
- judging the probable direction of the ball from an opponent's back swing in tennis.

Reaction time can be tested using the ruler drop test or sport-specific tests.

Reaction time is generally improved through sport-specific training.

FIGURE 8.23 A wicket keeper or cricketer in slips requires a quick reaction time.

Factors affecting reaction time

TABLE 8.8 Factors affecting reaction time

Factor	Effect on reaction time
Age	*Reaction time increases with age (gets slower).* Fastest between the ages of 19 and 30
Sex	*Men will generally have a faster reaction time than women.*
Intensity of the cue	*Greater intensity = shorter reaction time as it is more easily detected.* Easier to detect therefore quicker to react to.

Factor	Effect on reaction time
Number of choices	*Simple Reaction Time — only one cue and one response* (therefore, the choice is simple) *Choice Reaction Time — more than one cue and one or more possible responses* The greater the number of choices a performer has, the greater the reaction time will be.
Probability of the cue occurring	*Anticipation/experience of cue occurring will reduce reaction time.*
Presence or absence of warning signs	*Presence of warning signs will reduce reaction time.* E.g. 'On your marks, set, go!'

TEST your knowledge

1 Define the term *body composition.*
2 Define the term *coordination*.
3 Define the term *reaction time*.
4 List three sports where reaction time may be more important than coordination.

APPLY your understanding

5 Rank the following actions or activities in order of importance with respect to reaction time. Rank them from 1 (very important) to 8 (not very important).
- 800-metre athletic race
- The uneven bar in women's gymnastics
- 50-metre sprint in Olympic swimming
- 100-metre swim in your school's inter-house swimming carnival
- The vault in gymnastics
- Netball
- Tennis
- Hockey

6 In small groups, design, test and assess your own unique static balance test.
7 Use the internet to search for reaction time tests. Then carry out three different tests and assess the value of each.

EXAM practice

8 **ACHPER Trial Exam 2015, question 7**
Body composition tests are designed to assess the proportion of body fat compared to lean tissue in an individual. Two recognised body composition tests are body mass index (BMI) and sum of skin folds. Evaluate the differences between these two tests and suggest the most appropriate test to be used by elite athletes. **3 marks**

studyon

Unit 4
AOS 1
Topic 2
Concept 5

Body composition, coordination and reaction time
Summary screen and practice questions

KEY SKILLS FITNESS COMPONENTS

- yellow identify the action word
- pink key terminology
- blue key concepts
- light grey marks/marking scheme

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Identify — determine the key characteristics or features
  Discuss — to go into detail about the characteristics of a key concept
- **Key terminology:**
  Factors that affect
  Action — golf swing
- **Key concepts:**
  Fitness components
- **Marking scheme:** *3 marks* — always check marking scheme for the depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

- **1 mark:** for identifying fitness component
- **1 mark:** for naming a relevant factor
- **1 mark:** for discussing how this factor links back to fitness component

KEY SKILL

- Analyse data to determine the major fitness components and the factors that affect them, and energy systems used in a variety of sporting events and physical activities

UNDERSTANDING THE KEY SKILL

To address this key skill, it is important to remember the following:

- Name and describe fitness components
- Identify and justify the importance of fitness components based on data
- Describe factors that affect each fitness component

PRACTICE QUESTION

a. **Identify** an important fitness component required to complete the action above. *(1 mark)*
b. **Discuss** a factor that affects the above fitness component. *(2 marks)*

SAMPLE RESPONSE

a. Flexibility
b. Joint type. The shoulder is a ball-and-socket joint allowing for increased range of movement, full golf swing, and therefore greater flexibility.

CHAPTER REVIEW FITNESS COMPONENTS

CHAPTER SUMMARY

- Fitness components are those aspects of fitness that should be performed to a reasonable level in any sport or activity.
- By addressing fitness components, as opposed to ‘fitness’, assessment can be more specific.
- Aerobic-based fitness components include aerobic power, muscular endurance and flexibility.
  - Aerobic power is the maximum rate of energy production from the aerobic energy system.
  - Muscular endurance is the ability of a muscle or group of muscles to sustain repeated contractions against a resistance for an extended period of time.
  - Flexibility is the range of movement around a joint.
- Anaerobic-based fitness components include agility, anaerobic capacity, muscular power, muscular strength and speed.
- Agility is a combination of flexibility and speed, which allows the performer to change direction with maximal speed and control.
- Anaerobic capacity is the total amount of energy obtainable from the anaerobic energy systems (the combined capacity of the ATP-CP system and anaerobic glycolysis system).
- Muscular power is the ability of a muscle or group of muscles to exert a maximum amount of force in the shortest period of time.
- Muscular strength is the peak force that a muscle can develop.
- Speed is defined as the ability to move the body or part of the body from one point to another as quickly as possible.
- Balance, reaction time and coordination are fitness components that are determined by the interaction between an individual’s mental processes and muscular movements.
  - Balance is the ability of the body to remain in a state of equilibrium while performing a desired task.
  - Reaction time is the time between a stimulus and the first response. The average reaction time is 0.2 seconds.
  - Coordination is the ability to use different parts of the body together smoothly and efficiently.
- Body composition can impact a person’s performance in an activity. Different body compositions tend to lend themselves to different sports.
- Age, sex and the percentage of fast or slow muscle fibres significantly affect most fitness components.

eBook*plus*

Interactivity
Fitness components quiz
Searchlight ID: int-6806

studyon

Sit VCAA exam

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 The ability to utilise oxygen to generate energy is called
(A) anaerobic capacity.
(B) muscular endurance.
(C) aerobic capacity.
(D) aerobic power.

2 Which of the following events is most likely to rely predominately on muscular power?
(A) 100-metre sprint
(B) Shot put
(C) Weightlifting
(D) 400-metre sprint

3 Which of the following best describes the relationship between muscle fibre type and anaerobic capacity?
(A) A 50/50 percentage of slow- and fast-twitch fibres will result in the greatest anaerobic capacity
(B) The greater the percentage of slow-twitch fibres, the greater the anaerobic capacity
(C) The greater the percentage of fast-twitch fibres, the lower the anaerobic capacity
(D) The greater the percentage of fast-twitch fibres, the greater the anaerobic capacity

4 A one-off maximal effort against resistance requires which fitness component?
(A) Muscular power
(B) Speed
(C) Muscular strength
(D) Balance

5 Agility does not rely on which other fitness component(s)?
(A) Speed
(B) Balance
(C) Coordination
(D) Flexibility

6 Who is likely to generate the greatest speed?
(A) An individual with 85 per cent fast-twitch muscle fibres
(B) An individual with 85 per cent slow-twitch muscle fibres
(C) A 50-year-old male
(D) A 50-year-old female

7 Dynamic flexibility is
(A) flexibility around all joints.
(B) flexibility when moving.
(C) flexibility when stationary.
(D) flexibility done at the end of a training session.

8 Which of the following best describes an endomorph?
(A) More body fat than muscle
(B) More muscle than body fat
(C) Little fat and muscle
(D) Lots of fat and muscle

9 Reaction time is closely linked to which body system?
(A) Cardiovascular system
(B) Central nervous system
(C) Respiratory system
(D) Muscular system

10 Females tend to have a physiological advantage over males of similar age in which fitness component?
(A) Flexibility
(B) Aerobic power
(C) Muscular power
(D) Anaerobic capacity

TRIAL EXAM QUESTIONS

Question 1 **(ACHPER Trial Exam 2013, question 9 b and c)**

Claire and Rachel are Year 12 Physical Education students. Claire likes to swim and wants to design a training program that will improve her 400 m freestyle time. Her best time is 5 minutes 20 seconds but Claire would like to improve by 10 seconds and swim 5 minutes 10 seconds. Rachel competes with a local athletics club and wants to improve her 1500 m run time. Her best time is 5 minutes and she believes that with a well-designed training program she can improve her time to 4 minutes and 50 seconds.

Both girls undertook four fitness tests as part of their pre- and post-testing battery.

Fitness component	Claire	Rachel
Aerobic capacity	Harvard step-test	20-metre shuttle run test
Flexibility	Shoulder and wrist elevation test	Sit-and-reach test
Muscular endurance	Timed situp test	Timed situp test
Muscular strength	1 RM bench press test	1 RM leg press test

a. Explain why Claire chose a different flexibility test to Rachel. **1 mark**

b. Flexibility decreases as we age. What are two other factors that affect flexibility? Provide an explanation as to how each factor affects this fitness component. **4 marks**

Factor 1: ______________________________

Explanation: ______________________________

Factor 2: ______________________________

Explanation: ______________________________

Question 2

a. Complete the table below showing an understanding of muscular strength, power and endurance. **5 marks**

Component of fitness	Description	Example of a recognised fitness test
Muscular power		Vertical jump
		1 RM bench press
	Ability of a muscle or muscle group to perform repeated muscular contractions	

b. List two factors and explain how each factor affects the strength of a muscle. **4 marks**

INQUIRY QUESTION

Why do we use fitness tests and what needs to be taken into consideration when deciding on a specific fitness test?

CHAPTER

9 Fitness assessment: rationale and tests

Fitness tests need to be chosen carefully and administered in an appropriate way for results to be meaningful.

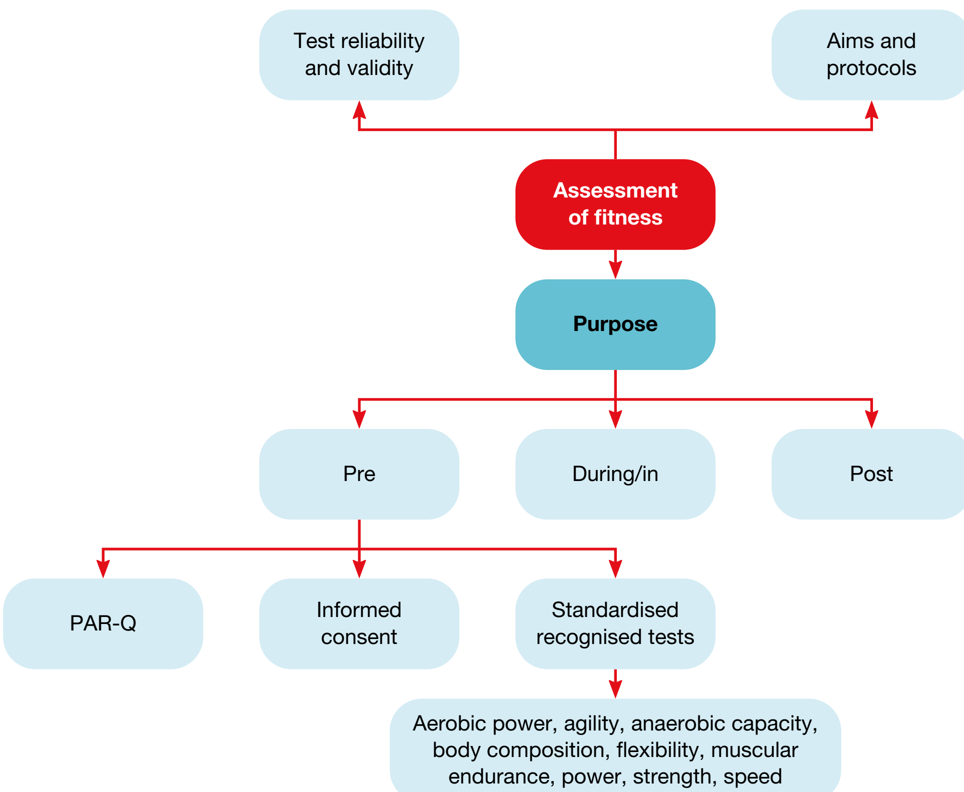
KEY KNOWLEDGE

- Assessment of fitness including:
  - the purpose of fitness testing including physiological, psychological and sociocultural perspectives
  - pre-participation health screening (PAR–Q)
  - informed consent
  - test aims and protocols
  - test reliability and validity
- Methods of at least two standardised, recognised tests for aerobic power, agility, anaerobic capacity, body composition, flexibility, muscular endurance, power and strength and speed

KEY SKILLS

- Determine an appropriate fitness testing regime based on the physiological, psychological and sociocultural needs of the individual and the requirements of the activity
- Conduct a valid and reliable assessment of fitness using ethical protocols
- Perform, observe, analyse and report on practical laboratory exercises designed to assess fitness prior to designing a training program
- Justify the selection of fitness tests in relation to the physiological, psychological and sociocultural requirements of the test subject

CHAPTER PREVIEW



9.1 The types of fitness testing

KEY CONCEPT After activity analysis is completed, and you have identified the physiological requirements important to the activity, fitness testing can occur. It can be completed at multiple stages within a training program to ensure specificity, and ultimately, success.

Types of fitness testing

There are a number of different tests that can be used to assess fitness. These are often chosen based on the needs of the participant(s). For a test to be accurate, it needs to be completed free from error. This is very difficult to do. Even with specialised equipment, the equipment needs to be calibrated to each participant and for every test for maximal accuracy. This can be time-consuming and expensive.

Sometimes accuracy is not as important as practicality; for example, a local club coach may need to test a large number of players to motivate them at the beginning of the season. In this instance, practicality will be more important than accuracy.

In-laboratory tests

In-laboratory tests are fitness tests that are carried out under controlled sports-science laboratory conditions.

In-laboratory tests are those tests conducted under clinical laboratory conditions. They are the preferred means of assessing fitness components (especially for elite participants) because they often provide the most accurate indication of functional abilities. However, laboratory tests often require the use of expensive and sophisticated equipment, controlled environments, qualified personnel and take considerable time to complete, which can limit their accessibility and therefore their use. An example of such a state-of-the-art fitness testing program is the annual AFL draft selection camp at the Australian Institute of Sport (AIS) in Canberra. This testing has also been used to identify potential participants for the women's AFL draft.

FIGURE 9.1 The AFL uses laboratory testing to get reliable and accurate results to identify potential draftees.

Field tests

The alternative to laboratory testing is a carefully chosen battery of easily administered **field tests**, using readily available and inexpensive equipment. Such tests, although not as precise as laboratory tests, can provide estimates or predictions of fitness levels. They also allow simultaneous testing of large groups. Field tests are the type of fitness test that you will most often use in your Physical Education classes. Most fitness testing completed in a senior Physical Education class will be field tests where students undertake their own fitness testing under the observation of a classmate.

Field tests are fitness tests that are carried out in team training or class activity settings.

Direct tests

Direct tests are considered a very accurate measure of fitness. Direct tests are those that provide an immediate measure of the fitness component. The best example of a direct test is a VO_2 max. test, where the test gives the VO_2 value in L/min.

These are highly accurate and individualised but often require specialised equipment and are completed in laboratories, which can make this form of testing less practical.

Indirect tests

Unlike direct tests, indirect tests provide a result that can then allow an estimation or prediction to occur, generally using normative data (norms), in order to determine the measure of the fitness component. These tests are less accurate as they are compared to norms and are not individualised; however, they are far more practical, especially with large groups. Most field tests are indirect tests. An example of an indirect test is the multi-stage fitness test, where the level achieved can be used to predict a VO_2 max. value.

Maximal tests

While most tests require the subject to contribute their 'best' efforts, maximal tests are those that require subjects to work until exhaustion. This is generally associated with aerobic power tests. The best example of a maximal test is the VO_2 max. test. Maximal (or exhaustive) tests provide the most accurate means of determining maximum oxygen uptake.

VO_2 max. testing

VO_2 max. tests (treadmill, bicycle ergometer and rowing ergometer) are direct maximal tests.

Participants work to exhaustion by progressively increasing their workload on a treadmill, bicycle ergometer, rowing ergometer or other sport-specific ergometer. The workload on a treadmill, for example, can be altered by increasing both the speed and incline.

The individual is attached via a mouthpiece to a device and computer that continuously collect and analyse the expired air and calculate the amount of oxygen used. The test continues until the individual's oxygen consumption reaches a plateau or they indicate that they are unable to continue (usually the latter).

Results of VO_2 max. can be given in absolute or relative forms. An absolute figure provides L/min whereas a relative figure is given in mL/kg/min. A relative figure allows better comparison between participants as it takes into account the participant's weight.

Submaximal testing

Submaximal tests measure a subject's efforts at certain intensity levels, below maximal, and then predict maximal capacity. Like maximal testing, this term is generally only used for aerobic power tests. Given the need for sophisticated and expensive equipment and other constraints of the maximal laboratory tests, a number of submaximal tests have been developed to provide a predictive value for maximum oxygen uptake. The individual works to a preset submaximal level and the results are used to estimate this value.

Submaximal tests to measure aerobic power use either physiological markers that highly correlate with maximum oxygen uptake (e.g. the heart rate response to submaximal exercise) or other measures of endurance performance (e.g. the distance run in a set time). Several cycle ergometer and step tests use heart rate responses, either during or after the exercise, as the basis for predicting maximum oxygen uptake. Such tests are based on the linear relationship between heart rate and oxygen uptake. A similar relationship exists between exercise intensity and oxygen uptake (see chapter 6).

It is important that students are aware of types of recognised **standardised tests** for aerobic power, agility, anaerobic capacity, body composition, flexibility, muscular endurance, power and strength, and speed.

Standardised tests follow clear protocols that allow them to be confidently and successfully repeated.

TEST your understanding

1 Using an example, outline what a laboratory fitness test is.
2 Using an example, outline what a field fitness test is.
3 Give examples of a maximal and a submaximal test for aerobic power.
4 Discuss the differences between a direct and indirect test, using examples.
5 Describe the most accurate form of testing.
6 Define the term *standardised fitness test*.

APPLY your understanding

7 Watch the videos found using the **Fitness tests** weblinks in your eBookPLUS.
(a) List the tests completed and the fitness component each was testing.
(b) Identify what type of test each test is.
(c) Discuss the accuracy and practicality of each test.
(d) Discuss any limitations of the testing.

EXAM practice

8 Identify and justify what type of testing is most likely to be used by a Year 12 Physical Education class to test aerobic power. **3 marks**

studyon
Unit 4
AOS 1
Topic 3
Concept 1
Types of fitness testing
Summary screen and practice questions

eBook*plus*
Weblinks
Fitness tests

9.2 The purpose of fitness testing

KEY CONCEPT When using fitness testing for training, the purpose is to ensure specificity and success. However, the specific purpose depends on the stage within the training program at which the testing is performed.

Pre-training program testing

Fitness testing before the season, once activity analysis is completed, should be performed as a minimum to ensure specificity. The results of pre-testing should provide the blueprint for the training program.

Pre-training program fitness testing aims to achieve the following goals.

Assess strengths and weaknesses of participants

Fitness tests identify an individual's strengths and weaknesses in the major components of fitness that are important to a particular sport or activity. This information allows the design of a specific individual training program that is geared to maintaining strengths and improving weaknesses.

Motivate participants

Fitness test results that outline specific capacities and attributes, and identify individual strengths and weaknesses, can provide strong motivation and incentive for participants to continue training and to strive for improvement. This is particularly likely if the results are positively and constructively presented. Fitness testing is a way of predicting future performance and allowing the participant to know to what level they can realistically aim.

Assess suitability of participants to a sport or position

Fitness test results enable participants to ascertain their capacity to perform certain tasks. The tests can indicate specific personal attributes that the participant and coach can use to help determine the types of event or playing position to which the player is best suited. A soccer player who scores highly in a test of aerobic power, for example, may be best suited to playing as a midfielder or on-baller — roles that involve covering greater distances in the game — rather than in a set position such as goalie.

Set benchmarks

Collecting data from pre-training testing can allow the participant and coach to set 'benchmarks' for training. This data can also be referred to as baseline data. Collection of baseline data allows realistic and specific goals to be set and accurate evaluation to occur. This can be done at an individual level or a group level for team sports.

Testing during training

Fitness testing during a training program can help coaches evaluate how the participant and training program are going. The number of times testing is undertaken will depend on the length of the program. Testing should not occur any earlier than six weeks into a training program to allow chronic adaptations to occur (see chapter 12).

Testing during training aims to:

- motivate participants. Participants may have set goals and testing results may encourage the participant to maintain or improve in order to achieve their goal.
- evaluate the effectiveness of the program. Testing results will indicate if there have been improvements in fitness components. If the training program is effective, improvements would be expected. If this has not occurred, then the training program will need to be modified.

This type of feedback is vital in monitoring progress and training efficiency, as well as driving necessary modifications.

eBook*plus*

Digital doc
Pre-test checklist for testing in the laboratory'
Searchlight ID: doc-22229

Post-program testing

Post-program testing is completed once the training program is over. This provides vital information for the participant about the impact of the training program.

Post-training testing aims to:

- evaluate the effectiveness of the training program. If the training program has achieved its aims, it would suggest the methods and principles (chapter 11) have been applied correctly and that a similar process should be put in place for the next training program. If the training program has failed to achieve its aims, it would suggest significant modifications are required. This would involve reviewing the methods and principles put in place.
- review benchmarks. This will help determine how effective the program has been and also help in the preparation of future programs.
- motivate participants. Participants may be motivated by either positive or negative results.

The reason for testing will differ depending on when, during the training program, the fitness testing is undertaken.

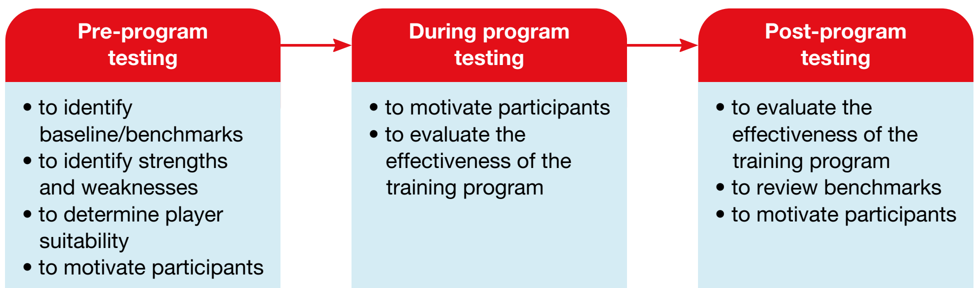


FIGURE 9.2 Reasons for fitness testing

Choosing fitness tests

There are a number of factors that need to be considered when choosing appropriate fitness tests. As previously mentioned, the tests should replicate the requirements of the activity as identified in the activity analysis. Other considerations include the physiological, psychological and sociocultural perspectives.

Physiological perspectives

Fitness tests should be chosen taking into account physiological perspectives such as current fitness and health conditions. One of the most effective ways to gain information about the physiological state of a subject is through pre-participation health screening: PAR-Q.

Pre-participation health screening, most often done through a PAR-Q, is a vital component of fitness testing, particularly pre-training program testing. Pre-participation screening involves a series of questions about the participant's current health. These often include questions about heart health, previous and current injuries and current exercise levels. This information can then be analysed to determine if fitness testing could be a risk for the individual. It can also be used to determine the level of risk and choose appropriate tests.

For example, you would not ask an overweight 50-year-old to complete a VO_2 max. test or multi-stage fitness test — rather you may choose the Rockport 1.6 km walk. An overweight 50-year-old is unlikely to have high levels of aerobic power, so completing the VO_2 max. test or multi-stage fitness test, which are exhausting in nature, may be physically dangerous for them. In contrast, the Rockport 1.6 km walk is a submaximal test and is therefore unlikely to put the participant at risk.

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of <u>any other reason</u> why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q:</u> The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ______________________________
SIGNATURE ______________________________ DATE ______________
SIGNATURE OF PARENT ______________________ WITNESS______________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

FIGURE 9.3 PAR-Qs should be used as a minimum for pre-participant screening.

Psychological perspectives

Like physiological perspectives, the current psychological state of a subject may influence the effectiveness of testing and should therefore be considered carefully when choosing appropriate fitness tests. Knowing the purpose of the testing for the individual is an important step in this.

A participant who wants to know their strengths and weaknesses may choose different tests to someone who is starting their first gym program. A coach and a personal trainer will test for different reasons and thus the tests chosen may differ.

A questionnaire, similar to a PAR-Q, can be used to determine the psychological state of the participant. Collecting such information is not only important in managing risks but can also provide vital information about the participant's motivation and goals, which can help when choosing specific tests.

eBook*plus*

Digital document
Pre-test screening questionnaire
Searchlight ID: doc-22227

For example, a participant who is undertaking testing and a training program to improve their overall health and wellbeing is more likely to undergo the seven-stage abdominal strength test than a 1 RM bench press. A participant wanting to improve their athletic performance for rugby is more likely to undergo a 1 RM test.

For an example of an adult pre-test screening questionnaire from Exercise and Sports Science Australia, go to the **Pre-test screening questionnaire** digital document in your eBookPLUS.

Sociocultural perspectives

It is important to recognise that sociocultural factors can affect the fitness tests that are available for use. When choosing a test, it is important to consider the resources available. Low socioeconomic status can restrict the number of tests available for use; for example, when measuring body composition, DEXA and TOBEC scans are expensive, so waist circumference measurements may have to be used instead. Whether you are testing an individual or a group will also impact your choice of test; for example, the 30-second Wingate test can only test one person at a time, whereas the phosphate recovery test can test large groups at once. In some cultures it is not appropriate for women to expose skin, especially in the company of males, so to measure body composition, skinfold measurements would not be appropriate but body mass index would be. When choosing fitness tests, you should be able to justify your choice considering these factors.

Fitness tests test battery

Testing sessions should be scheduled to coincide with the beginning and end of each training phase so that the effectiveness of the training phase can be assessed. Likewise, if a specific intervention has been programmed, pre- and post-testing is recommended to assess the impact of the intervention.

All test sessions should be scheduled at the same time of day to avoid fluctuations in physiological responses due to circadian rhythm (Winget et al. 1985) and to promote consistency in how the participant presents themself for each test session.

It is recommended that the field tests be completed in a standardised order. This order should be determined in light of physiological considerations; that is, the completion of one test should not adversely affect performance in subsequent tests, thus promoting optimal performance and allowing for a valid comparison to previous test results. This test order will also require minimal recovery time between tests, thus allowing for an overall efficient testing session.

For example:

Day 1: vertical jump, 20 m sprint, Illinois agility test, multi-stage fitness test, yo-yo test

Day 2: phosphate recovery test.

TEST your understanding

1 Outline two reasons for pre-training program testing.
2 Outline two reasons for post-training program testing.
3 Discuss why six weeks of training is recommended between testing.
4 List three factors that should be taken into consideration when choosing fitness tests.

APPLY your understanding

5 Identify and justify the best aerobic power test for a Year 12 class of 25 students studying basketball.
6 Explain the purpose of a PAR-Q.
7 Discuss how testing mid-training program can be motivating.
8 Explain the importance of planning the order of fitness testing.

EXAM practice

9 Justify the use of field tests for a Year 12 class based on a psychological and sociocultural perspective. **2 marks**

study on

Unit 4	**Purpose of fitness testing**
AOS 1	Summary screen
Topic 3	and practice
Concept 2	questions

9.3 How to conduct fitness testing

KEY CONCEPT Successful fitness testing relies on sound procedures. There are many tests available for assessing each of the fitness components. It is therefore important to select tests carefully to ensure that the testing is valid, accurate and pertinent to the needs of the participant.

Test protocols

Ensuring the participant has a clear understanding of the testing process will help the subject, no matter the purpose, prepare from a psychological perspective. Players' rights and facilitators' responsibilities are an essential aspect of fitness and training. Before any fitness tests are carried out, it is essential that all facilitators clarify all testing procedures and risks to their participants. Participants should be clearly informed about the nature of the fitness for sporting situation testing they are being directed to undertake, including:

- aims of testing
- methods of testing
- safeguards for testing (those responsible for managing fitness testing procedures must be qualified and experienced in all fitness-testing protocols).

The best way to ensure the above is to get the participants' informed consent.

studyon
Unit 4 | AOS 1 | Topic 3 | Concept 3
Conducting fitness tests
Summary screen and practice questions

studyon
Unit 4 | AOS 1 | Topic 3 | Concept 4
Test aims and protocols
Summary screen and practice questions

Informed consent

Most accredited fitness centres now have standard forms for their clients to complete that give their acknowledgement of risks associated with the fitness testing and training programs they are about to undertake (see figure 9.4). These forms may also acknowledge that all fitness test results are confidential and only to be used for agreed personal fitness or sports training outcomes. Informed consent aims to protect the interests of both the testing organisation and subjects. It has both legal and ethical implications.

Informed consent should:

- clearly identify the testing organisation and the departments or individuals involved in conducting the testing
- clearly explain the nature of any sport science test to be performed. This should include any possible risks.

INFORMED CONSENT FOR EXERCISE TESTING

I hereby voluntarily give consent to engage in a fitness test. I understand that the cardiovascular fitness test will involve progressive stages of increasing effort and that at any time I may terminate the test for any reason. I understand that during some tests I may be encouraged to work at maximum effort and that at any time I may terminate the test for any reason.

I understand there are certain changes that may occur during the exercise test. They include abnormal blood pressure, fainting, disorders of heart beat, and very rare instances of heart attack. I understand that every effort will be made to minimise problems by preliminary examination and observation during testing.

I understand that I am responsible for monitoring my own condition throughout testing, and should any unusual symptoms occur, I will cease my participation and inform the test administrator of the symptoms. Unusual symptoms include, but are not limited to chest discomfort, nausea, difficulty in breathing, and joint or muscle injury.

Also, in consideration of being allowed to participate in the fitness test, I agree to assume all risks of such fitness testing, and hereby release and hold harmless ___________________________, and their agents and employees, from any and all health claims, suits, losses or causes of action for damages, for injury or death, including claims for negligence, arising out of or related to my participation in the fitness assessments.

I have read the foregoing carefully and I understand its content. Any questions that may have occurred to me concerning this informed consent have been answered to my satisfaction.

Name	Date
Witness	Date

FIGURE 9.4 Most accredited fitness centres have standard release forms.

- clearly outline that the individual can withdraw consent, freely and without prejudice, at any time before, during, or after testing
- outline the specific uses of the information obtained from the testing sessions and insure that the confidentiality of information obtained during testing will be protected
- require participants to advise the tester if they have any injury, illness, or physical defect at the time of testing. Ideally also complete a PAR-Q (see figure 9.3).
- outline the risks of the testing
- obtain the participant's signature. When the participant is less than 18 years of age and the consent of a parent or guardian is required, the consent documentation should provide a statement for the parent or guardian to sign.

Test reliability and validity

An appropriate fitness test must be valid; that is, it should measure what it claims to measure. If a test claims to measure aerobic power, for example, then it should be of sufficient duration to test the capacity of this energy system.

A fitness test must also be reliable — it must be able to be replicated with consistancy. For a test to be reliable, the only variable that should change between tests is the participant. Reliability depends on a number of factors remaining constant, so the following elements are vital (as far as possible) on each test occasion:

- performing the same warm-up
- conducting the same sequence of tests
- providing the same recovery period between tests
- testing the participant at approximately the same time of day
- testing the participant when they are in a similar hydration and nutritional state
- conducting the tests in similar environmental conditions (heat, humidity and air movement).

Trained and experienced administrators of the tests are also required to ensure reliability. It is important that the person conducting the testing always does so to the best of their ability, under the most stable and reliable conditions.

The results of the selected tests must be interpretable and comparable, and the participant should receive feedback about:

- what the results represent (good, average or poor performance)
- how the results compare with previous results
- how the results compare with those of other participants in the reference group
- the consequences and implications of the results.

studyon

Unit 4	**Test reliability and validity** Summary screen and practice questions
AOS 1	
Topic 3	
Concept 5	

TEST your understanding

1 Outline the essential criteria for successful fitness testing.
2 List the ways to ensure a fitness test can be accurately repeated after a period of weeks or months.
3 Discuss the importance of informed consent.
4 Suggest two situations where informed consent may need to be gained from someone other than the participant.

APPLY your understanding

5 **Practical activity: protocols of fitness testing (fitness centre)**
In groups, visit a local fitness centre and interview management staff on their centre's procedures for conducting fitness testing with their clients. Ask for samples of any paperwork used. Write a report that assesses the centre's methods.

EXAM practice

6 Outline three ways in which a testing facilitator can ensure testing can be completed with minimal risks. **3 marks**

9.4 Fitness tests

KEY CONCEPT Fitness tests should be chosen based on the activity analysis. There are multiple tests for each fitness component and each test should replicate the requirements (movement patterns and muscle movements) of the activity and meet the physiological, psychological and sociocultural needs of the individual.

TABLE 9.1 Recognised standardised tests

Fitness component	Test
Aerobic power	Multi-stage fitness test Yo-yo test Cooper 12-minute run test 2.4 km run test Rockport 1.6 km walking test VO_2 max. Astrand–Ryhming cycle ergometer test VO_2 max. treadmill test Harvard step-test
Agility	Illinois agility test Semo agility test 5-0-5 agility test
Anaerobic capacity	Phosphate recovery test 30-second Wingate test Repco peak power test
Body composition	Body mass index Waist circumference Skinfold measurements Hydrodensitometry (underwater) weighing Bioelectrical impedance DEXA and TOBEC scans
Flexibility	Trunk flexion (sit-and-reach) test Trunk rotation test Groin flexibility test Shoulder and wrist elevation test Trunk and neck extension test Ankle extension/dorsiflexion test Shoulder rotation test
Muscular	
Endurance	60-second pushup test 30-second situp test Curlup (crunch) test Pullup/modified pullup test Flexed arm hang test
Power	Basketball throw Vertical jump Standing long jump Magaria Kalamen stair sprint test
Strength	1 RM (bench press, back squat, leg press) Grip strength dynamometer Push–pull dynamometer Seven-stage abdominal strength test
Speed	20-metre sprint test 35-metre sprint test 50-metre sprint test

studyon
Unit 4
AOS 1
Topic 3
Concept 6
Fitness tests
Summary screen and practice questions

Aerobic power tests

Aerobic power — the rate at which aerobic metabolism can supply energy through the use of the aerobic pathway — can be assessed in a number of ways. An individual can ascertain the efficiency of their aerobic pathway by assessing their maximum oxygen uptake. Maximal aerobic power can be determined by either maximal tests, in which the individual works to their maximum or exhaustion, or submaximal tests, in which the individual works less intensely to determine a predicted maximum oxygen uptake.

Multi-stage fitness test

The multi-stage fitness test (also known as the beep test) was developed by Leger and Lambert. The nature of the short runs and turns in this test link closely with most team sports, but they are not a good indicator for sports that require consistent motion such as cycling, running or rowing.

Aim

To keep up with the beeps for as long as possible

Equipment

- Flat 20-metre stretch of suitable floor space
- Marking cones
- Multi-stage fitness test audio recording

Method

1. Measure out a 20-metre section of floor space (the shuttle).
2. The participant must arrive at the end of the shuttle before the beep.
3. For the first minute the beeps on the audio recording will sound at the rate for the participant to travel at a speed of 8.5 kilometres per hour, and will then increase in speed by 0.5 kilometres per hour each minute following.
4. When the participant fails to arrive at the end of the shuttle by the beep they withdraw and their level is recorded.

eBook*plus*

Interactivity
Multi-stage VO_2 calculator
Searchlight ID: int-6808

Results

1. Enter the participant's results into the **Multi-stage VO_2 calculator** interactivity in your eBookPLUS.
2. Consult the ratings in table 9.2 for the participant's aerobic fitness level.

TABLE 9.2 **Maximal oxygen uptake (VO_2 max.) norms for men and women 18–35 (mL/kg/min)**

	Age (years)			
	Males		Females	
Rating	18–25	26–35	18–25	26–35
Excellent	> 60	> 56	> 56	> 52
Good	52–60	49–56	47–56	45–52
Above average	47–51	43–48	42–46	39–44
Average	42–46	40–42	38–41	35–38
Below average	37–41	35–39	33–37	31–34
Poor	30–36	30–34	28–32	26–30
Very poor	< 30	< 30	< 28	< 26

It is important to note that different sports will have different means and ranges for aerobic power. For example, the AIS lists the norms shown in table 9.3a for AFL, tennis and hockey at the national level.

TABLE 9.3a Multi-stage fitness test norms (level achieved) for various sports according to the AIS

Sport	Sex	Age	Mean score
AFL — AIS	Male	Approx. 18	13.5
Hockey — national	Female	U21	11.9
Hockey — national	Male	U21	14.9
Tennis — national	Female	16+	11.2
Tennis — national	Male	16+	13.4

TABLE 9.3b Beep test norms for young people aged 16–25

Male							
16–17 yrs	< 5/1	5/1–6/8	6/9–8/2	8/3–9/9	9/10–11/3	11/4–13/7	> 13/7
18–25 yrs	< 5/2	5/2–7/1	7/2–8/5	8/6–10/1	10/2–11/5	11/6–13/10	> 13/10
Female							
16–17 yrs	< 4/2	4/2–5/6	5/7–7/1	7/2–8/4	8/5–9/7	9/8–11/10	> 11/10
18–25 yrs	< 4/5	4/5–5/7	5/8–7/2	7/3–8/6	8/7–10/1	10/2–12/7	> 12/7

Note: The results are presented as the level number followed by the number of shuttles.

Yo-yo test

Aim

To keep up with the audio recording as long as possible

Equipment

- Measuring tape
- Cones/markers
- Yo-yo audio recording

Method

1. Measure out a 20-metre test course as per figure 9.5.

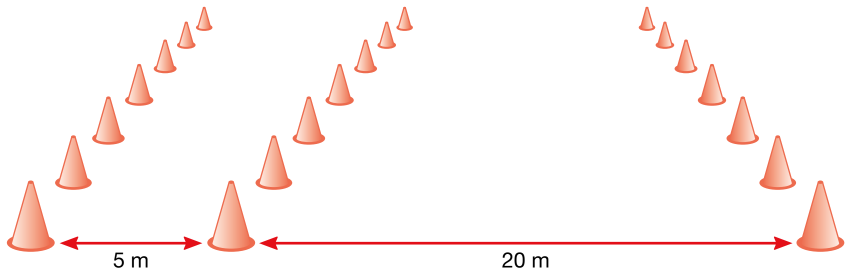


FIGURE 9.5 Set up for the yo-yo intermittent recovery test

2. Place markers 2 metres apart at both ends of the 20-metre test course (i.e. at start and turning lines).
3. In addition to marking the 20-metre line, measure out a 5-metre distance behind the start line.

4. Place a marker on the recovery line aligned to the middle of the two markers on the start line.
5. Participants assume a starting position on the start line.
6. The yo-yo test audio is started. (There are two levels of audio available: level 1 is for beginners and level 2 is advanced. For VCE Physical Education, level 1 is recommended.)
7. At the time of the first signal, the participants run forward to the turning line. At the sound of the second signal, participants arrive and turn at the turning line and then run back to the start line arriving on the next beep. When the start marker is passed, the participants continue forward at a reduced pace (jogging) toward the 5-metre mark, where they then turn around the cone and return to the start line. At this point, the participants stop and wait for the next signal to sound. It is important that the participants are stationary on the start line before the commencement of each sprint.
8. Participants are required to place one foot either on or over the start or turning lines at the sound of each beep.
9. Participants should continue running for as long as possible, until they are unable to maintain the speed as indicated by the audio.
10. The end of the test is indicated by the inability of a participant to maintain the required pace for two trials. The first time the start line is not reached, a warning is given; the second time the participant must withdraw.
11. When the participant withdraws, the last level and the number of 2×20-metre intervals performed at this level are recorded on the appropriate recording sheet. (The last 2×20-metre interval is included, even if the participant did not complete at the right pace.) For valid results, participants must attempt to reach the highest level possible before stopping.
12. Yo-yo test predicted VO_2 max. (mL/kg/L min^{-1}) = IRTl distance (metres) $\times$ 0.0084 + 36.4

   See VO_2 max. norms, table 9.2.

   For example:

   17-year-old female achieves a score of 15.6 = 1000 metres

   $1000 \times 0.0084 + 36.4 = 44.8$ mL/kg/min

   This would be considered good.

eBook*plus*

Interactivity
Yo-yo test calculator
Searchlight ID: int-6809

Results

TABLE 9.4 Yo-yo test norms

Level 1 norms for adult men and women

	Males		Females	
Rating	**Metres**	**Level**	**Metres**	**Level**
Elite	> 2400	> 20.0	> 1600	> 17.5
Excellent	2000–2400	18.7–20.0	1280–1600	16.5–17.5
Good	1520–2000	17.3–18.7	1000–1280	15.6–16.5
Average	1000–1520	15.6–17.3	680–1000	14.6–15.6
Below average	520–1000	14.2–15.6	320–680	13.1–14.6
Very poor	< 520	< 14.2	< 320	< 13.1

Level 2 norms for adult men and women

	Males		Females	
Rating	Metres	Level	Metres	Level
Elite	> 1280	> 16.5	> 800	> 15.1
Excellent	1000–1280	15.6–16.5	720–800	14.7–15.1
Good	720–1000	14.7–15.6	480–720	14.1–14.7
Average	480–720	14.1–14.7	360–480	13.2–14.1
Below average	280–480	12.3–14.1	160–360	11.2–13.2
Very poor	< 280	< 12.3	< 160	< 11.2

It is important to note that different sports will have different means and ranges for aerobic power. For example, the AIS has the following norms for the following sports at the national level.

TABLE 9.5 **Yo-yo test norms for various sports according to the AIS**

Sport	Sex	Age	Mean level
Netball — national	Female	U17	15.7
Soccer — national	Male	U17	20.6
Basketball— state	Female	U17	15.6
Basketball — state	Male	U17	16.2

Cooper 12-minute run test

Dr Kenneth Cooper devised this test in 1968 and its popularity reflects its ease of implementation. It is based on the assumption that an individual will run a greater distance within the time limit if they have a well-developed aerobic capacity.

Aim

To run as far as possible in 12 minutes

Equipment

- Athletics track or oval, preferably with a lap length of 200–400 metres.
- One marking cone for every 20 metres of track
- Stopwatch
- Measuring wheel to calculate lap distance and intervals
- Whistle

  Note: If students have access to a tracking technology such as an app or GPS watch, these can be a more efficient method of measurement.

Method

1. Place cones every 20 metres for easy calculation of distance covered.
2. The participant aims to complete as many laps as possible within the 12-minute time limit by running.

3. When the whistle blows to end the time period, the participant walks to the nearest marker.
4. Calculate the number of laps completed and the number of metres covered in the final lap.

Results

1. Calculate and record the total metres covered.
2. Consult the ratings in table 9.6 for the participant's aerobic fitness level.

TABLE 9.6 Ratings for Cooper's 12-minute run test (metres covered)

Rating	Males aged 15–16 years	Females aged 15–16 years	Males aged 17–19 years	Females aged 17–20 years
Excellent	> 2800	> 2100	> 3000	> 2300
Above average	2500–2800	2000–2100	2700–3000	2100–2300
Average	2300–2499	1700–1999	2500–2699	1800–2099
Below average	2200–2299	1600–1699	2300–2499	1700–1799
Poor	< 2200	< 1600	< 2300	< 1700

2.4 km run test

Aim

The aim of this test is to complete the 2.4 km course in the shortest possible time.

Equipment

- 2.4 km flat and hard running course
- Stopwatch

Method

1. Participants line up behind the starting line
2. On the command 'go,' the clock is started and they begin running at their own pace.
3. Time stops when participant reaches 2.4 km.
4. Although walking is allowed, it is strongly discouraged.

Results

You can predict VO_2 max. from the test, where VO_2 max. units is mL.kg.min^{-1}, and time in minutes.

$$VO_2\ max. = (483/\text{time}) + 3.5$$

Compare to relevant VO_2 max. norms (see table 9.2).

Rockport 1.6 km walking test

Aim

The purpose of this test is to walk as fast as possible for 1.6 km (1 mile).

Equipment

- Flat 1.6 km track
- Stopwatch
- Heart rate monitor (if possible)

Method

1. Walk for 1.6 km and record the time taken.
2. After you have completed the distance, immediately take your heart rate.

If you do not have a heart rate monitor, you can manually count the number of beats for 20 seconds (using carotid or wrist pulse), and then multiply that by three to get your minute heart rate.

Results

Use the time taken, your body weight in pounds (1 kg = 2.20462 pounds), age and finishing heart rate in the following equation.

Females: VO_2 = 139.168 – (0.388 × age) – (0.077 × weight in lb.) – (3.265 × walk time in minutes) – (0.156 × heart rate)

Males: add 6.318 to the equation for females above.

Compare to relevant VO_2 max. norms (see table 9.2).

eBook*plus*

Interactivity
Rockport 1.6 km walking test calculator
Searchlight ID: int-6813

Astrand–Ryhming cycle ergometer test

Aim

The lower the heart rate during the test, the more efficient the aerobic energy system.

Equipment

- Cycle ergometer
- Clock or stopwatch
- Heart rate monitor
- ECG monitor (optional)

Method

1. Participants pedal on a cycle ergometer at a constant workload for 7 minutes.
2. Heart rate is measured every minute, and the steady state heart rate is determined.

Results

Females: VO_2 max. = (0.00193 × workload + 0.326) / (0.769 × HRss – 56.1) × 100

Males: VO_2 max. = (0.00212 × workload + 0.299) / (0.769 × HRss – 48.5) × 100

Compare to VO_2 max. norms (see table 9.2).

eBook*plus*

Interactivity
Astrand–Ryhming cycle ergometer test
Searchlight ID: int-6814

eBook*plus*

Interactivity
Harvard step-test calculator
Searchlight ID: int-6807

Weblink
Harvard step-test

Harvard step-test (short form)

Aim

To maintain the stepping rate with a low heart rate. The higher the fitness index, the higher the aerobic power.

Equipment

- Step or platform 20 inches (50.8 cm) high
- Stopwatch
- Metronome or cadence audio recording

Method

1. The participant steps up and down on the platform at a rate of 30 steps per minute (every two seconds) for 5 minutes or until they cannot maintain the stepping rate for 15 seconds.
2. The participant immediately sits down on completion of the test, and heart rate is measured between 1 to 1.5 minutes after finishing.

Results

Fitness index (short form) = (100 × test duration in seconds) divided by (5.5 × heart rate between 1 and 1.5 minutes)

Fitness index score is determined by the above equation. For example, if the total test time was 300 seconds (i.e. the whole 5 minutes was completed), and the number of heart beats between 1–1.5 minutes was 90, then the fitness index would be 61.

Note: You are using the total number of heart beats in the 30-second period, not the rate (beats per minute) during that time.

TABLE 9.7 **Harvard step-test fitness norms**

Rating	Fitness index (long form)
Excellent	> 96
Good	83–96
Average	68–82
Low average	54–67
Poor	< 54

(norms from: Fox et al. 1973)

FIGURE 9.6 Harvard step-test

FIGURE 9.7 Harvard step-test

Anaerobic capacity tests

Anaerobic capacity (or anaerobic metabolism) involves two energy systems — the ATP–CP system and the anaerobic glycolysis system. Anaerobic capacity tests are designed to measure the total amount of energy provided by the anaerobic energy systems.

Phosphate recovery test

This test was originally developed for Australian Rules football, but it is suitable for a variety of sports that involve repeated high-intensity, short-duration efforts. The test stresses the ability of the body to replenish high-energy phosphates between each repetition of the test.

Aim

To run past as many cones as possible for each sprint.

Equipment

- Marking cones of various colours, with two sets numbered 1–10
- Stopwatches
- Whistle
- Recording sheets
- Appropriate area such as an oval

Method

1. Set up the course as shown in figure 9.8. Place the cones numbered 1–10 every 2 metres from the centre in the formation shown.
2. Participants work in pairs, with one partner running while the other records. They then reverse roles. Each participant should be thoroughly familiar with the test protocol.
3. A timekeeper, who works with two stopwatches and a whistle, controls the test.

eBook*plus*

Interactivity
Phosphate recovery test calculator
Searchlight ID: int-6815

4. Each participant performs one of the following sets:
   8 × 7-second sprints, departing every 30 seconds (work-to-rest ratio of 1:3.3)
   8 × 5-second sprints, departing every 30 seconds (work-to-rest ratio of 1:5).
5. Participants must perform each sprint at maximum effort. The timekeeper blows the whistle to start and stop each sprint.
6. Both stopwatches are started as the sprint begins. Watch 1 is clocked off at 7 or 5 seconds (according to the set), with an appropriate whistle signal to the runner. Watch 2 continues ticking over as the participant jogs or walks to the other end of the course.
7. At 30 seconds (watch 2) the timekeeper blows the whistle to begin the next sprint. Timing of the sprint should begin on watch 1.
8. This procedure is repeated until participants have completed eight sprints. Refer to figure 9.9 for a sample procedure to follow.

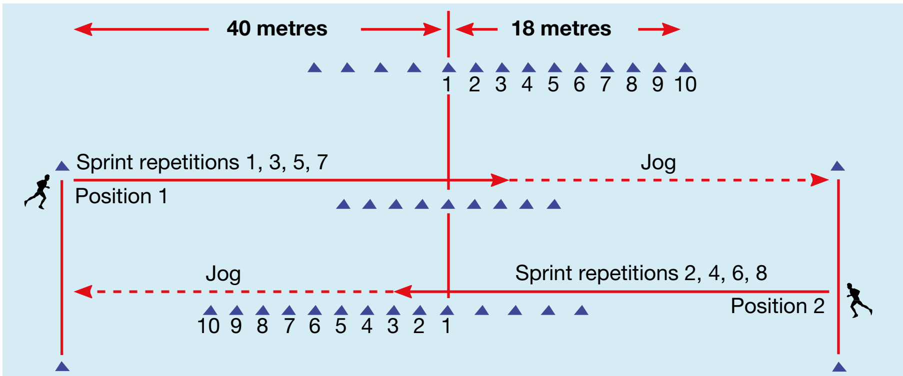


FIGURE 9.8 Phosphate recovery test course

Signal (stopwatch 2) (minutes: seconds)	Action — runners	Timekeeper	Scorer(s)
'Set'	Line up	Set both stopwatches to zero	Line up with markers in position 1 in direction of sprint
Whistle (go)	Sprint as quickly as possible for 7 seconds — sprint 1	Stopwatch 1: start Stopwatch 2: start	Ready
'Stop' (00:07)	Jog through to far line	Stopwatch 1: stop, reset Stopwatch 2: allow to run	Count number of markers passed at 'stop' (if between markers, count last marker passed). Record score, e.g. 8
'Set' (00:25)	Line up to sprint back in opposite direction	Stopwatch 1: on zero Stopwatch 2: on 25 second 'set'	Move to line up with second lot of markers at position 2
Whistle (00:30)	Sprint 2	Stopwatch 1: start Stopwatch 2: on 30 second (whistle)	Ready

Signal (stopwatch 2) (minutes: seconds)	Action — runners	Timekeeper	Scorer(s)
'Stop' (00:37)	Jog to end	Stopwatch 1: stop (7 second), reset Stopwatch 2: on 37 second	Record second score, e.g. 7 Move back to original position
'Set' (00:55)	Line up	Stopwatch 1: on zero Stopwatch 2: on 55 second 'set'	Move back to original position 1
Whistle (01:00)	Sprint 3	Stopwatch 1: start (whistle) Stopwatch 2: on 60 second	Ready
'Stop' (01:07)	Jog to end	Stopwatch 1: stop (7 second), reset Stopwatch 2: on 67 second	Record third score, e.g. 6
'Set' (01:25)	Line up	Stopwatch 1: zero Stopwatch 2: 85 second 'set'	Move to position 2
Whistle (01:30)	Sprint 4	Stopwatch 1: start (whistle) Stopwatch 2: 90 second	Ready
'Stop' (01:37)	Jog to end	Stopwatch 1: stop (7 second), reset Stopwatch 2: 97 second	Record fourth score, e.g. 4
Continue this procedure for eight sprints (total elapsed time = 3 minutes 37 seconds).			

FIGURE 9.9 Sample procedure for the phosphate recovery test, 8 × 7-second sprints departing every 30 seconds

Scoring

1. Record scores on the recording sheet (see figure 9.10).
2. Scorers must be in position to accurately read scores from the two sets of numbered cones. When the participants sprint from left to right, they are scored using the top set of numbered cones; when running right to left, they are scored using the bottom set of numbered cones.
3. The participants score points for each repetition according to the number of cones they have passed when the whistle blows to signify the end of the sprint.

Results

1. Calculate the total score by adding the points from each sprint repetition (figure 9.10).
2. Calculate the best possible score by multiplying the best single score by the number of repetitions.
3. Calculate the total decrement score (value that reflects the decline in performance scores relative to a best possible score) by subtracting the total score from the best possible score.

4. Calculate the percentage decrement score by dividing the total decrement score by the best possible score and multiplying by 100.
5. Refer to table 9.8 to obtain ratings for the percentage decrement. The lower the total decrement and percentage decrement scores, the better the result.

TABLE 9.8 Percentage decrement ratings for the phosphate recovery test

Rating	Percentage decrement score
Excellent	< 12
Good	12–19
Average	20–29
Fair	30–40
Poor	> 40

Source: Adapted from Dawson, Ackland, Roberts & Lawson 1991.

Phosphate recovery test score

Participant's name: **Maximum number of repetitions to be completed:**

× 5/7 seconds (delete 1)
Going every 30/40 seconds (delete 1)

Repetition number	1	2	3	4	5	6	7	8	Total
Score									
Decrement									

Calculations
Best possible score ________________ – total score ________________ = total decrement
(Repetition × best score)

$$\frac{\text{Total decrement}}{\text{Best possible score}} \times \frac{100}{1} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ \% of decrement score}$$

FIGURE 9.10 Sample recording sheet for the phosphate recovery test

30-second Wingate test

Aim
To pedal as fast as possible for 30 seconds

Equipment
- Stationary exercise bike

Method
1. The participant should first perform a cycling warm-up of several minutes.
2. The participant is instructed to pedal as fast as possible for 30 seconds.
3. In the first few seconds, the resistance load is adjusted to the pre-determined level, which is usually about 45 g/kg body weight (Fleisch) or 75 g/kg body weight (Monark) for adults.

Results

Some of the measures that can be gained from this test are mean and peak power (ideally measured in first five second interval of the test, expressed in watts), relative peak power (determined by dividing peak power by body mass, expressed as W/kg), mean peak power, minimum peak power, and a fatigue index determined from the decline in power.

Power Output ($kpm \cdot min^{-1}$) = [revs × resistance (kg) × dist (m) × 60 (sec)] / time (sec)

Watts = $kpm \cdot min^{-1}$ / 6.123

Watts/kg = Watts / body weight (kg)

Fatigue Index = [(Peak Power Output – Min Power Output) / Peak Power Output] × 100

TABLE 9.9 Wingate norms

	Male	Female
% Rank	Watts	Watts
90	822	560
80	777	527
70	757	505
60	721	480
50	689	449
40	671	432
30	656	399
20	618	376
10	570	353

eBook*plus*

Interactivity
30-second Wingate test calculator
Searchlight ID: int-6810

Repco peak power (phosphate power) test

The Repco peak power test can be quickly and easily administered. It assesses phosphate power output while cycling on a bicycle ergometer. It can also be adapted to involve arm cranking.

Equipment

- Cycle ergometer (Repco is recommended)
- Stopwatch
- Weight scales

Method

1. Weigh the participant before the test (in kilograms).
2. Set up the cycle ergometer to suit the physique of the participant. Adjust seat height so that the leg is almost fully extended when the pedal is at the lowest point.
3. The participant performs a light cycle as a warm-up.
4. When indicated, the participant stands on the pedals and accelerates to maximum power, which they maintain for 10 seconds.
5. Allow two trials with at least a 3-minute rest between trials.

FIGURE 9.11 Participant performing the Repco peak power test

eBook*plus*

Interactivity
Phosphate power (Repco peak power) test calculator
Searchlight ID: int-6816

Results

1. Record the maximum workload (in watts, indicated on the speedometer of the Repco cycle ergometer) reached during the test.
2. Divide the maximum workload (watts) by the weight of the participant (kilograms).
3. Obtain a rating for peak power output from table 9.10.

TABLE 9.10 Peak power test index ratings (watts per kilogram)

Rating	Males aged 14–34 years	Females aged 14–34 years
Excellent	19.6 or more	16.7 or more
Very good	17.0–19.5	14.3–16.6
Good	14.4–16.9	11.9–14.2
Average	11.8–14.3	9.5–11.8
Fair	9.2–11.7	7.1–9.4
Poor	< 9.2	< 7.1

TEST your understanding

1 Define the term *aerobic power*.
2 Define the term *anaerobic capacity*.
3 List the common characteristics of reliable aerobic power tests.
4 List the common characteristics of reliable anaerobic capacity tests.

APPLY your understanding

5 **Practical activity: aerobic and anaerobic tests**
(a) Complete as many aerobic power and anaerobic capacity tests as you can.
(b) Compare your ratings for at least two aerobic power tests. Were they similar or different? Explain why this might be so.
(c) Compare your ratings for at least two anaerobic capacity tests. Were they similar or different? Explain why this might be so.
(d) Describe each of the tests and identify one sport they might be suited to.

EXAM practice

6 Identify and justify an appropriate aerobic power test for the following participant(s). **6 marks**
– Olympic road cyclist
– Beginner at the gym
– Year 12 class

7 Identify and justify an appropriate anaerobic capacity test for the following participant(s). **6 marks**
– AFL footballer
– Beginner at the gym
– Year 12 class

9.5 Muscular strength, power and endurance tests

KEY CONCEPT As muscular strength, power and endurance have different requirements, they are tested differently. Muscular strength tests involve working until maximum effort is achieved. Muscular power tests require maximal distance and endurance tests require as many repetitions as possible in a set time or working as long as possible.

Muscular strength tests

Muscular strength is defined as the maximum effective force that a muscle or muscle group can exert once. It is therefore classically assessed through tests that measure the amount of force produced with a single maximal effort. A range of tests can be used that assess either the single or repeat maximal capacity (usually up to 3 RM) of different muscles and muscle groups. It is important to note that muscular strength can vary dependent on the muscle and/or muscle group, therefore a number of tests may be required to gain a more accurate assessment of strength.

One repetition maximum (1 RM) test

The one repetition maximum (1 RM) test is a popular method of measuring isoinertial muscle strength. It is a measure of the maximal weight a participant can lift with one repetition. Most commonly used movements are the bench press and leg press. However, 1 RM testing may not be recommended for some populations, including the elderly, cardiac patients, adolescents and some sedentary populations. For these populations other options for assessing strength should be used.

Aim

To lift as much as you can for one repetition only

FIGURE 9.12 1 RM leg press

FIGURE 9.13 1 RM leg press

FIGURE 9.14 The 1 RM bench press

Equipment

- Free weights (barbells) or other gym equipment

Method

A number of different procedural protocols exist. The following outline is one such protocol.

1. Begin with a warm-up of 5–10 repetitions at 40–60 per cent of the participant's estimated maximum weight.
2. After a brief rest period (3–5 minutes), increase the load to 60–80 per cent of the participant's estimated maximum, and the participant attempts to complete 3–5 repetitions.
3. At this point a small increase in weight is added to the load and a 1 RM lift is attempted.
4. If successful, wait another 3–5 minutes, add a small amount of weight and have the participant attempt one more repetition.
5. Keep adding small amounts of weight until the participant cannot successfully lift the weight.
6. The goal is to determine the participant's 1 RM in 3 to 5 trials.
7. The participant should be allowed ample rest (at least 3–5 minutes) before each 1 RM attempt.
8. The last successful completed repetition, with no assistance from a spotter, is the participant's repetition maximum.

(*Note:* A spotter should always be employed during the performance of this test and trained personnel should supervise the testing.)

eBook*plus*

Interactivity
One repetition maximum (1 RM) test calculator
Searchlight ID: int-6817

Results

1. Take the participant's 1 RM weight and divide it by their body weight (in kilograms). For example, if they bench-pressed 120 kilograms and weigh 80 kilograms, the score is 1.5.
2. Refer to table 9.11 to obtain ratings for this test.

TABLE 9.11 1 RM scores for bench press and leg press

Rating	Bench press: males	Bench press: females	Leg press: males	Leg press: females
Excellent	1.4	0.7	2.8	2.2
Very good	1.2	0.6	2.4	2.0
Good	1.0	0.5	2.0	1.8
Fair	0.8	0.4	1.8	1.4
Poor	0.6	0.3	1.4	1.2

Source: Sport Fitness Advisor, www.sport-fitness-advisor.com.

Grip strength dynamometer

The grip strength dynamometer test is one of the most popular strength tests. It is easy to perform and reliable in providing an index of muscular strength because it has a reasonably high correlation with total body strength. Norms for the test are also readily available, and the dynamometer is relatively inexpensive.

Aim

To squeeze your hand as hard as possible

Equipment

- Handgrip dynamometer

Method

1. First adjust the dynamometer to suit the participant's hand size. The second joint of the fingers should fit comfortably under the handle.
2. The participant (in a standing position) holds the dynamometer above their body and lowers it to their side while squeezing vigorously (for approximately 5–10 seconds), exerting their maximum force. Ensure the dial of the dynamometer faces away from the participant's body.
3. During the test, do not allow either the dynamometer or the participant's hand to come into contact with the participant's body.
4. Three trials are recommended for each hand, with a 3-minute rest between trials.

Results

1. Record the best score for each hand (in kilograms), as read from the dial.
2. Refer to table 9.12 to obtain ratings for grip strength.

TABLE 9.12 Handgrip strength norms and ratings (kilograms)

Rating	Males aged 16–17 years	Males aged 18–39 years	Females aged 16–17 years	Females aged 18–39 years
Excellent	41 or more	54 or more	31 or more	39 or more
Good	36–40	50–53	29–30	36–38
Average	34–35	47–49	27–28	33–35
Fair	32–33	43–46	22–26	30–32
Poor	31 or less	42 or less	21 or less	29 or less

Source: Adapted from Leelarthaepin, B 1992, *Assessment of physical fitness: a practical approach*, Biomediscience Services, New South Wales.

Push–pull dynamometer

The push–pull dynamometer enables an assessment of the strength of the upper back muscles (pull) and the chest and shoulder muscles (push). The test is simple to complete and the dynamometers are relatively inexpensive.

Aim

To pull and then push using your arms as much as possible

Equipment

- Push–pull dynamometer

Method

1. The participant holds the dynamometer with both hands in front of their chest, with the dial facing away from their body and the reading at zero (see figure 9.15).
2. They then pull the handles outwards and apart with as much force as possible for approximately 5–10 seconds. After a rest for 3 minutes, they repeat the action.

FIGURE 9.15 The push–pull dynamometer test

3. The participant then pushes the handles inwards and together with as much force as possible for approximately 5–10 seconds. Again, after a rest for 3 minutes, the participant repeats the action.

Results

Record the participant's best attempt for both the pull and push phases of the test.

(*Note:* No relevant norms are available for this test.)

Seven-stage abdominal strength test

Aim

To complete a situp as the difficulty increases

Equipment

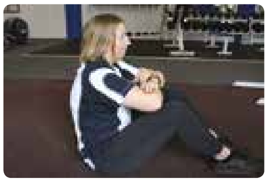
- Flat surface
- 5 lb (2.5 kg) and 10 lb (5 kg) weights

Method

1. Participant lies on their back, with their knees at right angles and feet flat on the floor.
2. The participant then attempts to perform one complete situp for each level in the prescribed manner (see norms below), starting with level 1.
3. Each level is achieved if a single situp is performed in the prescribed manner, *without the feet coming off the floor*. As many attempts as necessary can be made.

Results

TABLE 9.13 Norms for seven-stage abdominal strength test

Level	Rating	Description	
0	Very poor	Cannot perform level 1	
1	Poor	With arms extended, the athlete curls up so that the wrists reach the knees	
2	Fair	With arms extended, the athlete curls up so that the elbows reach the knees	
3	Average	With the arms held together across abdominals, the athlete curls up so that the chest touches the thighs	

Level	Rating	Description
4	Good	With the arms held across chest, holding the opposite shoulders, the athlete curls up so that the forearms touch the thighs 
5	Very good	With the hands held behind head, the athlete curls up so that the chest touches the thighs 
6	Excellent	As per level 5, with a 5 lb (2.5 kg) weight held behind head, chest touching the thighs 
7	Elite	As per level 5, with a 10 lb (5 kg) weight held behind head, chest touching the thighs 

Muscular power tests

Muscular power is the ability to use strength quickly to produce an explosive movement. Chapter 8 explains that muscular power depends on strength and speed. It is central to actions in most sports where successful performance requires distance, height or any quick generation of force.

Most tests of muscular power measure either upper body power (arm, shoulder, chest and upper back muscles) or leg power (hip, thigh and calf muscles).

Basketball throw

Aim

To throw the ball as far as possible

Equipment

- Basketball
- Measuring tape
- Wall

Method

1. With back flush against the wall and legs fully extended, hold ball at chest height.

2. With arms only (back should stay against wall) push the ball out in front as far as you can.
3. Repeat three times with sufficient recovery (at least 1 minute) and record best score.
4. Some tests will include a hoop on the participant's toes to ensure the ball is kept low and the movement isolates the arms and chest.

FIGURE 9.16 Seated basketball throw test

Vertical jump

The vertical jump test, also referred to as the Sargeant jump test, is a test of leg power. It is easy to administer and has been used in test batteries for many years.

Aim

To jump as high as possible

Equipment

- Vertical jump board (recommended) or measuring tape attached to a wall
- Magnesium chalk

Method

1. The participant chalks the tips of their middle fingers with magnesium chalk.
2. The participant determines their standing height by fully extending arm overhead and recording the height reached (see figure 9.17a).
3. The participant stands side on to the jump board, takes a deep squat and springs as high as possible (see figure 9.17b), touching the jump board with the hand and fingers closest to the board. They should keep their arm extended above their head so a chalk mark shows the height reached. Record this height.
4. The result calculated is the difference between the height reached on the jump and the initial standing height.
5. The participant rests for at least 3 minutes, then attempts a second trial.

Results

1. Record the best score obtained from the two trials. (Subtract standing height from jumped height.)
2. Refer to table 9.14 for ratings of leg power.

TABLE 9.14 Ratings for the vertical jump test (centimetres)

Rating	Males aged 15–17 years	Males aged 18–34 years	Females aged 15–17 years	Females aged 18–34 years
Excellent	59 or more	62 or more	39 or more	32 or more
Good	48–58	48–61	33–38	25–31
Average	30–47	33–47	20–32	15–24
Fair	13–29	20–32	8–19	5–14
Poor	12 or less	19 or less	7 or less	4 or less

Norms

It is important to note that different sports will have different means and ranges for muscular leg power and the vertical jump. For example, the AIS has the following norms for particular sports at various levels.

TABLE 9.15 AIS norms for the vertical jump test

Sport	Sex	Age	Mean score
Netball — national	Female	U17	44 cm
AFL	Male	Approx. 18	60 cm
Basketball — state	Female	U17	48 cm
Basketball — state	Male	U17	62 cm
Cricket — national	Female	Open	44 cm
Cricket — national	Male	U19	56 cm

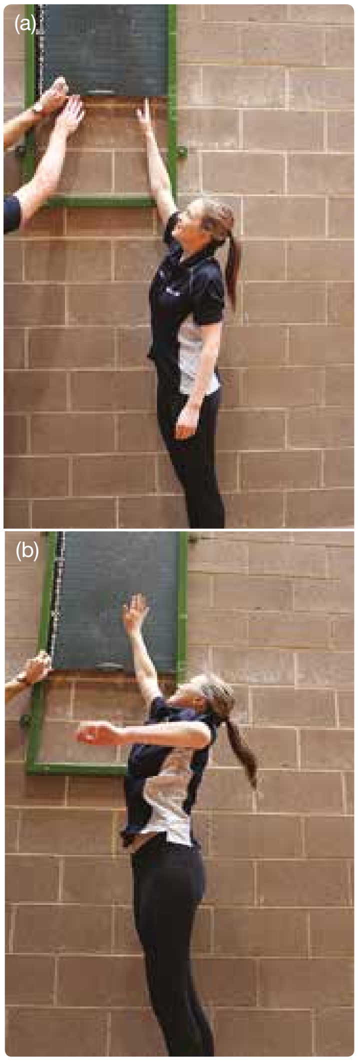


FIGURE 9.17 The vertical jump test

Standing long jump

The standing long-jump test is easily administered. It assesses the level of a participant's leg muscle power (mainly the quadriceps and calf muscle groups).

Aim

To jump as far (horizontally) as possible

Equipment

- Tape measure
- Safe jumping area such as a sprung wooden floor, sandpit or fixed mat
- Gym shoes

Method

1. The participant stands behind a line with their feet shoulder width apart.
2. The participant bends their knees and swings their arms back and forth (see figure 9.18), jumping as far forward as possible and landing on both feet. Allow two trials with at least 3 minutes' rest between each trial.
3. The score is the distance from the starting line to the point where the participant's heel lands closest to the line.

Results

1. Record the best score obtained from the two trials.
2. Refer to table 9.16 for ratings of leg power.

TABLE 9.16 Ratings for the standing long-jump test (centimetres)

Rating	Males aged 17 years	Males aged 18+ years	Females aged 17 years	Females aged 18+ years
Excellent	230 or more	239 or more	175 or more	180 or more
Good	216–229	226–238	163–174	168–179
Average	204–215	213–225	151–162	157–167
Fair	192–203	201–212	134–150	142–156
Poor	191 or less	200 or less	133 or less	141 or less

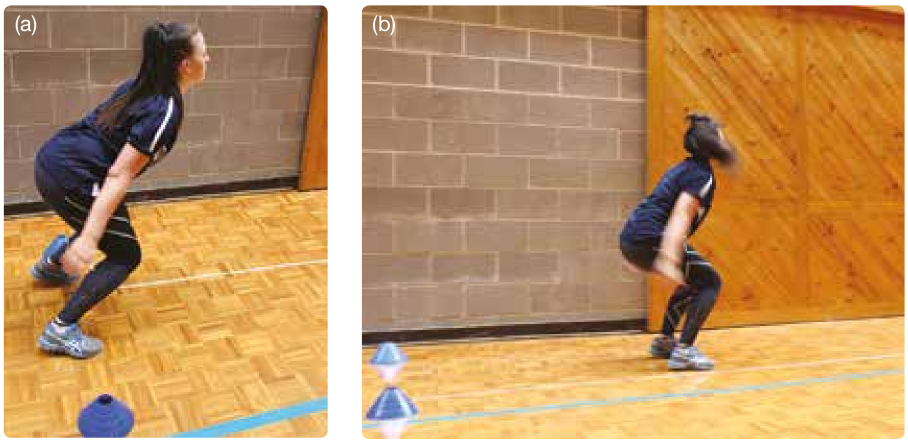


FIGURE 9.18 The standing long jump test

Magaria Kalamen power test

Power is a combination of strength and speed. These qualities are tested in the Magaria Kalamen power test.

Aim

To run up the steps as quickly as possible

Equipment

- Stopwatch
- Assistant
- Flight of 12 steps, with a run-up of 6 metres and the third, sixth and ninth steps emphasised.

Method

1. Measure and record the participant's weight.
2. Measure the vertical distance between the third and ninth steps.
3. The participant sprints to and up the flight of steps, taking three steps at a time (third, sixth and ninth steps).
4. The assistant records the time taken to get from the third step to the ninth step (the stopwatch starts when the participant's foot lands on the third step and stops when their foot lands on the ninth step).
5. Repeat this test three times, with 2–3 minutes' recovery between trials.

Results

1. Record the best score obtained from the three trials.
2. Calculate the power using this equation:

$$P = \frac{9.8(M \times D)}{t}$$

where P = power (watts)
M = body mass (kg)
D = vertical distance between steps 3 and 9 (m)
t = time (s).

eBook*plus*

Interactivity
Magaria Kalamen power test calculator
Searchlight ID: int-6818

Muscular endurance tests

Muscular endurance is the ability of a particular muscle or muscle group to continue working at the desired level of effort for as long as the situation demands (see chapter 8). Tests for muscular endurance will usually focus on one area of the body and therefore can readily be made specific for a particular sport's requirements in the competitive situation. Most muscular endurance tests require the participant to complete the exercise for as long as they can or complete as many repetitions as they can in a set time, forcing the muscles/muscle group to work in the face of fatigue.

60-second pushup test

Aim

To complete as many pushups as you can to test the endurance of the upper body

Equipment

- Flat surface

Method

Men should use the standard 'military-style' pushup position with only the hands and the toes touching the floor in the starting position.

Women have the additional option of using the 'bent knee' position.

1. To do this, kneel on the floor, hands on either side of the chest and keep your back straight.
2. Lower the chest down towards the floor, always to the same level each time, until either your elbows are at right angles or your chest touches the ground (see figure 9.19).
3. Do as many pushups as possible until exhaustion or 60 seconds is reached.
4. Count the total number of pushups performed.
5. Compare to relevant norms.

Results

TABLE 9.17 Norms for 60-second pushup test

Men						
Age	17–19	20–29	30–39	40–49	50–59	60–65
Excellent	> 56	> 47	> 41	> 34	> 31	> 30
Good	47–56	39–47	34–41	29–34	25–31	24–30
Above average	35–46	30–38	25–33	21–28	18–24	17–23
Average	19–34	17–29	13–24	11–20	9–17	6–16
Below average	11–18	10–16	8–12	6–10	5–8	3–5
Poor	4–10	4–9	2–7	1–5	1–4	1–2
Very poor	< 4	< 4	< 2	0	0	0

Women						
Age	17–19	20–29	30–39	40–49	50–59	60–65
Excellent	> 35	> 36	> 37	> 37	> 25	> 23
Good	28–35	30–36	31–37	25–31	21–25	19–23
Above average	21–27	23–29	22–30	18–24	15–20	13–18
Average	11–20	12–22	10–21	8–17	7–14	5–12
Below average	6–10	7–11	5–9	4–7	3–6	2–4
Poor	2–5	2–6	1–4	1–3	1–2	1
Very poor	0–1	0–1	0	0	0	0

FIGURE 9.19 The 60-second pushup test

60-second situp test

The maximum situps test is a basic item in many fitness test batteries, and it is designed to provide a measure of the endurance of the abdominal muscles. However, there are many variations of the test. Some have a time limit of 30 or 60 seconds, while others involve a predetermined number of repetitions.

The participant's body position also varies with different formats of this test — using leg positions from slightly bent to fully flexed, and using arm positions from hands clasped behind the head (not recommended) to arms folded across the chest. The test outlined here is a standardised protocol for the maximum situps test performed with bent knees.

Aim

To complete as many repetitions as possible in the time permitted

Equipment

- Gym mat
- Stopwatch

Method

1. The participant lies on a mat with their knees flexed so the angle of their lower legs to their thighs is approximately 90 degrees. They place their arms across their chest, with each hand on the opposite shoulder (see figure 9.20a).
2. On the start command, the participant curls upwards and forwards, raising their body trunk until their elbows make contact with their thighs (see figure 9.20b). Then they return to the starting position.
3. The participant repeats this procedure as many times as possible within the 1-minute time limit.
4. A partner should count the number of correct situps completed and check for correct procedure.

Results

1. Record the number of situps completed within the time limit.
2. Compare the results with the ratings provided in table 9.18.

TABLE 9.18 Abdominal muscle endurance ratings (number of situps completed in 60 seconds)

Rating	Males aged 15–19 years	Females aged 15–19 years
Excellent	48 or more	42 or more
Good	42–47	36–41
Average	38–41	32–35
Fair	33–37	27–31
Poor	32 or fewer	26 or fewer

Source: Adapted from Nieman 1993.

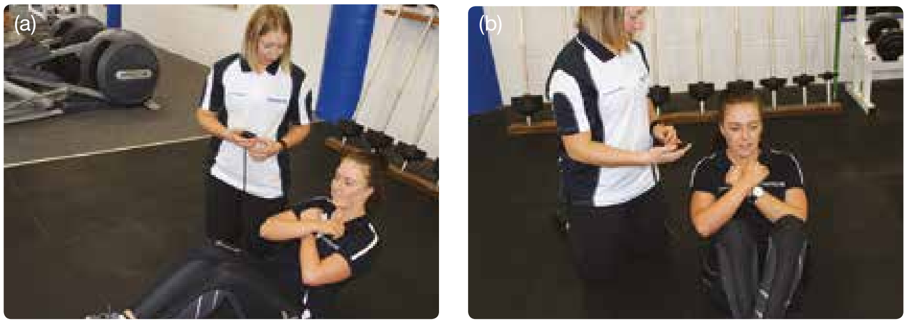


FIGURE 9.20 Correct body form for the timed situps test

Curlup (crunch) test

A modification of the traditional situps test, the curlups test assesses endurance of the abdominal muscles. The aim is to complete as many curlups as possible at a rate of 20 per minute (up to a maximum of 60).

Aim

To complete as many repetitions as possible

Equipment

- Gym mat
- Cadence (or rate) audio recording

Method

1. The participant lies on the mat with their knees bent at a 90-degree angle, keeping their arms straight.
2. A partner kneels beside the participant and places a straight arm across the top of the participant's knees, forming a 'wall'.
3. Using the cadence audio recording, the participant curls up in time with the set rate. They must slide their hands along the top of their thighs until their hands touch the 'wall'. The 'up' position must be held for 1 second. The participant then returns to the starting position.
4. The participant repeats the action until they complete 60 curlups. However, if they do not perform two consecutive curlups satisfactorily, they must withdraw from the test.

Results

1. Record the number of correctly completed curlups.
2. Refer to table 9.19 for the ratings for this test.

TABLE 9.19 Ratings for the curlups test (number completed)

Rating	Males aged 17–18 years	Females aged 17–18 years
Excellent	60	45–60
Good	60	32–44
Average	31–59	26–31
Fair	30	25
Poor	29 or fewer	24 or fewer

Source: Adapted from Wright 1997.

Pullup/modified pullup test

Participants who are unable to complete one standard pullup can use the modified pullups test (this is the method given below).

Aim

To complete as many repetitions as possible

Equipment

- An adjustable horizontal bar

Method

1. Set the bar at approximately the waist height of the participant.
2. The participant takes up the starting position, holding their body in a firm, straight position with their head, trunk and legs in line and their heels on the floor.
3. From this extended position the participant pulls with their arms to raise their chest to the bar. Then they return to the starting position.
4. The participant repeats the action as many times as possible.

Results

1. Record the number of properly executed pullups.
2. Refer to table 9.20 for the ratings for this test.

TABLE 9.20 Ratings for the modified pullups test (number completed)

Rating	All persons
Excellent	23 or more
Good	19–22
Average	15–18
Fair	7–14
Poor	6 or less

Source: Adapted from Sherriff 1991.

Flexed arm hang test

Aim

To hang with the chin above the bar as long as possible

Equipment

- Stopwatch
- Horizontal overhead bar at an adequate height
- Stool (optional)

Method

1. Participant grasps the overhead bar using an overhand grip (palms facing away from body), with the hands at shoulder width apart.

2. On the command 'ready, go', timing starts.
3. The participant should attempt to hold this position for as long as possible.

Results

TABLE 9.21 Norms for the flexed arm hang test

Gender	Excellent	Above average	Average	Below average	Poor
Male	>13	9–13	6–8	3–5	<3
Female	>6	5–6	3–4	1–2	0

Source: Table adapted from Davis et al. (2000)

TEST your understanding

1 Define the term *muscular strength*.
2 Define the term *muscular power*.
3 Define the term *muscular endurance*.
4 Describe the 1 RM bench press test.

APPLY your understanding

5 **Practical activity: muscular strength, power and endurance tests**
(a) Complete as many muscular strength, power and endurance tests as you can.
(b) Compare your ratings for at least two muscular strength tests. Were they similar or different? Explain why this may be so.
(c) Compare your ratings for at least two muscular power tests. Were they similar or different? Explain why this may be so.
(d) Compare your ratings for at least two muscular endurance tests. Were they similar or different? Explain why this may be so.
(e) Describe each of the tests and identify one sport to which they may be suited.

6 Identify and justify an appropriate muscular strength test for the following participants.
– Elite tennis player
– Year 12 class
– Beginner at the gym

EXAM practice

7 Discuss, using specific examples, the differences between tests for muscular strength, power and endurance of the lower body. **6 marks**

9.6 Speed and agility tests

KEY CONCEPT Speed and agility tests require athletes to cover a set distance as quickly as possible. The difference between speed and agility tests is that agility tests require different movements or changes of direction.

Speed

Speed can refer to either whole-body speed — where the aim is to cover a specified distance in the shortest possible time — or part-body speed — where the aim is to move one or more parts of the body as quickly as possible to complete a movement (see chapter 8). Methods of assessing part-body speed are necessarily dependent on sophisticated recording methods, so most tests of speed centre on whole-body measurements.

Most tests of whole-body speed use distances of 5–50 metres. For testing of 5 metres, 10 metres and 20 metres distances, electronic timing gates are recommended to avoid human error.

20-metre sprint test

Aim

To run as quickly as possible for 20 metres

Equipment

- Measuring tape or marked track
- Stopwatch or timing gates
- Cone markers

Method

1. Complete a standardised warm-up.
2. On 'go', start stopwatch and participant sprints 20 metres.

Results

There are limited norms for the 20-metre sprint; however. the AIS have found the following mean values for Australian sportspeople.

TABLE 9.22 AIS norms for the 20-metre sprint test

Sport	Sex	Age	Mean (seconds)
Netball — national	Female	U17	3.52
AFL	Male	Approx. 18	3.04
Basketball — state	Female	U17	3.56
Basketball — state	Male	U17	3.24
Tennis — national	Female	16+	3.49
Tennis — national	Male	16+	3.09

35-metre sprint test

Aim

To run as quickly as possible for 35 metres

Equipment

- Measuring tape or marked track
- Stopwatch or timing gates
- Cone markers

Method

1. Complete a standardised warm-up.
2. On 'go', start stopwatch and participant sprints 35 metres.

Results

TABLE 9.23 Norms for the 35-metre sprint test (for Australian team sport players)

Rating	Men	Women
Very good	< 4.80	< 5.30
Good	4.80–5.09	5.30–5.59
Average	5.10–5.29	5.60–5.89
Fair	5.30–5.60	5.90–6.20
Poor	> 5.60	> 6.20

50-metre sprint test

The 50-metre sprint test measures whole-body speed over a short distance.

Aim

To sprint as quickly as possible over 50 metres

Equipment

- 50-metre marked course
- Stopwatch

Method

1. The participant warms up.
2. On the start command, the participant runs the 50-metre course as quickly as possible.
3. Record the time taken to cover the distance to the nearest one-hundredth of a second.
4. The participant completes two trials.

Results

1. Record the lowest time taken to complete the test.
2. Refer to table 9.24 for the ratings for this test.

TABLE 9.24 Ratings for the 50-metre sprint test (seconds)

Rating	Males aged 16–17 years	Females aged 16–17 years
Excellent	Under 7.1	Under 8.0
Good	7.1–7.3	8.0–8.4
Average	7.4–7.8	8.5–8.9
Fair	7.9–8.2	9.0–9.3
Poor	Over 8.3	Over 9.4

Source: Adapted from Wright 1997.

Agility tests

Agility is a combination of speed and flexibility and refers to the ability of a performer to change direction with maximal speed and control. It can be planned or unplanned (reaction) (see chapter 8).

Tests to assess this component of fitness generally involve running around and between obstacles (e.g. hats, chairs or cones) as quickly as possible. A number of recognised tests exist, but it is also possible to design tests that are specifically relevant to particular sports.

Illinois agility test

The Illinois agility test has been incorporated into test batteries for many years. It measures the ability to quickly change direction without losing control or balance.

Aim

To complete course, changing direction and moving around cones, as quickly as possible

Equipment

- Six chairs or cones
- Tape measure
- Stopwatch

Method

1. Set up the course as shown in figure 9.21.
2. The participant lies on their stomach with their hands beside their chest and their forehead on the starting line.
3. On the start command, the participant jumps up and completes the course as quickly as possible. One foot must touch the end line.
4. Record how long it takes the participant to complete the course.
5. Run two trials if necessary (so the participant has some practice).

Results

1. Record the best time taken to complete the course to the nearest tenth of a second.
2. Compare results with the ratings shown in table 9.25.

TABLE 9.25 **Ratings for the Illinois agility test (seconds)**

Rating	Males	Females
Excellent	Under 15.9	Under 17.5
Good	15.9–16.7	17.5–18.6
Average	16.8–18.6	18.7–22.3
Fair	18.7–18.8	22.4–23.4
Poor	18.9 or over	23.5 or over

Source: Adapted from Schell & Leelarthaepin 1994.

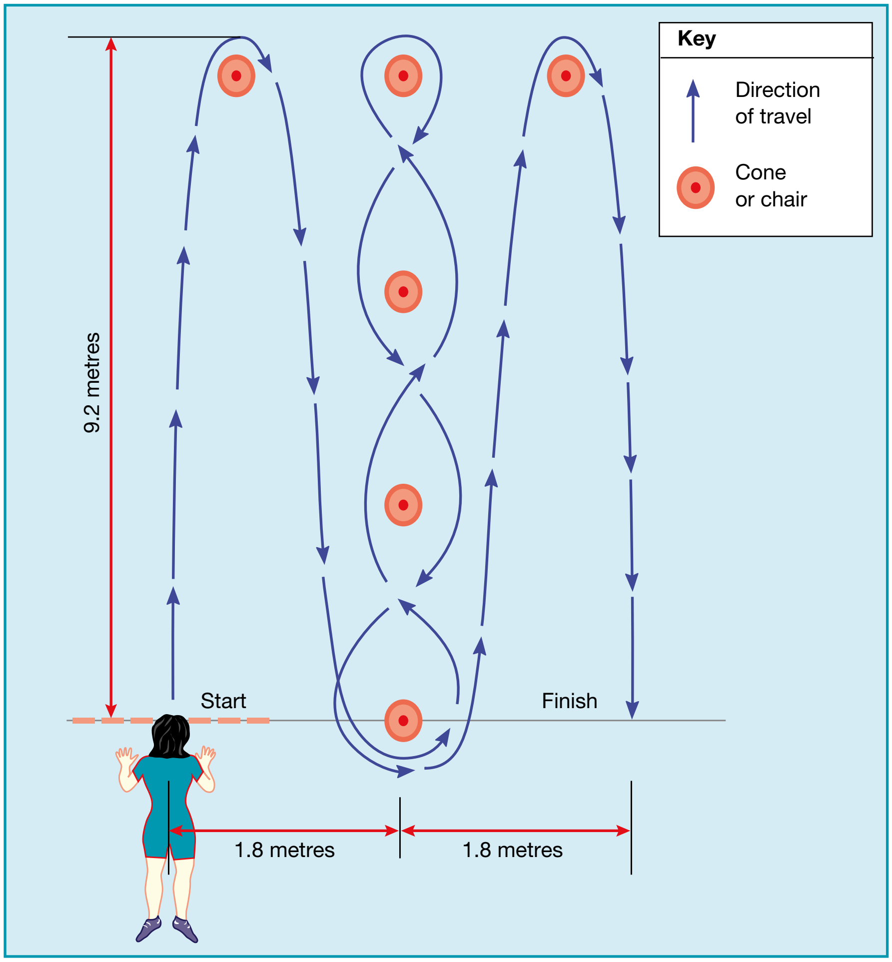


FIGURE 9.21 Floor plan for the Illinois agility test

Semo agility test

The Semo agility test assesses the agility of a participant in manoeuvring forwards, backwards and sideways. It is particularly well suited to sports such as tennis, volleyball, badminton and basketball.

Aim

To complete course, using a variety of movements (sprinting, running backwards and side-stepping) moving around cones, as quickly as possible

Equipment

- Four cones or chairs
- Stopwatch
- Tape measure

Method

1. Set up the course as shown in figure 9.22.
2. The participant completes the course, beginning at point A with their back to the square.
3. The participant always faces the same direction, therefore requiring sideways, backwards and forwards locomotion.
4. Allow at least one practice trial and two re-trials.

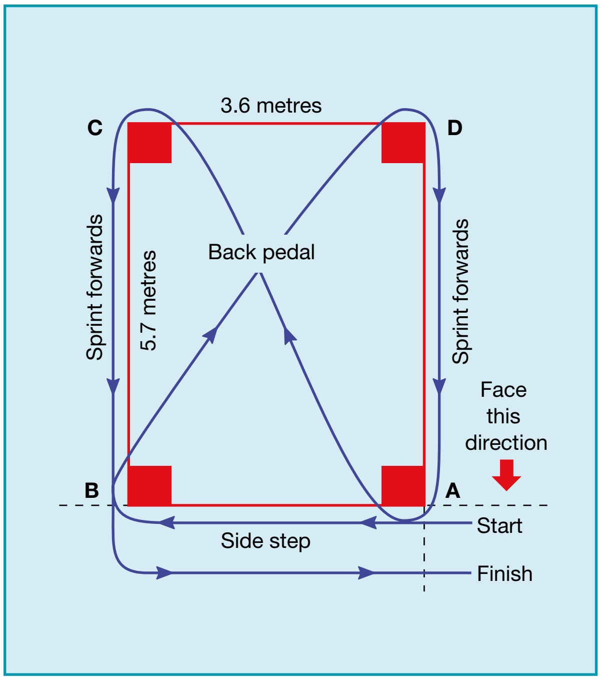


FIGURE 9.22 Floor plan for the Semo agility test

Results

1. Record the best time taken to complete the course to the nearest tenth of a second.
2. Compare results with the ratings shown in table 9.26.

TABLE 9.26 Ratings for the Semo agility test (seconds)

Rating	Males	Females
Excellent	Under 10.7	Under 12.19
Good	11.49–10.7	12.99–12.19
Average	13.02–11.50	13.90–13.00
Fair	13.79–13.03	14.49–13.91
Poor	13.80 or over	14.50 or over

Source: Adapted from Malpeli, R Horton, M & Davey, G 1994, *Physical education, VCE Units 3 and 4*, Thomas Nelson, South Melbourne.

eBook*plus*

Weblink
5-0-5 agility test

5-0-5 agility test

Aim

To sprint, change direction and sprint back as quickly as possible

Equipment

- Start/stop timing gates or stopwatch
- Non-slip running surface
- Cone markers

Method

1. Set up markers 5 and 15 metres from a line marked on the ground (see figure 9.23).
2. The participant sprints from the 15-metre marker towards the line (run in distance to build up speed) and through the 5-metre markers, turns on the line and runs back through the 5-metre markers.
3. The time is recorded from when the participant first runs through the 5-metre markers, and stopped when they return through these markers (that is, the time taken to cover the 5-metre up and back distance — 10-metre total).
4. Repeat after at least 3 minutes passive recovery. The best of two trials is recorded.
5. The turning ability on each leg should be tested. The participant should be encouraged to not overstep the line by too much, as this will increase their time.

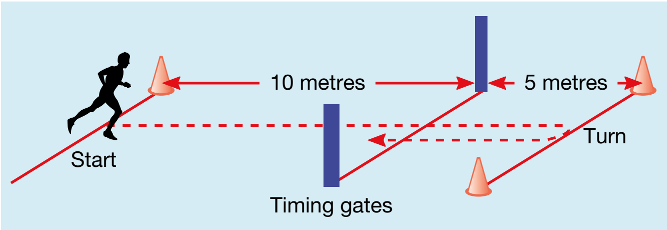


FIGURE 9.23 5-0-5 agility test

Results

There are limited norms for the 5-0-5 agility test; however, the AIS have found the following mean values for Australian sportspeople.

TABLE 9.27 5-0-5 agility test norms

Sport	Sex	Age	Mean left foot (seconds)	Mean right foot (seconds)
Cricket — national	Female	open	2.49	2.45
Cricket — national	Male	U19	2.27	2.28
Rugby — elite	Male	U19	2.30	n/a
Tennis — national	Female	16+	2.48	2.49
Tennis — national	Male	16+	2.33	2.33

TEST your understanding

1 Define the term *speed*.
2 Define the term *agility*.
3 Outline the main differences between the three agility tests.

APPLY your understanding

4 **Practical activity: speed and agility tests**
(a) Complete as many speed and agility tests as you can.
(b) Compare your ratings for at least two speed tests. Were they similar or different? Explain why this may be so.
(c) Compare your ratings for at least two agility tests. Were they similar or different? Explain why this may be so.
(d) Describe each of the tests and identify one sport to which they may be suited.

5 Identify and justify an appropriate agility test for the following participants.
- Elite rugby player
- Year 12 class
- Beginner at the gym

EXAM practice

6 Identify and justify which recognised agility test would be most appropriate for a squash player. **3 marks**

9.7 Flexibility and body composition tests

KEY CONCEPT There are a range of flexibility and body composition tests. They differ significantly in terms of practicality and accuracy.

Body composition tests

Body composition refers to the relative proportions of bone, muscle and fat within the body. Assessment measures range from sophisticated, individualised and expensive measures such as hydrodensitometry, to measures that are less accurate but more available and accessible for larger numbers, such as body mass index.

The 'gold standard' test for body composition is underwater weighing. This is a sophisticated process that requires specialist, expensive equipment and complex calculations, however it is believed to be the most accurate measure. This is used for those with invested interest in body composition and generally not used by the general public. Body mass index is more likely to be used by the general public. While it is not very accurate, it provides a helpful guide for body composition.

It is important to note that body composition tests are often used in assessing the health of an individual as body composition can give an indication of obesity.

Body mass index (BMI)

The body mass index is used to assess weight relative to height.

Aim

To assess weight relative to height

Equipment

- Weight scales
- Height scale or measuring tape

Method

1. Weigh the participant when they are wearing minimal clothing.
2. Measure the height of the participant when they are not wearing shoes.

Results

1. Calculate the participant's body mass index using the following formula:

$$\frac{\text{Weight (kilograms)}}{\text{Height (metres)}^2}$$

2. Refer to table 9.28 for the relevant classifications.

TABLE 9.28 General BMI ratings for males and females

Rating	Males	Females
Underweight	19 or less	18 or less
Acceptable weight range	20–25	19–24
Overweight	26–30	25–30
Obese	31 or more	31 or more

eBook*plus*

Interactivity
Body mass index calculator
Searchlight ID: int-6819

Waist circumference

Aim

To measure around the waist

Equipment

- Tape measure

Method

1. Find the top of your hip bone and the bottom of your ribs.
2. Breathe out normally.
3. Place the tape measure midway between these points and wrap it around your waist.
4. Check your measurement.

Results

TABLE 9.29 Guidelines for healthy waist measurement, men and women

Your health is at risk if your waist size is:	
Men	Over 94 cm (about 37 inches)
Women	Over 80 cm (about 31.5 inches)

These guidelines are based on World Health Organization and National Health and Medical Research Council recommendations.

Skinfold measurements

Skinfold measurement is the most widely used measure for determining body composition, and specifically body fat percentage. Skinfolds can be measured at several specific sites, the more common being the abdomen, calf, subscapula, suprailiac, thigh and triceps. Testers can use many different combinations of skinfold site measurements to predict percentage body fat. The two-site skinfold test, using the triceps and subscapula sites, has been the most commonly used test for young people aged 6–17 years.

Equipment

- Skinfold calipers (e.g. Harpenden, Fat-o-meter)

Method

1. Locate and mark the following skinfold sites on the right-hand side of the participant's body:
   (a) triceps — the back of the upper arm midway between the shoulder and elbow joints (see figure 9.24)
   (b) subscapula — just below the lowest point of the scapular or shoulder blade.
2. Pick up the skinfold between the thumb and forefinger about 1 centimetre above the marked site. The skinfold should include skin and subcutaneous fat but not muscle.
3. Apply the calipers to the marked location, slowly releasing the pressure on the caliper trigger so the pinchers exert full tension on the skinfold.

eBook*plus*

Weblink
Skinfold measurement test

eBook*plus*

Digital doc
Skinfold measurement protocols
Searchlight ID: doc-22228

4. When the pointer on the dial steadies, take the measurement in tenths of a millimetre.
5. To ensure accuracy, take three readings at each site. Record the median score.

FIGURE 9.24 Skinfold measurement test using the tricep

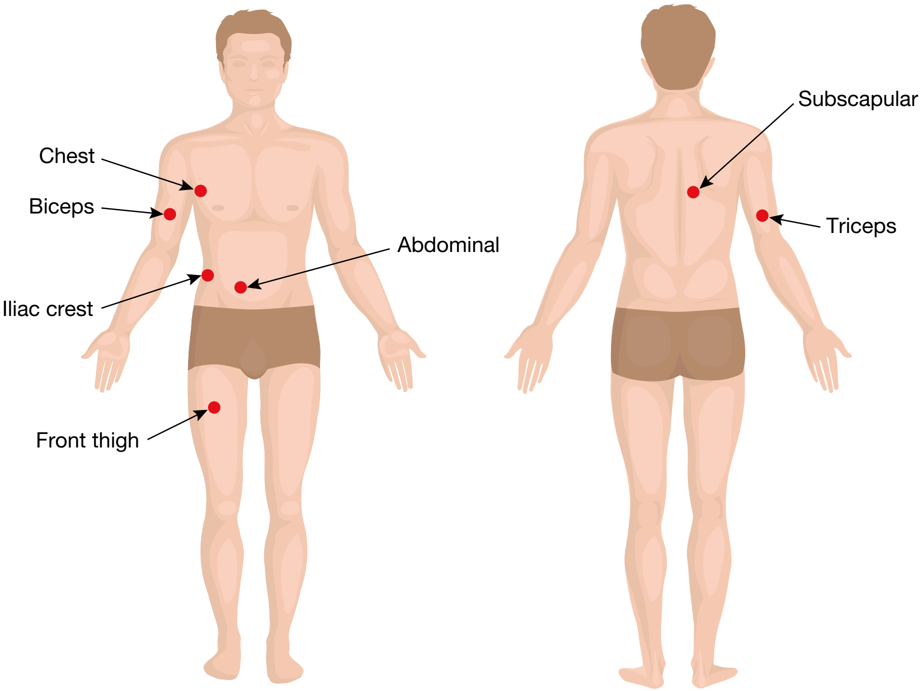


FIGURE 9.25 The sites for skinfold measurements

Results

1. Add the two median scores for the two sites to give a skinfolds total.
2. Refer to figure 9.26 to obtain the predicted percentage body fat and body fat standards.

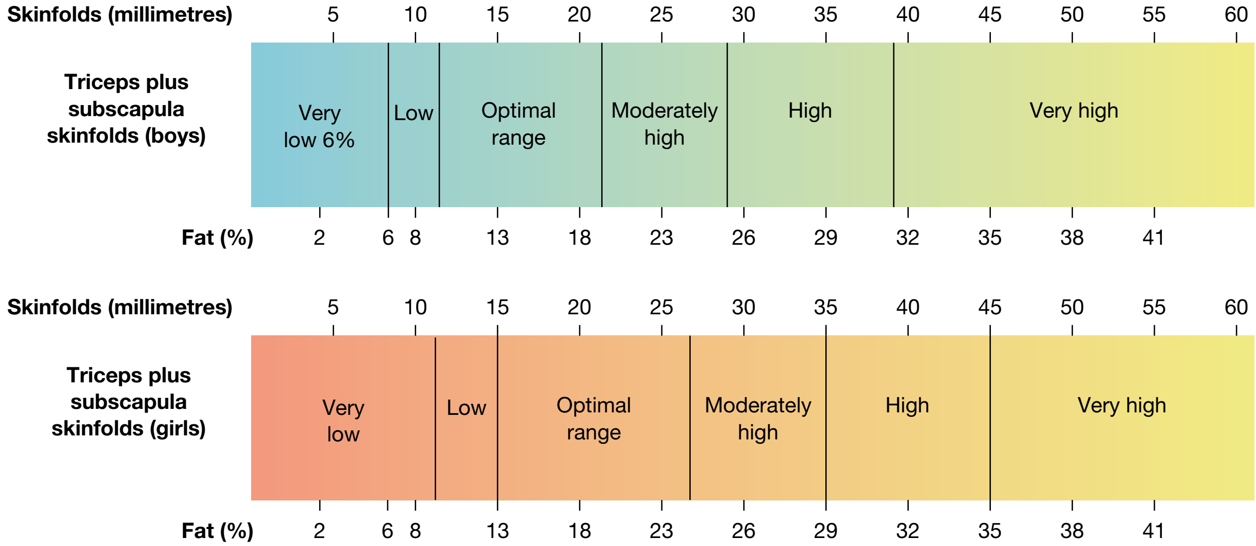


FIGURE 9.26 Predicted percentage body fat and body fat standards using triceps and subscapula skinfold sites for 6–17-year-olds

Source: Adapted from *Journal of Physical Education, Recreation and Dance*, vol. 58, no. 9, p. 99.

Hydrodensitometry (underwater) weighing

Aim

To measure the density of the body in order to then calculate the percentage of body fat

Equipment

- Hydrostatic stainless steel weighing tank, including underwater mounted chair and scale
- Weighted belt
- Nose clip
- A simpler set-up may include a chair and scale suspended from a diving board over a pool or hot tub.

Method

1. The dry weight of the subject is first determined. The subject, in minimal clothing, then sits on a specialised seat, expels all the air from their lungs, and is lowered into the tank until all body parts are submerged.
2. Underwater weight is recorded.
3. This procedure is repeated several times to get a dependable underwater weight measure.

Results

$$\text{Body density} = Wa / ((Wa - Ww) / Dw) - (RV + 100\ cc))$$

where Wa = body weight in air (kg), Ww = body weight in water (kg), Dw = density of water, RV = residual lung volume and 100 cc is the correction for air trapped in the gastrointestinal tract. The body density (D) can be converted to per cent body fat (%BF) using the Siri equation.

eBook*plus*

Weblink
Hydrodensitometry

eBook*plus*

Interactivity
Hydrodensitometry calculator
Searchlight ID: int-6811

Bioelectrical impedance

The proportion of body fat can be calculated as the current flows more easily through the parts of the body that are composed mostly of water (such as blood, urine and muscle) than it does through bone, fat or air.

Aim

To predict how much body fat a person has by combining the bioelectric impedance measure with other factors such as height, weight, gender, fitness level and age

Equipment

- Bioelectric impedance analyser
- Many bathroom weighing scales are also available with a bioelectric impedance analyser.

Method

1. Stand on the analyser. Participant should not be in contact with any other non-conducting surface, with legs apart and arms away from the body.
2. Some devices require a pair of electrodes are placed on the hand and wrist, and another pair placed on the ankle and foot (usually opposite sides of the body).
3. Follow the instructions of your particular device.

Results

See figure 9.26 for skinfolds and body fat norms.

DEXA and TOBEC scans

DEXA: Uses a whole body scanner that has two low-dose x-rays at different sources, which simultaneously read bone and soft tissue mass. This technique is based on the assumption that bone mineral content is directly proportional to the amount of photon energy absorbed by the bone being studied.

TOBEC: This method is based on lean tissue being a better conductor of electricity than fat.

Aim

To measure bone density and the proportion of body fat compared to lean tissue in the body.

Equipment

- DEXA specialised x-ray
- TOBEC machine

Method

DEXA

1. Participant lies down on x-ray table. The sources are mounted beneath a table with a detector overhead.
2. Participant must lie still throughout the procedure.
3. The scanner passes across the person's reclining body, with data collected at 0.5 cm intervals. A scan takes between 10 and 20 minutes.

FIGURE 9.27 DEXA scan

TOBEC

1. Participant lies in a cylinder that generates a very weak electromagnetic field.
2. The strength of the field depends on the electrolytes found in the water within a person's body. In about 10 seconds, TOBEC makes 10 conductivity readings that estimate lean body mass.

Results

See figure 9.26 for skinfolds and body fat norms.

Flexibility tests

Flexibility may be dynamic or static. Most tests of flexibility measure static flexibility because dynamic flexibility tests are difficult to implement.

Flexibility testing requires careful monitoring of safety measures. The participant should be thoroughly warmed up before attempting carefully monitored maximal stretches — it is essential that a full and measurable total body warm-up is carried out beforehand. This is to ensure a full range of movement is safely possible at a particular joint or sequence of joints. Safety is paramount in these tests.

Trunk flexion (sit-and-reach) test

The sit-and-reach test has been a standard assessment in most fitness test batteries for many years. However, there are variations in the method and scoring of this test. The following protocol is for the modified sit-and-reach test, which measures the flexibility of the hamstrings and lower back.

Aim

To reach forward as far as you can

Equipment

- Sit-and-reach box (recommended) or bench and ruler

Method

1. Sit on the floor with legs stretched out straight ahead. Shoes should be removed.
2. The soles of the feet are placed flat against the box/bench. Both knees should be locked and pressed flat to the floor — the tester may assist by holding them down.
3. With the palms facing downwards, and the hands on top of each other or side by side, the subject reaches forward along the measuring line as far as possible. Ensure that the hands remain at the same level, not one reaching further forward than the other.
4. After some practice reaches, the subject reaches out and holds that position for at least one or two seconds while the distance is recorded. Make sure there are no jerky movements.

An alternative method is to complete the test using one leg bent and one leg straight, and test each leg separately.

Note: An alternative, modified method is to complete the test with one leg bent and the other straight, and test each leg separately.

Results

1. Record the best score measured in centimetres to the nearest half-centimetre.
2. Refer to table 9.30 for ratings for this test using the one legged method. For norms using the two legged method, go to the weblink Sit and reach norms: two legs in your eBookPlus.

eBook*plus*

Weblink
Sit-and-reach norms: two legs straight

TABLE 9.30 Ratings for the modified sit-and-reach test using one leg at a time (centimetres)

Rating	Males aged 17 years	Males aged 18 years	Females aged 17 years	Females aged 18 years
Left leg				
Greatly above base standard	33 or more	35 or more	35 or more	39 or more
Well above base standard	29–32	28–34	31–34	29–38
Above base standard	22–28	22–27	24–30	24–28
Below base standard	21 or less	21 or less	23 or less	23 or less
Right leg				
Greatly above base standard	34 or more	37 or more	36 or more	38 or more
Well above base standard	30–33	30–36	31–35	30–37
Above base standard	22–29	22–29	24–30	24–29
Below base standard	21 or less	21 or less	23 or less	23 or less

Source: Adapted from Wright 1997.

FIGURES 9.28 The sit-and-reach test

Trunk rotation test

Aim

To reach as far as you can each side

Equipment

- Wall
- A piece of chalk or pencil
- Ruler or tape measure

Method

1. On a wall, mark a line (vertical). Stand with your back facing the wall, about an arm's length away from the wall, directly in front of the line, with your feet shoulder-width apart.
2. Extend your arms out directly in front of you, parallel to the floor.
3. Twist to your right and touch the wall behind you with your fingertips (arms extended and parallel to the floor). Feet cannot move.
4. Mark where your fingertips touched the wall, and measure the distance in centimetres from the line. A point before the line is a negative score and a point after the line is a positive score.
5. Repeat for the left side with your feet in the same position.

Results

TABLE 9.31 Trunk rotation test norms

Rating	Score (cm)
Excellent	20
Very good	15
Good	10
Fair	5
Poor	0

eBook*plus*

Weblink
Trunk rotation test

Groin flexibility test

Aim
To let your knees drop as close to the ground as possible

Equipment
- Ruler or tape measure

Method
1. Sit on the floor with your knees bent, and your feet flat on the floor and legs together.
2. Let your knees drop down to the ground as far as possible, keeping your feet together.
3. Hold on to your ankles with both hands, and pull them as close to your body as possible.
4. Measure the distance from your heels to your groin.

Results
TABLE 9.32 Groin flexibility norms

Rating	Score (cm)
Excellent	5
Very good	10
Good	15
Fair	20
Poor	25

Shoulder and wrist elevation test

The shoulder elevation test measures the flexibility of the shoulder joint. It is sometimes referred to as the shoulder hyper-extension test.

Aim
To reach as high as possible

Equipment
- 2-metre rulers
- Tape measure

Method
1. Use the tape measure to determine the length of the participant's arm from their acromial process to their fingertips.
2. The participant lies on the floor with their arms fully extended overhead. They grasp one ruler with their hands shoulder-width apart.
3. The participant raises the ruler as high as possible while keeping their chin on the floor. Read the measurement off the other ruler, which is held vertical (see figure 9.29).

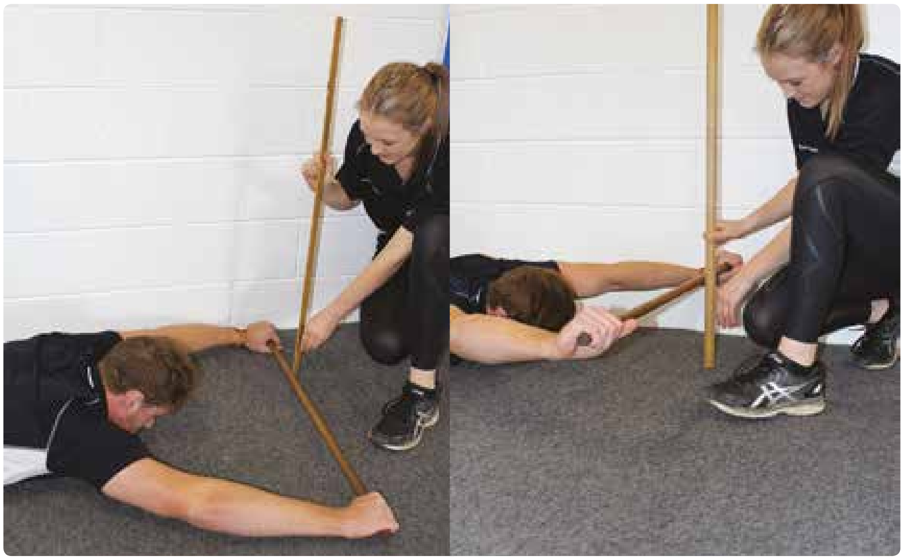
Results

1. Calculate the score obtained by subtracting the measurement of the height reached from the participant's arm length. Record this score.
2. Refer to table 9.33 for the ratings for the shoulder elevation test.

TABLE 9.33 Ratings for the shoulder elevation test (centimetres)

Rating	Males	Females
Excellent	14 or less	13 or less
Good	15–19	14–19
Average	20–29	20–27
Fair	30–32	28–30
Poor	33 or more	31 or more

Source: Adapted from Malpeli, Horton & Davey 1997.



FIGURES 9.29 The shoulder and wrist elevation test

Trunk and neck extension test

The static flexibility test (trunk and neck) is a measure of the static flexibility of the trunk and neck.

Aim

To lift head as high as possible

Equipment

- Ruler or measuring tape
- Assistant

Method

1. The participant lays prone on the floor with their hands clasped at the side of their head.
2. They raise their trunk as high as possible while still keeping their hips in contact with the floor.
3. Record the height from the tip of their nose to the floor.
4. Repeat the test three times.

Results

1. Select the best recorded height.
2. Refer to table 9.34 for the ratings for this test.

TABLE 9.34 Normative results for the static flexibility test (trunk and neck) (centimetres)

Rating	Males	Females
Excellent	> 25	> 24.8
Good	25.0–20.3	24.7–19.7
Average	20.2–15.2	19.6–14.6
Fair	15.1–7.6	14.5–5.1
Poor	< 7.6	< 5.1

Source: Adapted from Johnson, BL & Nelson, JK 1986, *Practical measurements for evaluation in PE*, 4th edn.

Ankle extension/dorsiflexion test

The ankle extension/dorsiflexion test is a measure of the static flexibility of the ankle.

Aim

To stretch feet back towards body as much as possible

Equipment

- Ruler or measuring tape
- Assistant

Method

1. The participant stands facing a wall with their feet flat on the ground and their toes touching the wall.
2. They lean into the wall.
3. The participant slowly slides their feet back from the wall as far as possible, keeping their feet flat, knees fully extended and chest touching the wall.
4. Measure the distance between the front of the participant's toes and the base of the wall.
5. Repeat the test three times.

Results

Refer to table 9.35 for the ratings for this test.

TABLE 9.35 Normative results for the static flexibility test (ankle) (centimetres)

Rating	Males	Females
Excellent	> 88.89	> 81.27
Good	88.89–82.55	81.27–77.47
Average	82.54–74.93	77.46–67.31
Fair	74.92–67.31	67.30–61.60
Poor	< 67.31	< 61.60

Source: Adapted from Johnson, BL & Nelson, JK 1986, *Practical measurements for evaluation in PE*, 4th edn.

Shoulder rotation test

Aim

To move an object over your head with the shortest distance between your hands

Equipment

- Stick or towel
- Ruler or tape measure

Method

1. Hold a towel or a stick in front of the body with both hands wide apart and palms facing downwards.
2. Maintaining the hand grip on the object, lift it over the head to behind the back.
3. Repeat the test, moving hands closer together each time until the movement cannot be completed.

Alternatively, if your hands can slide along the stick or towel, start with the hands close together and, as you swing the object over your head, slowly slide the hands apart just enough to enable it to go over your head and behind you.

4. Repeat a few times.
5. Measure the minimum distance between the hands.

Results

TABLE 9.36 Shoulder rotation test norms (centimetres)

Rating	Men	Women
Excellent	< 7.00	< 5.00
Good	7.00–11.50	5.00–9.75
Average	11.51–14.50	9.76–13.09
Fair	14.51–19.75	13.10–17.75
Poor	> 19.75	> 17.75

eBook*plus*

Interactivity
Shoulder rotation test calculator
Searchlight ID: int-6812

TEST your understanding

1 Define the term *flexibility*.
2 Define the term *body composition*.
3 List the main characteristics of reliable flexibility tests.
4 Rank the body composition tests from most accurate to least accurate.
5 Describe what is meant by a 'gold standard' test.

APPLY your understanding

6 **Practical activity: body composition and flexibility tests**
   (a) Complete as many body composition and flexibility tests as you can.
   (b) Compare your ratings for at least two body composition tests. Were they similar or different? Explain why this might be so.
   (c) Compare your ratings for at least two flexibility tests. Were they similar or different? Explain why this may be so.
   (d) Describe each of the tests and identify one sport to which they might be suited.
7 Identify and justify an appropriate flexibility test for the following participants.
   – Elite badminton player
   – Year 12 class
   – Beginner at the gym

EXAM practice

8 Discuss the relationship between practicality and accuracy of body composition tests using specific examples. **3 marks**
9 For the shoulder and wrist elevation and sit-and-reach tests, identify and justify a participant who is likely to use it, as it replicates their flexibility requirements. **4 marks**

KEY SKILLS

- Determine an appropriate fitness testing regime based on the physiological, psychological and sociocultural needs of the individual and the requirements of the activity
- Conduct a valid and reliable assessment of fitness using ethical protocols
- Perform, observe, analyse and report on practical laboratory exercises designed to assess fitness prior to designing a training program
- Justify the selection of fitness tests in relation to the physiological, psychological and sociocultural requirements of the test subject

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- When choosing a test, the following should be considered: replicating the requirements of the sport, the physiological state (PAR-Q), psychological state and sociocultural needs of the subject
- Recognised and standardised tests are more likely to be accurate and comparable to norms

PRACTICE QUESTIONS

1. **Justify** the use of a VO_2 max. test for an Olympic marathon runner. *(2 marks)*
2. **Outline** two procedures that will increase the accuracy and reliability of pre- and post-fitness testing. *(2 marks)*

SAMPLE RESPONSE

1. The VO_2 max. test is a maximal laboratory test, which is expensive but very accurate as it is individualised. It is a direct test that an Olympic marathon runner would require and be willing to pay for.
2. The tests are completed using the same equipment each time and the participant completes the same warm-up prior to the test each time.

An alternative response could be:

1. Exhaustive, expensive, highly accurate, individualised, direct
2. They are completed using the same equipment.
   They are completed with the same pre-test conditions (warm-up, nutrition).
   They are completed at the same time of day.
   The same testing protocols are followed.

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Justify — explain why the option you chose is the best option
  Outline — general description but not in detail
- **Key terminology:**
  VO_2 max. test — exhaustive, expensive, highly accurate, individualised
  Accuracy and reliability — only one variable, the participant should change
- **Key concepts:**
  Olympic marathon runner — elite, individual, high aerobic power
  Procedures — equipment, preparation, recording, environment
- **Marking scheme:** *1. 2 marks*
  2. 2 marks — always check marking scheme for depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

- **1 mark:** for each of two reasons
- **1 mark:** for outlining each of two procedures

CHAPTER REVIEW FITNESS ASSESSMENT: RATIONALE AND TESTS

CHAPTER SUMMARY

- Fitness testing is integral to any serious fitness training program and to any participant and should be completed after activity analysis.
- Fitness assessment provides a measurement of physiological responses to physical activity within a controlled environment.
- Sophisticated laboratory tests or simpler field tests can be used to assess fitness levels.
- Participants can undergo fitness testing before, during and after a training program. Testing can identify specific attributes of the participant, determining the participant's strengths and weaknesses, monitoring progress and providing motivation.
- Pre-participation health screening (PAR-Q) and informed consent are an important part of the testing process.
- There are clear testing protocols that should be put in place to ensure safety and ultimate test reliability and validity.
- A wide variety of tests is available to assess each fitness component.
- Selecting a particular test is a matter of deciding which test best suits the needs of the individual and the activity and should take into account the physiological, psychological and sociocultural perspectives.

eBook*plus*

Interactivity
Fitness assessment: rationale and tests quiz
Searchlight ID: int-6820

studyon

Sit VCAA exam

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 Which of the following is a maximal test for aerobic capacity?
(A) 20-metre shuttle run
(B) Yo-yo test
(C) Cooper 12-minute run
(D) VO_2 max. treadmill test

2 Which of the following tests does not require the participant to run as long as they can?
(A) 20-minute shuttle run
(B) Yo-yo test
(C) Cooper 12-minute run
(D) VO_2 max. treadmill test

3 The cycling track sprint ranges from 600 metres to 1000 metres. An athlete who scores highly in which test would be best suited to this event?
(A) Phosphate recovery test
(B) Wingate cycling test
(C) VO_2 max. cycle test
(D) Squat test

4 Which test requires the participant to complete as many repetitions as possible?
(A) Flexed arm hang test
(B) 1 RM squat
(C) 3 RM bench press
(D) 60-second pushup test

5 Pre-training program testing does not
(A) motivate athletes.
(B) set benchmarks.
(C) identify strengths and weaknesses.
(D) identify predominant muscle groups and energy systems required for activity.

6 Which of the following shows the correct order of tests to ensure the most accurate results?
(A) Least to most fatiguing
(B) Most to least fatiguing
(C) Aerobic tests first then anaerobic tests, as the aerobic tests act as a warm-up
(D) B and C

7 To ensure reliability of tests when comparing a number of participants on the same fitness component, what should be the only variable that changes between tests?
(A) The participant
(B) The test, as long as it still tests the same fitness component
(C) When the testing is held
(D) The norms used

8 Post-season testing
   (A) should not be done unless the athlete is elite.
   (B) should use the same tests as used in any pre- or in-season testing.
   (C) can use different tests but must test the same fitness components and energy systems.
   (D) is a waste of time as the season is finished.

9 Which of the following is the most accurate method of testing body composition?
   (A) BMI
   (B) Waist circumference
   (C) DEXA scan
   (D) Hydrodensitometry (underwater weighing)

10 If an 18-year-old male scored 58 centimetres on the vertical jump, it would be considered
   (A) excellent.
   (B) good.
   (C) fair.
   (D) poor.

TRIAL EXAM QUESTIONS

Question 1 **(ACHPER Trial Exam 2015, question 7)**

Body composition tests are designed to assess the proportion of body fat compared to lean tissue in an individual. Two recognised body composition tests are body mass index (BMI) and sum of skin folds. Evaluate the differences between these two tests and suggest the most appropriate test to be used by elite participants.

3 marks

Question 2 **(ACHPER Trial Exam 2013, question 9c)**

Flexibility decreases as we age. What are two other factors that affect flexibility? Provide an explanation as to how each factor affects this fitness component.

4 marks

Factor 1:
Explanation:
Factor 1:
Explanation:

INQUIRY QUESTION

If you were the coach of the Australian Soccer Team, how would you design the team's training program and what strategies would you use to record each player's physiological, psychological and sociological responses to the training program that you design?

CHAPTER

10 Monitoring and planning a training program

The ultimate purpose of designing, planning and implementing a training program is to achieve specific chronic adaptations that will enable an athlete to perform the best they can in their chosen sport or activity. This chapter investigates the important aspects that need to be considered in the overall planning of an effective training program, including the components of a discrete exercise training session, and monitoring and recording of physiological, psychological and sociological training data.

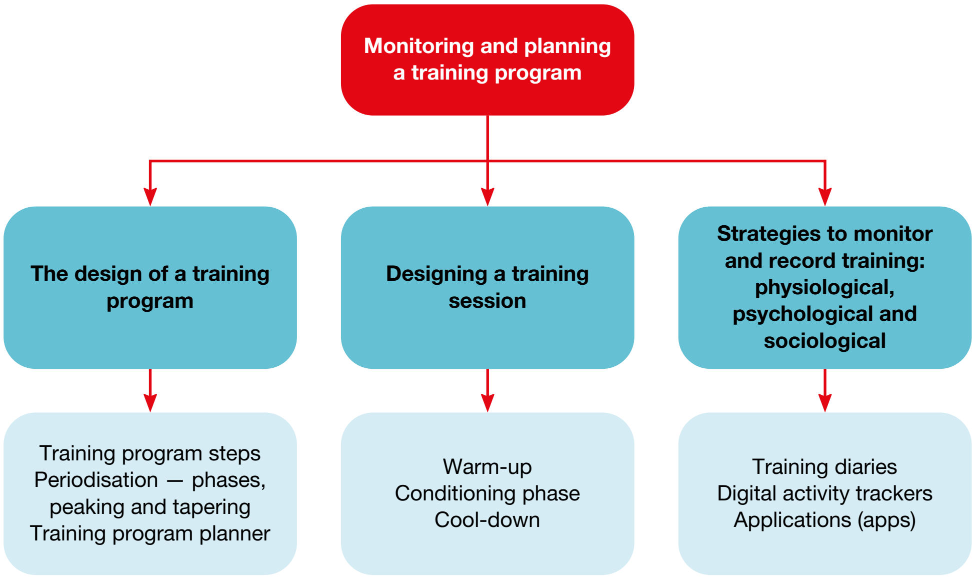
KEY KNOWLEDGE

- Strategies to monitor and record physiological, psychological and sociological training data, including training diaries, digital activity trackers and apps
- Components of an exercise training session including warm-up, conditioning phase and cool-down

KEY SKILLS

- Explain the importance of maintaining physiological, psychological and sociological records of training
- Conduct and participate in all components of an exercise training session
- Reflect on the physiological, psychological and sociological aspects of participation in a variety of training sessions
- Analyse training data to identify appropriate modifications to a training program

CHAPTER PREVIEW



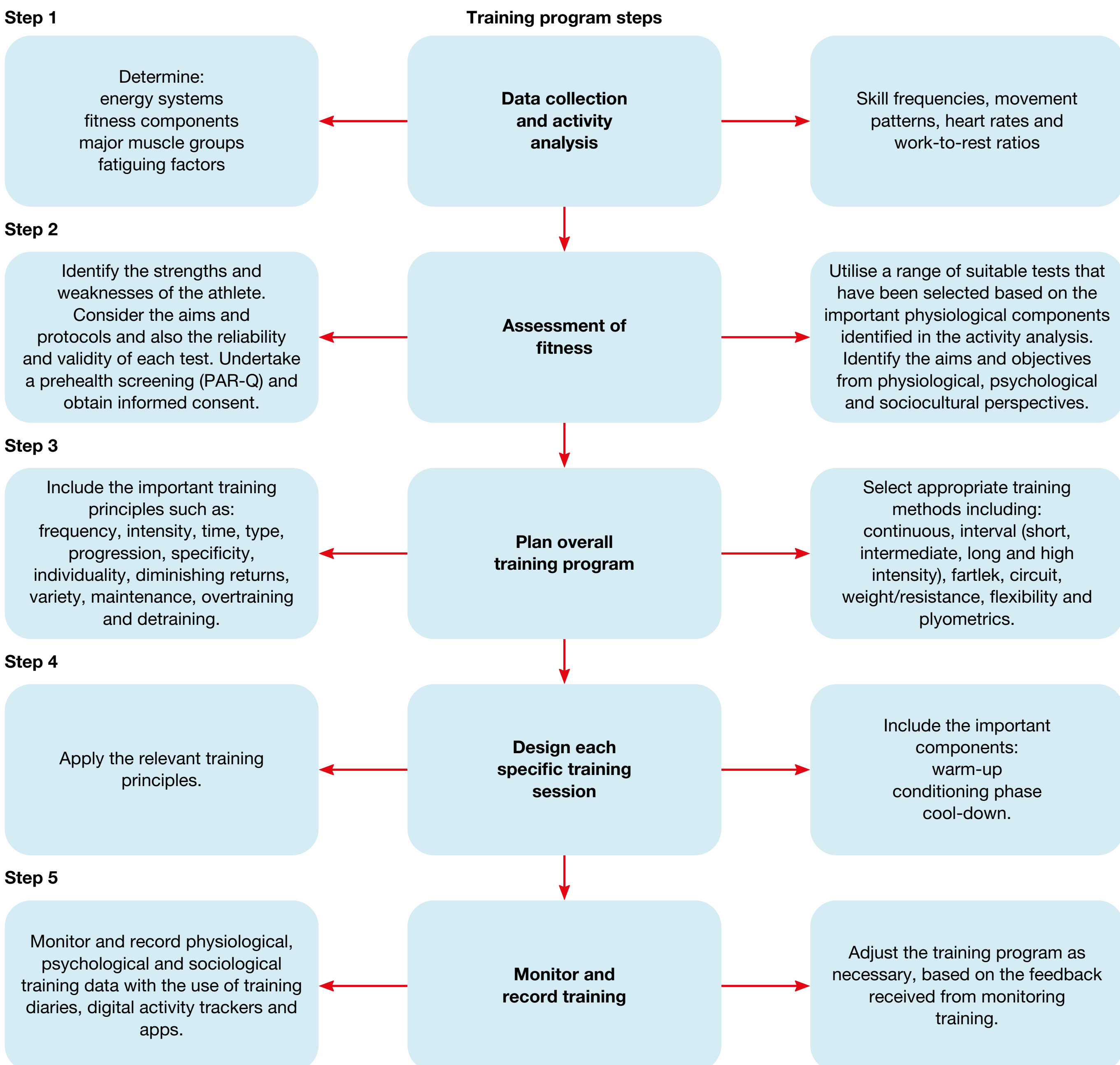
10.1 The design of a training program

KEY CONCEPT To maximise the benefits of a training program, it is essential that it be well designed. There are a number of important steps that should be undertaken when planning and implementing a training program.

Planning a training program

Devising and implementing a training program requires a carefully considered, step-by-step approach in which the coach and/or athlete incorporates the activity analysis, fitness assessment, training principles, training methodology and session-by-session detail into an overall plan.

FIGURE 10.1 Summary of the steps involved in planning a training program



In order to develop the most effective training program for achieving the desired chronic adaptations and improving the physiological capacity of an athlete and their performance, there are important steps that should be undertaken. Figure 10.1 provides a summary of these steps.

When designing a training program, all steps should be considered and then implemented in order for the program to be successful.

Activity analysis

Collect data in order to undertake an activity analysis to determine the relevant energy systems, fitness components, muscle groups and the associated fatiguing factors required by the activity or sport (see chapter 7 for more detail about conducting an activity analysis). The actual training program must be specifically designed to develop the physiological capacity of the athlete to meet these requirements.

eBook*plus*

Interactivity
Training program steps
Searchlight ID: int-6821

Assessment of fitness

Carry out a pre-fitness assessment using a range of suitable fitness tests that have been selected based on the results of the activity analysis (see chapter 9 for more detail about conducting a fitness assessment). This pre-fitness assessment enables the athlete's strengths and weaknesses to be identified, and also determines a suitable starting point (baseline) in terms of training workloads.

Training methods and principles

Select the appropriate training methods to be incorporated into the training program based on the findings of the activity analysis and the results of the pre-fitness assessment battery. Incorporate the correct application of the important training principles to each of the training methods selected (refer to chapter 11).

FIGURE 10.2 All training sessions require careful planning.

Periodisation of the training program

The ultimate success of a training program is dependent upon the appropriate application of the concept of periodisation. Periodisation is simply a process of dividing the annual training plan into a series of manageable phases, with each phase designed to target a specific goal to be developed within a designated period of time. You will study the concept of periodisation in more detail later in this chapter, and develop a greater understanding of the following aspects: training phases, tapering and peaking.

Training program matrix or planner

Before implementing a training program it is important to develop an overall training program matrix or planner that incorporates all of the training methods and sessions that are to be applied. It is crucial that the process of developing a training program planner begins with identifying and setting specific dates for achieving competition or personal goals. These dates form the basis for assigning the specific training phases. The ***general preparatory phase*** develops a fitness foundation for the pre-competition phase, which incorporates work of increasing intensity. The athlete's aim is to reach their peak fitness in readiness for the ***competition phase*** and this will include preceding tapering periods. The ***transition phase*** is the essential link between the end of the competition phase and the beginning of the preparatory phase and provides the athlete with an opportunity for physiological and psychological recovery by reducing the training load.

Specific training sessions

For each method of training that will be incorporated into the overall program, it is necessary to determine the total number of training sessions to be undertaken per week and over the duration of the program. This then allows you to plan the content of each training session in terms of training method, activities to be performed, intensity, volume and duration. When planning the specifics of each training session, adherence to the principles of training, especially specificity, intensity and progressive overload, must be considered and applied appropriately.

To obtain maximum benefit from each training session, it is also necessary to carefully consider how it is structured. Basically, all training sessions should consist of a warm-up, a conditioning component, a cool-down and stretch. More specific detail about the format of a training session will be provided later in this chapter.

TEST your understanding

1. Outline the key steps that need to be addressed when designing a training program.
2. Explain why it is important for a training program to be carefully planned.
3. Define the concept of *periodisation*.
4. List the three main training program phases.
5. Identify the three main components that comprise a specific training session.

APPLY your understanding

6. Discuss the importance of undertaking Step 1 (Data collection/activity analysis) as a part of the training program design process.
7. Explain the purpose of completing Step 2 (Assessment of fitness).
8. For a sport of your choice, design a 12-month training plan that shows when each of the training phases would take place.
9. Develop an individual training session template that would suit the sport of your choice.

EXAM practice

10 **adapted from ACHPER Trial Exam 2010, question 11**

Soccer is one of the most popular sports in the world today. A game of soccer consists of two 45-minute halves. Mathew Ryan is a goal keeper and Massimo Luongo is a midfielder for the Australian 'Socceroos'.

A goal keeper's role is mainly defensive and involves staying in the penalty area environs to prevent the opposition from scoring a goal. Most of a goal keeper's movements involve short sprints, kicking, throwing, leaping and jumping with frequent rest periods between work bouts.

A midfielder's role involves offensive and defensive plays. A midfielder covers far more of the playing field, with extended movement patterns involving sprinting, cruising, jogging and walking, in addition to kicking, dribbling and heading the ball, with far fewer rest periods than a goal keeper.

(a) With reference to the game of soccer, discuss why it is important to conduct an activity analysis prior to designing a training program. **4 marks**

(b) Identify the purpose of conducting fitness testing on Ryan and Luongo. **1 mark**

(c) Outline why Ryan and Luongo's coach would develop a training planner or matrix. **2 marks**

10.2 Periodisation of training

KEY CONCEPT An extended training program is typically separated into three phases or periods: the preparatory phase, the competition phase and the transition phase.

Training program plans will differ according to the specifics of the sport. Some sports will have a number of different competition phases interspersed throughout a 12-month period, some will have only one major competition as the main focus in order to peak, and for others there will be weekly matches within the defined competition phase. Typically, a traditional or linear periodisation model involves the training program plan being divided into the following three phases which may be manipulated according to the specific requirements of a particular sport or activity.

1. Preparatory phase (pre-season)
2. Competitive phase (in-season)
3. Transition phase (off-season)

Within each of the three phases, the athlete will train to accomplish certain goals. There will be a shift from an emphasis of high volume and low intensity in the preparatory phase to an emphasis of low volume and high intensity as the competition phase nears.

Preparatory phase

The preparatory phase (pre-season phase) of training is the first phase of training within a yearly training program. The major objective of this phase of training is to provide a suitable fitness and skill base for the phases of training that follow.

The **preparatory phase** of training is commonly referred to as the pre-season or conditioning phase of training. It usually lasts 2–4 months and is arguably the most important phase in an overall training program plan. In this phase of training the major objective is to provide a suitable fitness and skill base for the competition phase. It forms the foundation for all subsequent training to be built on.

The preparatory phase can be further divided into two sub-phases based upon the characteristics of training:

1. *The general preparatory sub-phase.* This sub-phase is concerned with obtaining a general fitness base and developing the main physiological requirements of the athlete's sport or activity. Strength building exercises are introduced during this phase. Emphasis is placed on maximising the capacities of the relevant energy systems, particularly the aerobic energy system. Fitness testing and specific skill correction are also a common focus of this period of training. The volume of training is generally high, but the intensity is low to begin with, slowly increasing as the phase progresses. This sub-phase usually lasts 4–10 weeks.
2. *The specific preparatory sub-phase.* As the competition phase approaches, there is a shift in training towards more specific game-related training. There should be a gradual reduction in the volume of training as the intensity starts to progressively increase. A greater amount of variety is also introduced into the training program during this sub-phase and it usually lasts 2–6 weeks.

Competition phase

The **competition phase** (in-season phase) of training is the phase of training in which the emphasis is on maintaining fitness and skill level developed during the preparatory phase, and further developing and refining strategies, tactics and game plans.

The **competition phase** is preceded by a short pre-competition phase so that by the time the competition phase, or in-season phase, of training begins, the athlete should have achieved optimal fitness and skill levels. The focus of the pre-competition phase is to ensure that the athlete is at their peak fitness for competition. This is where an athlete continues to increase the intensity of their training and adjust the volume appropriately. This sub-phase may also incorporate practice matches and tactical training in readiness for competition. A taper period to allow the athlete to recover and reduce any residual fatigue for subsequent competition is often included towards the end of this sub-phase. The emphasis of the competition phase of training should be on maintaining these attributes, and further developing and refining strategies, tactics and game plans.

Because of the demands of competition, particularly if games are weekly (as is the case with many sports such as football, basketball and netball), training needs to be planned carefully. This is to allow for recovery and to ensure that players are at their peak both physiologically and psychologically on game day. Individual training sessions in the day or two after competition should allow for adequate recovery. Subsequent sessions early in the week should be relatively longer and/or more intense. Sessions towards the end of the week should be shorter and less intense, so that players are fully recovered by the day of competition.

The competition phase usually lasts 4–6 months for most sports played at an elite level.

FIGURE 10.3 All levels of competition require that the correct phases of training are implemented in order to maximise performance.

Transition phase

The **transition phase** (off-season phase) is designed to provide the athlete with both a physiological and psychological respite from the rigours of competition and training. The key to the transition phase of training is to create a balance between recovery and maintenance of training. It is imperative that adaptations do not reverse to pre-training levels during this phase. This phase should begin with a short period of active rest and little formal training. Thereafter, the aim during this phase should be for the athlete to remain reasonably active through involvement in a range of recreational activities and low-intensity training to maintain a suitable level of fitness. Cross-training provides variety and is a good way to allow for active recovery both physiologically and psychologically while preserving a base level of fitness. It is essential that the athlete's diet is carefully monitored during this period of time. The off-season phase usually lasts for 6–12 weeks.

The **transition phase** (off-season phase) of training is designed to provide the athlete with a break from the physiological and psychological demands of competition and training. The aim in this phase is for an athlete to remain reasonably active through participation in recreational and low-intensity activities.

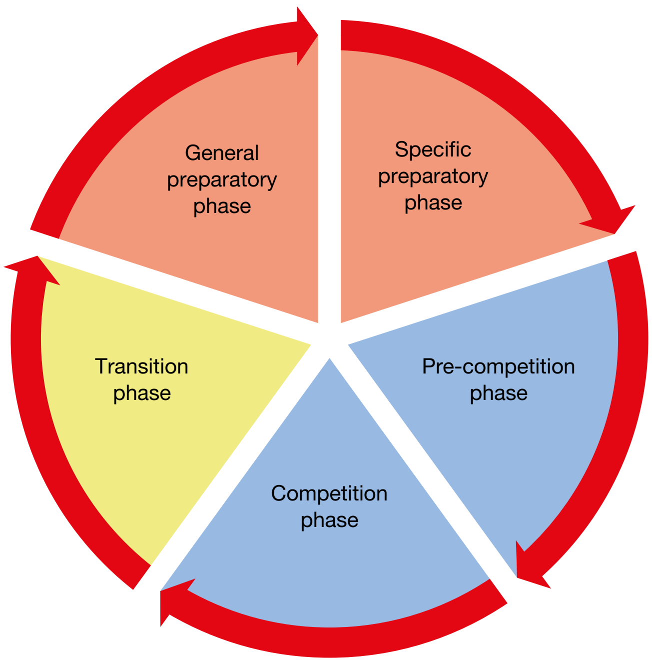


FIGURE 10.4 Periodisation is a cyclic process where each phase transitions into the next.

Block periodisation involves designing a training program with highly specific, targeted blocks of work.

Another form of periodisation that has become popular is **block** or nonlinear **periodisation** which incorporates blocks of highly specific and concentrated periods of work with more frequent variations in load. Each sport will differ in the way that a block or nonlinear periodisation model is designed; however, some general principles apply.

- Each training block focuses on a small number of targeted fitness components and/or skills.
- The length of each training block is typically 2–14 weeks as this period of time allows for chronic adaptations to occur without too much corresponding fatigue.
- There are only a small number of blocks that are generally incorporated into an overall training program.
- Each training block is sequenced consecutively in order to achieve optimal performance for competition.
- Variations in the levels of imposed stress stimulate more rapid adaptations.
- Allows for an athlete to prepare for multiple events throughout the year.

One of the main differences between the traditional or linear and block periodisation models is that traditional or linear periodisation aims to improve a variety of fitness components and skills simultaneously over a longer period of time, whereas block or nonlinear periodisation is more specialised and concentrated in its approach to each work block.

Peaking and tapering

The main goal of a training program is to prepare an athlete to be able to perform at their best, however it is not generally possible for an athlete to remain at their optimum level of performance all year round. Hence, athletes often aim to be at their best performance state for particular competitions. The nature of the sport determines when the athlete needs to be performing at their optimum. A triathlete may aim to be at his or her best level of performance for major events such as National and World Championships and the Olympic Games, whereas an Australian Rules Football player would aim to perform at his or her best on a weekly basis; however he or she would also hope to be at optimum level of performance during finals. Each program needs to be individualised to cater for these differences and also take into account the particular athlete's overall goals.

Peaking refers to the planning of training so that an athlete reaches their optimum state of readiness to perform at a particular predetermined time.

Tapering is a reduction in training that allows the athlete time for extra recovery and for their energy stores to be fully restored.

Peaking and **tapering** are important parts of the periodisation of training. Peaking aims to allow an athlete to reach their optimal fitness to perform at a predetermined competition. Periods of intense training can have a negative effect on an athlete's performance capacity and it is therefore essential that a reduction in training load occurs in preparation for optimal performance.

This reduction in training — known as tapering — allows the athlete time for extra recovery and for their energy stores to be fully restored. At the end of a taper the athlete should be in peak condition and should be in their ultimate readiness to compete. Tapering used to involve a reduction in both the volume and the intensity of training. However, now it is widely recognised that the quantity of training should be reduced but the intensity should remain at the same level (or may in some cases even be increased).

While most athletes and coaches agree that tapering is a good thing, there are wide differences in opinion as to how tapering periods should be constructed. These debates revolve around:

- how long a tapering period should be
- the extent to which training volume and frequency should be reduced during tapering and the rate at which these variables should be reduced.

The above variables are adapted according to the needs of the athlete and the particular sport or activity for which they are training. The concept of tapering is not appropriate for all sports, particularly sports which have weekly competitions;

however, these athletes still require periods of recovery in order to perform at their peak. The most prominent change that occurs as a result of effective tapering is an increase in muscular strength. Some coaches have a certain amount of apprehension in allowing their athletes to undertake a period of tapering, as they worry that it will cause a reduction in their aerobic conditioning. Research reveals that although a considerable amount of training is required for significant improvements in aerobic capacity to be achieved when starting a training program, much less training is required to maintain them and reducing the load with appropriate tapering should not cause any detraining. Every individual athlete will respond differently to tapering, however most athletes will improve or at least maintain their current level of performance.

Some of the benefits of tapering include:

- allows for replenishment of fuel substrates such as glycogen
- provides an opportunity for psychological refreshment
- heightens enzyme activity
- increases red blood cell volume
- allows for the repair of muscle micro-trauma.

Greg Wells, from the Canadian Sport Centre, summarises seven characteristics that seem to be common to successful tapering techniques.

1. Total training volume is reduced by 60–90 per cent.
2. The volume of high-intensity training remains high (high intensity is relative to the event being prepared for).
3. The level of difficulty is reduced by increasing recovery time.
4. The frequency of training is reduced slightly (up to 20 per cent).
5. The time of the taper period is between four and 21 days, depending on the individual.
6. Use a **fast decay exponential taper** design.
7. Activities performed during taper are specific to the athlete's competitive demands.

eBook*plus*

Weblink
Tapering

A **fast decay exponential taper** involves reducing the training load progressively, with a greater reduction at the beginning of the taper and sustaining the low training load.

FIGURE 10.5 Matthew Dellavedova would have followed a very well-designed training program in order to be at his peak and contribute to the Australian Boomers' success at the Rio 2016 Olympic Games. The Boomers narrowly missed a medal and came fourth after a disappointing match against Serbia.

TEST your understanding

1. Identify the role of the preparatory phase of training and make a distinction between the general and specific preparatory sub-phases.
2. Identify the role of the competitive phase of training and make a distinction between the pre-competition and competition sub-phases.
3. Identify the role of the transition phase of training and explain the types of activities that could be included during this phase.
4. Why does the athlete need to pay more attention to their diet during the transition phase?
5. Explain the difference between a traditional periodisation model and a block periodisation model.
6. Explain the relationship between peaking and tapering.

APPLY your understanding

7. Show how the volume and intensity of training is manipulated during each phase of training by completing the **Phases of training** digital document in your eBookPLUS.
8. Design a 12-month training program planner using a traditional or linear periodisation model that would suit a sport of your choice. Complete your planner including the following information:
   - In the Months section of the template, insert names of each month.
   - In the Competition dates section of the template, highlight when important competitions will occur.
   - Indicate your training goals for each phase; e.g. increase aerobic capacity, maintain muscular strength.
   - Indicate how you would manipulate the volume and intensity of training during each phase: high, medium or low.

   An example of an **Athlete's training program planner template** is provided as a digital document in your eBookPLUS, and also shown below. Make sure that the design of your template is applicable to the sport of your choice.

12-MONTH TRAINING PROGRAM PLANNER

	General preparatory		Specific preparatory			Pre-competition		Competition			Transition	
Months	1	2	3	4	5	6	7	8	9	10	11	12
Training goals												
Competition dates												
Volume												
Intensity												

H – high, M – medium, L – low

9. How would you design your training program differently using a block periodisation model?
10. For a sport of your choice, describe how you would appropriately taper the training program in order for the athlete to peak at their optimum performance for competition.

eBook*plus*

Digital documents

Phases of training
Searchlight ID: doc-21027

Athlete's training program planner template
Searchlight ID: doc-20128

10.3 Components of an exercise training session

KEY CONCEPT The components of an exercise training session include the warm-up, conditioning phase (skill and fitness), cool-down and stretch.

The most important part of any training program is the actual training sessions. The specific content of each training session will depend on various factors such as the overall aim of the program and its timing within the periodisation plan. However, all training sessions should be structured to include the following:

1. a warm-up component
2. a conditioning component (skill development and/or fitness conditioning)
3. a cool-down component
4. a stretching component.

The warm-up component

Each training session should begin with a **warm-up**. Essentially the warm-up is designed to prepare the body both physiologically and psychologically for the conditioning phase of the training session. The athlete gradually increases the intensity level of physical activity performed in order to increase the heart rate, blood flow and ultimately the temperature of the muscles to be used. A warm-up provides the opportunity for the body to transition from a resting state to the higher physiological demands of the conditioning phase of training. The length and types of activities to be undertaken in a warm-up is dependent upon the intensity of the conditioning phase, the ability level, the age of the athlete and the weather conditions. Generally the harder the conditioning phase and/or the older the athlete, the more extensive the warm-up should be. The length of the warm-up should also be increased in cold weather environments. The warm-up should produce mild sweating without any feelings of fatigue and should consist of movements that mimic the muscle actions required in the conditioning phase of the training session.

The **warm-up** is activities and exercise undertaken at the beginning of a training session that are designed to prepare the body both physiologically and psychologically for the conditioning phase of the training session.

FIGURE 10.6 An effective warm-up was a crucial part of Sharni Layton's preparation in this Constellation Cup match against the New Zealand Silver Ferns.

studyon

Unit 4
AOS 2
Topic 1
Concept 4

Warm-up
Summary screen and practice questions

The phases of a warm-up

An effective warm-up prepares the respiratory, cardiovascular and muscular systems to be at their optimum readiness for subsequent activity and generally consists of the following phases.

- General phase — low- to moderate-intensity cardiovascular continuous whole body cyclic exercise such as jogging, swimming or cycling to begin to increase the heart rate and blood flow to the muscles. This phase should be about 5–10 minutes in length.
- Dynamic range of movement phase — dynamic range of movement exercises (dynamic stretching) such as leg kicks, side swings, lunges, trunk rotations and so on appropriately selected to target the specific muscles and joints to be used in the conditioning phase. The aim of this phase is to loosen and increase the mobility of the joints, muscles and connective tissue.
- Sport/activity specific phase — activities that involve agility, speed, acceleration and sport/activity specific skills are included in this phase. This prepares the body for the intensity that is required during the conditioning phase of training and it also increases the neuromuscular efficiency and consequently the speed at which muscles are able to respond to stimuli.

The warm-up is also a good time for the athlete to increase their focus and concentration and prepare mentally for subsequent performance.

It is important to note that while research has found that a warm-up results in many benefits to performance, it may be also detrimental to performance if it causes the core body temperature to increase two degrees above the normal range of 36.5–37.5 degrees Celsius. The optimal combination of intensity, duration and type of activity to be included in the warm-up is very individualised, however the time between the conclusion of the warm-up and the start of the event or conditioning phase should be less than 15 minutes.

The ultimate aim of the warm-up is the same for every athlete: to be 100 per cent ready to participate in an event, competition or the conditioning phase of training.

FIGURE 10.7 The Australian hockey team complete a dynamic warm-up prior to their international match.

The benefits of a warm-up

The warm-up prepares an athlete both physiologically and psychologically for the remainder of the training session.

It produces changes such as:

- increased blood flow to the muscles, resulting in an increase in muscle temperature and muscle fibre elasticity and therefore allows the muscles to contract more forcefully and relax more quickly. This permits the joints to work at their full range of movement and lessens the likelihood of injury.
- increased heart rate and dilation of blood vessels, which results in a greater oxygen and nutrient delivery to the muscle cells
- increased enzyme activity within the muscle cells due to increased muscle temperature, facilitating faster fuel breakdown and energy release within the muscle
- increased respiratory rate and pulmonary diffusion, resulting in increased delivery of oxygen to working muscles
- enhanced neural pathways, resulting in an increased rate, speed and strength of nerve impulses, allowing for more forceful muscular contractions
- increased availability of oxygen in the contracting muscle, which reduces the size of the oxygen deficit in subsequent higher-intensity activity.

The conditioning component

The conditioning component is the main focus of the training session and it may include a skill development phase and/or a fitness conditioning phase. The nature of the sport, activity or event will determine the percentage allocation of the skill and the fitness conditioning required. In sports such as golf that require a high level of skill and a lesser fitness conditioning need, there will be a greater emphasis on the skill development phase. In sports like triathlons, the fitness conditioning phase will have a greater emphasis in most sessions. In some sports, there is an equal need for both skill development and fitness conditioning and this needs to be balanced accordingly.

The conditioning component will include the application of specific training methods (discussed in chapter 11) that have been selected based upon the data/activity analysis. It is during the conditioning component of the training session that the focus is to improve the relevant fitness components, muscle groups, energy systems and motor skills required in the chosen sport, activity or event. The important training principles (discussed in chapter 11) should be applied appropriately during each session.

FIGURE 10.8 Meg Lanning would train like she plays in order to perform at her best as captain of the Australian women's cricket team.

studyon

Unit 4 | AOS 2 | Topic 1 | Concept 5

Conditioning phase
Summary screen and practice questions

Skill development phase

Activities designed to provide practice of skills, game plans, tactics and strategies are incorporated into the **skill development phase** of the training session. The skill development component can either precede or follow the fitness conditioning phase. If these activities are performed prior to the fitness conditioning phase, the athletes are generally less fatigued, more alert and better able to focus. However, the coach may want the athletes to practise skills while experiencing fatigue, as would be the case in a game. Therefore, they may schedule these activities to take place after the fitness-oriented work of the fitness conditioning phase. Of course, skill-related activities might also be incorporated into the conditioning phase.

The **skill development phase** includes activities designed to develop and/or provide practice of skills, game plans, tactics and strategies.

The **fitness conditioning phase** is the part of a training session that focuses on the development and/or maintenance of specific fitness components, muscle groups and energy systems required for a particular sport or activity.

Fitness conditioning phase

The primary objective of the **fitness conditioning phase** of the training session is the development and/or maintenance of the specific fitness components, muscle groups, energy systems and motor skills required for the particular sport or activity. To ensure optimum effectiveness, empirical evidence suggests an accepted order of priority for the development of fitness attributes.

1. Sprint and speed work should normally be undertaken first while the athlete's fatigue levels are low.
2. Strength and power training should follow next, while fatigue levels are still relatively low.
3. Aerobic activities and the development of local muscular endurance should usually be undertaken as the final part of the conditioning phase.

The cool-down component

Cool-down is low-intensity activity completed at the end of an exercise bout that allows the body to recover by maintaining an elevated blood flow to the muscles and preventing venous pooling, gradually returning the body to its resting physiological state.

In much the same way that exercise intensity must gradually increase during the warm-up, so too must it gradually decline towards the end of the training session. This gradual reduction of the intensity of the activities being performed is referred to as the **cool-down** and should be of approximately the same intensity and duration as the warm-up.

The type of activities performed in the cool-down should replicate the activities performed in the conditioning component so that the appropriate muscle groups are recovered effectively. An example is a cyclist who, after completing a series of sprints around the velodrome, completes a number of laps at a gradually decreasing pace. The cool-down should also incorporate a series of optimal static or PNF stretches of all the major muscles used in the skill development and conditioning components of the training session. The cool-down is the first stage in an athlete's recovery process after training.

The need for a cool-down

Venous pooling is an accumulation of blood in the veins in inactive muscles following activity.

The major physiological rationale for completing an active cool-down is to prevent **venous pooling**, remove metabolic waste from the muscles and reduce the likelihood of delayed onset muscle soreness (DOMS). Venous pooling refers to the accumulation of blood in the veins. After strenuous exercise, the heart continues to pump out blood forcefully and rapidly for some period of time. If an athlete ceases activity altogether at this point, their muscles are no longer contracting and helping to propel blood back to the heart (the so-called skeletal muscle pump effect). As a result, blood may pool in the veins, especially in the lower limbs. This venous pooling can result in a decreased venous return to the heart. Consequently, less blood is re-oxygenated via the lungs, and less metabolic by-products (carbon dioxide and lactic acid) are removed from the muscle tissues. The main aim of the cool-down is to bring the body back to resting levels in the most efficient way possible.

The stretching component of a cool-down

As discussed earlier, the most appropriate stretches to be used during the warm-up are ones that are dynamic in nature and consist of sport-specific, functional-based movements. Dynamic stretching involves using the momentum of the active muscle contractions to move the muscles and joints through a full range of movement. They should mimic the movements required in the specific sport, activity or event to prepare the neuromuscular system for the higher intensity movements that will follow.

At the end of the cool-down component of the training session, stretching should take place in order to improve the flexibility of the muscles and reduce any stiffness or soreness. An athlete will gain the most benefit from stretching when the muscles are still warm and the ligaments and joints are more elastic. The type of stretches undertaken at this stage are more static in nature and may include the following.

- Static stretching — involves taking the joint to its full range of movement that can be comfortably tolerated and holding it for a minimum time period of 10 seconds. The stretch reflex relaxes muscles and maintains or increases the flexibility and range of movement of joints.
- Passive stretching — involves the muscle relaxing with the use of an external force assisting you to achieve the stretch.
- Proprioceptive neuromuscular facilitation (PNF) — involves fully lengthening the muscle and isometrically contracting against a resistance for a time period before stretching again. This process is repeated until a full stretch is achieved. This type of stretch works on the theory of reciprocal inhibition that when an agonist muscle contracts, the antagonist muscle is inhibited which causes it to relax and achieve its full range of movement.
- Slow active stretching — involves the contraction of the opposing muscles to assist in relaxing the targeted muscle to achieve its full range of movement. This type of stretch is generally considered low risk because it is controlled by internal rather than external forces.

studyon
Unit 4
AOS 2
Topic 1
Concept 6
Cool-down
Summary screen and practice questions

FIGURE 10.9 Passive stretching

FIGURE 10.10 Static stretching

FIGURE 10.11 PNF stretching

FIGURE 10.12 Slow active stretching

TEST your understanding

1 Discuss how the warm-up prepares the athlete physiologically.
2 Discuss how the warm-up prepares the athlete psychologically.
3 Outline the three main phases that a warm-up consists of and explain the type of stretches that should be performed during the warm-up component of training.
4 Explain when a warm-up may be detrimental to performance.
5 Outline the two phases that may be included in the conditioning component of a training session.
6 Provide an example of a type of sport/activity that an athlete may prioritise a higher percentage of time allocation to undertaking skill development.
7 Describe and explain a situation in which a coach may incorporate the skill development phase prior to the fitness conditioning phase.
8 Describe and explain a situation in which a coach may incorporate the fitness conditioning phase prior to the skill development phase.
9 Explain venous pooling. Why does it occur and how does an active cool-down prevent it from happening?

APPLY your understanding

10 Explain the purpose of incorporating stretching at the end of a training session.
11 Design a 60-minute sample training session for a sport/activity of your choice. Your training session needs to include an appropriate selection of some example activities for each component. It should also indicate the recommended timing of each component. You should also provide information about the type, intensity, time and number of repetitions for each activity that you would recommend. Use the **Example training session** digital document in your eBookPLUS.
12 **Practical activity: training session in action** Put your training session into action. Become a coach and guide your peers/class through the training session that you have designed. You may need to modify the timing of each component based upon class time availability. Your teacher may also like to allocate a different training method or a particular sport/activity for each group to design and demonstrate their training session.

EXAM practice

13 **adapted from ACHPER Trial Exam 2014, question 7**
Daniel is a Year 12 student who trained to compete in an 8 km Fun Run. The race was held on a flat course that comprised 2 × 4 km laps. On the night of the race, the air temperature was 33 degrees Celsius. During the race, the following data was collected via a heart rate monitor and GPS:

Distance	Time (minutes)	Average heart rate
1 km	4:09	166 bpm
2 km	4:13	172 bpm
3 km	4:26	173 bpm
4 km	4:23	173 bpm
5 km	4:38	175 bpm
6 km	4:37	175 bpm
7 km	4:38	176 bpm
8 km	4:13	180 bpm

(a) Discuss the benefits for Daniel in undertaking a warm-up prior to competing in the 8 km Fun Run. **3 marks**
(b) What main consideration would Daniel need to take into account when designing the conditioning component of his training sessions leading up to the event? **1 mark**
(c) Outline the purpose of the conditioning component of a training session. **2 marks**
(d) State two main reasons why you would recommend that Daniel undertake a cool-down at the completion of the 8 km Fun Run. **2 marks**

eBook*plus*
Digital document
Example training session
Searchlight ID: doc-21029

10.4 Strategies to monitor and record training

KEY CONCEPT Athletes and coaches should use strategies to monitor and record their physiological, psychological and sociological training data in order to reach a peak level of performance.

Monitoring and recording strategies

There are a variety of different monitoring and recording strategies that are available for athletes to monitor and record their **physiological, psychological** and **sociological training data**. Advances in wearable technologies and applications have created the opportunity for athletes to collect data electronically and monitor their training more effectively. Training diaries, digital activity trackers and apps are very useful monitoring tools that an athlete and coach can use in order to increase the effectiveness of a training program. Monitoring training allows for a reconciliation between the aims of the program and what is actually being achieved. Monitoring training provides an understanding as to how hard an athlete is working paralleled with how well they cope physiologically, psychologically and sociologically with the training load. It is important that monitoring is used to inform, evaluate and modify training and not simply as a method of collecting data. The information provided can allow the athlete to incorporate the concepts of peaking and tapering effectively into their training program.

Physiological training data provides information about the body's physical functioning in response to training.

Psychological training data provides the athlete with an understanding of their mental readiness and mental capacity to train and perform: thoughts, feelings and cognitive characteristics that affect behaviour.

Sociological training data provides context about the broader social, cultural and environmental factors that contribute to an athlete's performance.

Over recent decades, increased physiology knowledge has had an impact on improving sports performance. This, combined with the current digital technology advancements, has meant that athletes are being more heavily monitored, further improving performance. The digital technology advancements have created an overwhelming number of digital monitoring systems that are available choose from. The choice of which to use is really dependent upon the information that the athlete and coach require. They need to ensure the information gathered has meaning when considering maintaining or modifying a training program. A combination of both subjective and objective data should be used in order to understand the whole picture of the athlete. Physiological responses may be influenced by both psychological and sociological factors. It is important that the type of data gathered is informative, relevant and useful in monitoring the aspects specific to the sport and the athlete. Data that is easily interpreted and practical in its application is more likely to support ongoing monitoring.

Coaches and athletes will often incorporate a variety of strategies to monitor training so that they can obtain a more comprehensive understanding of their physiological, psychological and sociological influences. Training diaries, digital activity trackers and application software provide a range of ways to monitor the effectiveness of a training program and minimise injury and/or illness. The ultimate goal of a training program is to achieve the necessary chronic responses to improve an athlete's performance in a particular sport or activity and monitoring training is essential to keep the athlete on track to reaching this goal.

FIGURE 10.13 Monitoring training allows the athlete to stay on track in reaching their training goal(s).

studyon

Unit 4 | AOS 2 | Topic 1 | Concept 2

Training diaries
Summary screen and practice questions

Training diaries

A training diary is an athlete's personal monitoring tool which can record both objective and subjective training information. An athlete can record objective data obtained from digital tracking and also record some subjective information such as emotional feelings, energy levels and environmental factors.

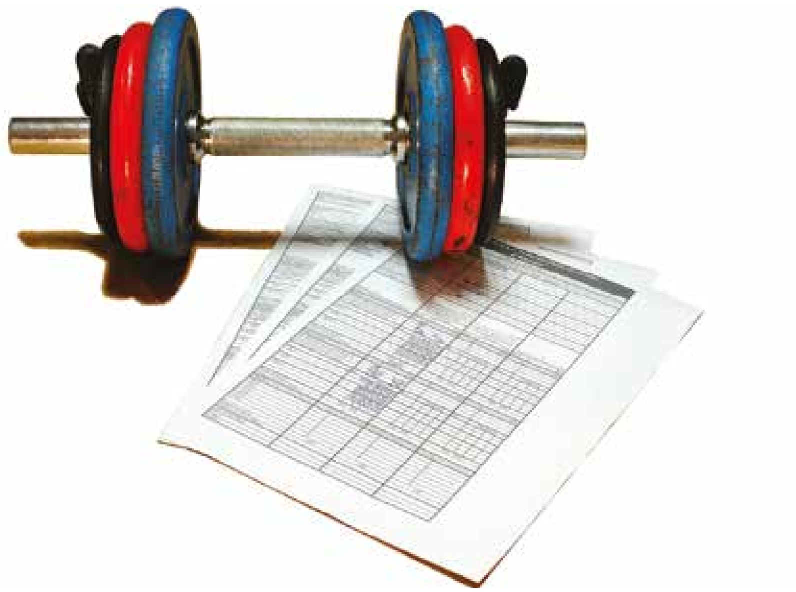


FIGURE 10.14 There are many physiological, psychological and sociological parameters that can be recorded in a training diary.

There are many benefits to keeping an accurate training diary, such as to:

- gather information about an athlete's physiological, psychological and sociological influences
- increase motivation
- improve goal setting
- track progress over time
- identify any limitations to training
- provide feedback to the coach for any sessions the athlete has undertaken without their presence
- apply progressive overload correctly and prevent overtraining
- record dates for competitions.

Most importantly, a training diary helps the athlete develop a greater self-knowledge about their training and development.

Some of the specific physiological, psychological and sociological variables that can be recorded in a training diary are as follows.

Physiological

- Energy level (**RPE**) during training
- Heart rate responses (resting, exercise and recovery)
- Muscle soreness
- Sleep patterns (quality and quantity)
- Nutritional information
- Breathing rate
- Perspiration levels

RPE (rating of perceived exertion — Borg Scale) is a subjective rating of how hard the athlete feels that they are working. It is a numerical scale ranging from 6 to 20, with 6 being no feeling of exertion and 20 being extremely hard. 13–14 is classified as moderate intensity and 15–16 is classified as vigorous.

Psychological

- Emotional and motivational variables
- Confidence levels
- Arousal levels
- Stress levels
- Goal setting

Sociological

- Temperature and weather conditions during training session
- Training time and day
- Time of training session
- Type of training session
- Place of training (indoors, outdoors, type of surface, venue)
- Training partners/team mates

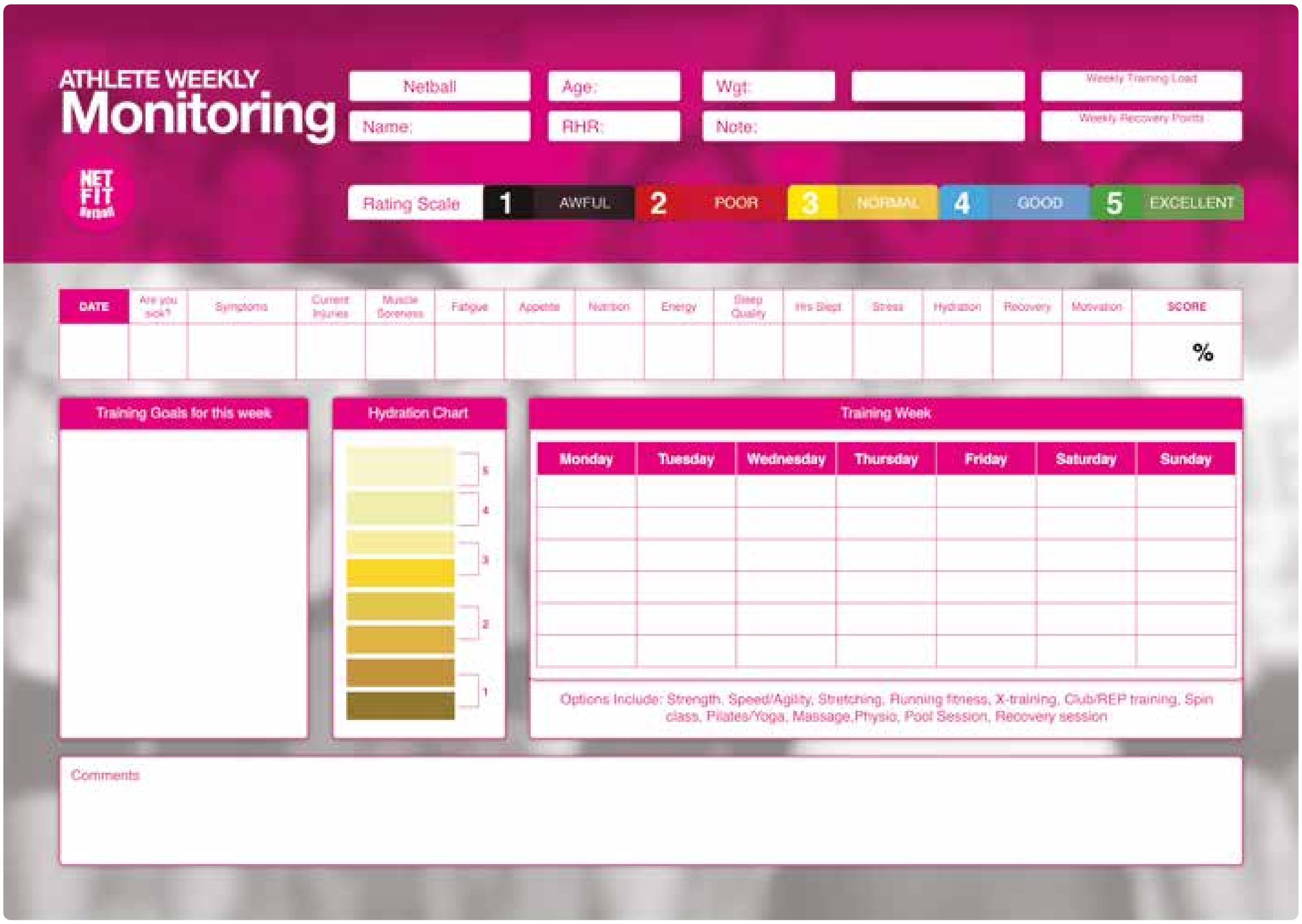


FIGURE 10.15 Sample training diary template used by elite netballers

Source: Sarah Wall, http://netfitnetball.com.au/

Digital activity trackers

Sports science and analysis is a continually growing field and wearable technology or digital trackers are accessed by elite sports people and recreational athletes alike. Data transmission from increasingly sophisticated sensors provides both individual athletes and teams with the increased ability to reach peak fitness levels. Whether it be from a smart watch, wristband, smart ring, belt, chest strap or head band, there are many parameters that a digital activity tracker and wearable devices can monitor, measure and track.

Elite sports people access information from advanced technology wearable devices and Australia has been leading the field in this particular area of sports science. The Australian Institute of Sport and the Cooperative Research Centre collaborated to develop a unique, evidence-based, highly accurate and accessible approach to athlete monitoring. Catapult Sports access the Global Positioning System (GPS) and the Global Navigation Satellite System (GNSS) and use **accelerometers, gyroscopes** and **magnetometers** to provide valuable inertial movement analysis. Each system collects the athlete's micro-movements and transfers the information into algorithms providing valuable metrics for athlete analysis. Athletes and/or coaches are able to make calculated decisions based upon the following parameters that are provided using the Catapult System:

FIGURE 10.16 There are many types of activity trackers available on the market for athletes to choose from.

An **accelerometer** is an instrument for measuring the rate that an athlete changes velocity.

A **gyroscope** is a sensory device that explains the direction of gravity and determines the position of an athlete.

A **magnetometer** measures the direction and strength of magnetic field.

Real time means that data is processed straight away and is available virtually immediately as a source of feedback.

- movement patterns
- intensity
- velocity
- distance covered
- acceleration
- efforts of force from the body
- player loads.

A digital tracking system such as this is highly accurate and valuable information is wirelessly transmitted in **real time** to the athlete or coach for immediate analysis and adjustment to training.

The following testimonial from Melbourne Football Club's Katy Mouritz (GPS Load Analyst) outlines just an example of how Catapult digital technology affects elite training:

'The system has enabled us to detect discrepancies in our training loads as well as enhancing training specificity, both of which we would not have been able to do with such accuracy or detail on a quantitative level without this technology.'

Take a look at the **Catapult wearable technology** weblinks in your eBookPLUS to find out more about how their digital technology monitors, measures and tracks athlete information.

eBook*plus*

eLesson
Wearable technology in elite sports
Searchlight ID: eles-2761

Weblinks
Catapult wearable technology

FIGURE 10.17 Catapult wearable technology

There are many other Global Positioning System (GPS) units that also have the ability to provide data for the analysis of various physiological parameters in real time, which is vital for monitoring athlete training. Rapid advancements in the area of sports science and research will continue to create digital activity tracking devices with increased accuracy and functionality. They will continue to develop to provide coaches and athletes with the best possible information that can be analysed to manage training volume and load, with the aim to optimise performance.

Recreational sportspeople use a variety of very accessible general fitness digital activity trackers to monitor, measure and track their progress in training. The popularity of these activity trackers has grown significantly in recent times. There are many brands available on the consumer market, which all offer different functions and features. Most digital activity trackers provide information on the number of steps, distance, calories burned and activity time. Some trackers also measure heart rate and allow a person to record sleep patterns and nutritional intake. The University of California, Berkley has even developed wearable technology that analyses the chemicals in a person's sweat as they train which sends information immediately to their smartphone. The metabolites (glucose and lactate) and electrolytes (sodium and potassium) measured in a person's sweat can help to determine muscular fatigue and hydration status. Some companies are also tapping into the idea of 'smart clothes', where activity sensors are embedded into everyday clothing.

eBook*plus*

Weblink
Wearable technology

Selecting the most appropriate digital activity tracker is really dependent upon what parameters a person wishes to track. A variety of parameters have already been mentioned that are provided by different activity trackers, such as number of steps, distance covered, calories expended, activity time and heart rate measures. Some trackers also offer the ability to record locations via inbuilt GPS and these are beneficial for people who require more precise measurements about distances that they have covered. Others also provide coaching features that give actionable advice to the user.

It important to note that not all digital activity trackers are suitable for all sports, so it is important to select the tracker that is best to track the requirements of a person's chosen sport. Make sure that you take this into account if you are considering the use of a digital activity tracker to measure, monitor and track a training program. Many activity trackers measure walking, running and cycling effectively but aren't so effective at measuring activities such as pilates, yoga and gym sessions. The user generally has to inform the tracker if they are undertaking these types of activities. If swimming is the main choice of activity, it is important that the activity tracker is waterproof.

FIGURE 10.18 Digital activity trackers each have different funtions and features.

Generally, the more costly the device, the more impressive the features; however, it is important to remember many features may not be necessary for the parameters that an individual wants to monitor. Most trackers use accelerometers to measure a person's movements and some combine the use of accelerometers with more sophisticated movement sensors. Digital activity trackers are generally categorised as everyday activity trackers, general fitness trackers or specific training trackers.

Fitbit, Jawbone, Garmin, Polar, Misfit, Moov, Withings and Apple are some of the common brands of activity trackers available on the market and each provides a range of different trackers to cater for the needs of recreational sportspeople, high-performance elite sportspeople and anyone in between. The rapid development and advancement of technology will allow more features or parameters to become more accessible to a larger variety of users. The current standard features of high-performance digital activity trackers for elite sportspeople are likely to be the standard features for recreational sportspeople in the future. The increases in sophistication in digital tracking technology will also result in a higher level of accuracy, greater ability to track more physiological, psychological and sociological parameters, and an increased automation of recording.

FIGURE 10.19 Advancements in digital technology will allow for more physiological, psychological and sociological parameters to be tracked in the future.

Application software (apps)

Pairing the data from digital activity trackers with application software allows for enhanced, holistic monitoring of a person's training progress. The incremental feedback gathered from combining the two sources increases the user's awareness of not only the physiological influences but also the psychological and sociological influences on their training.

FIGURE 10.20 There are many digital activity tracker companion apps and stand-alone apps available to measure, monitor and track training data.

The companion apps for digital activity trackers are important as these provide the interface where the user reviews the data for analysis. They are generally able to display, record and provide a greater amount of historical information than a digital activity tracker on its own.

Just like digital activity trackers, there are many and varied apps available that provide features valued by the recreational athlete and the elite sportsperson alike. Many fitness apps are self-monitoring tracking tools that allow the user to log workouts and record physiological, psychological and sociological information similar to that of a training diary. Apps are digital training diaries and have the advantage of being easily available on most smartphones.

There are thousands of fitness apps available and it is important to choose one that meets the needs of the user. Some apps connect to a community of people who can support and motivate the user throughout their training program. Strava, Fitocracy, Endomondo and Stridekick are examples of apps that allow the user to compete and connect with others for social support. Apps such as Sworkit, FitStar, C25K (couch to 5k) and Workout Trainer provide coaching tips, personalised training and workout routines. There are apps that have inbuilt GPS, allowing the user to track distance covered, such as MapMyRun and RunKeeper. There are also sport-specific training apps that provide training programs for a variety of different training methods, such as StrongLifts 5×5 and JetFit for resistance training and Pocket Yoga. Apps such as MyFitnessPal that provide calorie counting are for those who wish to monitor their nutritional intake, and apps such as Sleepbot track information about a person's sleep habits.

There are many fitness apps that are multi-functional and allow the user to measure, monitor and track a number of different parameters, including some of the apps that have already been mentioned. The best fitness apps are the easiest to use and permit

studyon
Unit 4 | AOS 2 | Topic 1 | Concept 3
Digital activity apps
Summary screen and practice questions

the user to set personal training goals, and monitor their physiological, psychological and sociological training data in order to keep them motivated and injury-free on the road to attaining their peak level of fitness and performance.

TABLE 10.1 Some of the benefits of using digital activity trackers and/or apps combined

Physiological factors	Psychological factors	Sociological factors
Step count Heart rate responses Sleep patterns Calorie expenditure Temperature Flights of stairs climbed Sweat analysis (new research)	Motivation Goal-setting Determination Increase self-efficacy Reminder notifications Positive self-talk	Training time and day Time of training session Type of training session Social support groups Break down barriers Education

TEST your understanding

1 Explain why coaches and athletes often access a variety of physiological, psychological and sociological strategies to monitor training.
2 What are four benefits of maintaining an accurate training diary?
3 Outline two physiological, two psychological and two sociological factors that can be recorded in a training diary.
4 Identify the benefits of using digital activity tracking for elite sportspeople.
5 Identify the important factors that need to be taken into account when considering the most appropriate digital activity tracker to use.
6 Outline some of the information that can be measured, monitored and tracked with the use of apps.
7 Describe two physiological, two psychological and two sociological benefits of using digital activity trackers and/or apps combined.

APPLY your understanding

8 A training diary is a great tool for you to use to improve your performance in any particular sport or activity. The parameters that are recorded and monitored through the use of a training diary should be specific to each individual and the particular sport and/or activity that they are training for.
(a) Design an appropriate training diary template that would be most suitable to use during a six-week training program for an athlete of your choice. Make sure that you consider the relevant physiological, psychological and sociological factors that are important to include.
(b) Explain how the information that will be recorded in the training diary will inform the participant of any necessary modifications that may need to be made to their training program.
9 Compare and contrast at least four different digital activity trackers and recommend the most appropriate one to use during a six-week training program for a given case study. Use the **Compare and contrast — digital activity trackers** digital document in your eBookPLUS to present your information.
10 Select an app that would be suitable to use during a six-week training program for an athlete of your choice. You must provide a justification as to the reasons for your selection.
11 **Practical activity: interview**
Interview someone who is currently undertaking a training program. This may be an elite sportsperson or someone who is just aiming to improve their fitness.
(a) Find out how they are measuring, monitoring and recording their training data and examine if and how any of the data they have gathered have helped inform their training program design.
(b) After you have gathered the information from the interview, critique the effectiveness of their monitoring and provide any necessary recommendations for improvements.
(c) Analyse whether you would provide any training program modifications based on the training data that has been monitored and recorded. Provide a justification for your decision.

eBook*plus*
Digital document
Compare and contrast — digital activity trackers
Searchlight ID: doc-21030

studyon
Unit 4 | AOS 2 | Topic 1 | Concept 1
Strategies to monitor and record data
Summary screen and practice questions

KEY SKILLS MONITORING AND PLANNING A TRAINING PROGRAM

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Explain — to make the meaning of something clear and understandable
  Discuss — to go into detail about the characteristics of a key concept
- **Key terminology:**
  Physiological —discuss the importance of recording data about the body's physical functioning in response to training
  Psychological — discuss the importance of recording data about the athlete's mental readiness and mental capacity to train and perform, such as feelings and cognitive characteristics
  Sociological — discuss the importance of recording data about the broader social, cultural and environmental factors that contribute to an athlete's performance.
  Cool-down — need to respond in relation to the low-intensity activity that is completed at the end of an exercise session
- **Key concepts:**
  Data records of training — discuss in relation to the lead-up to the Great Victorian Bike Ride event
  Purpose of a cool-down and the impacts of not completing one — respond in relation to the main reasons for completing a cool-down
- **Marking scheme:** *10 marks* — always check marking scheme for depth of response required, linking to key information highlighted in the question

KEY SKILLS

- Explain the importance of maintaining physiological, psychological and sociological records of training
- Conduct and participate in all components of an exercise training session
- Reflect on the physiological, psychological and sociological aspects of participation in a variety of training sessions
- Analyse training data to identify appropriate modifications to a training program

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- Be able to identify some of the physiological, psychological and sociological factors that can be recorded and describe the benefits of maintaining this information
- Be able to design and demonstrate an effective training session that includes the important components of the warm-up, conditioning phase and cool-down components
- Be able to critique the effectiveness of a training session in which you have participated, based on your knowledge of the requirements of each component
- Be able to recognise how physiological, psychological and sociological factors can be beneficial in informing an athlete or coach about the effectiveness of a training program

PRACTICE QUESTION

1 **ACHPER Trial Exam 2015, question 9**

A Year 11 Physical Education class at ACHPER Secondary College intends to complete the Great Victorian Bike Ride in 2015. They have entered the five-day event, which covers a total of 318 km. During term 4, they intend to complete the following training program for the nine weeks leading up to the event. Training includes a mixture of lunchtime, after-school and weekend cycling training.

Week	Tuesday	Wednesday	Saturday	Sunday	TOTAL
1	20 km cycle	Spin class 30 mins	40 km cycle	30 km cycle	90 km cycle
2	20 km cycle	Spin class 30 mins	45 km cycle	30 km cycle	95 km cycle
3	25 km cycle	Spin class 30 mins	45 km cycle	30 km cycle	100 km cycle
4	25 km cycle	Spin class 35 mins	50 km cycle	30 km cycle	105 km cycle
5	25 km cycle	Spin class 35 mins	55 km cycle	30 km cycle	110 km cycle
6	25 km cycle	Spin class 35 mins	60 km cycle	30 km cycle	115 km cycle
7	25 km cycle	Spin class 40 mins	70 km cycle	30 km cycle	125 km cycle
8	25 km cycle	Spin class 40 mins	75 km cycle	30 km cycle	130 km cycle
9	20 km cycle	20m SRT Test	30 km cycle	Rest	50 km cycle
10	Participate in Great Victorian Bike Ride				

a. **Explain** the importance for the Year 11 students in maintaining physiological, psychological and sociological data records of training in the lead up to the Great Victorian Bike Ride event. *(5 marks)*

b. Some of the Year 11 students were hesitant to perform a cool-down after every training session. **Explain** the purpose of a cool-down and **discuss** the impact of not completing one. *(5 marks)*

SAMPLE RESPONSE

a. Physiological training data provide information about the body's physical functioning in relation to training. Psychological training data provide the athlete with an understanding of their mental readiness and include thoughts, feelings and cognitive characteristics that may affect training. Sociological training data provide context about the broader social, cultural and environmental factors that contribute to an athlete's training performance. Monitoring training provides an understanding as to how hard an athlete is working, paralleled with how well they cope physiologically, psychologically and sociologically with the training load. It is important that monitoring is used to inform and evaluate a training program so that it remains effective in achieving the desired goals.

b. A cool-down involves the Year 11 students completing a low-intensity activity at the end of the conditioning component of the training session. The cool-down allows the heart rate and blood flow to the muscles to remain elevated, which assists in preventing venous pooling, removing metabolic by-products and gradually returning the body back to its resting physiological state. If the Year 11 students choose to cease their high-intensity conditioning component without completing a cool-down, their muscles will no longer continue to contract and help to propel blood back to the heart (skeletal muscle pump effect). As a result, blood may pool in their veins, especially in the lower limbs. This venous pooling can result in a decreased venous return to the heart. Consequently, less blood is re-oxygenated via the lungs, and less metabolic by-products (carbon dioxide and lactic acid) are removed from the muscle tissues.

HOW THE MARKS ARE AWARDED

- **3 marks:** (1 mark each) for describing the meanings of physiological, psychological and sociological that can be recorded
- **2 marks:** for linking how monitoring the factors can inform the athlete or coach about the effectiveness of a training program
- **1 mark:** for outlining what a cool-down consists of
- **2 marks:** for describing the purpose of a cool-down
- **2 marks:** for discussing the impact of not completing a cool-down

CHAPTER REVIEW MONITORING AND PLANNING A TRAINING PROGRAM

CHAPTER SUMMARY

The design and periodisation of a training program

- The design and implementation of a training program requires a step-by-step approach that incorporates information obtained from an activity analysis and fitness assessment, the appropriate application of training principles and the selection of relevant training methods.
- It is necessary to plan the length of the training program, ensuring that the proper periodisation of training is incorporated in the program. The number of specific training sessions and the content of each of these sessions then need to be determined and recorded via a training timetable.
- The term *periodisation of training* basically refers to the dividing of a training program into smaller phases of training. Typically, these phases of training are known as:
  – the preparatory phase
  – the competition phase
  – the transition phase.
- The preparatory (pre-season) phase of training aims to develop a suitable fitness and skill base for the competition phase. The main objective of the competition (in-season) phase is to maintain fitness and skill attributes, as well as develop and refine strategies, tactics and game plans. The transition (off-season) phase is designed to provide the athlete with a physiological and psychological break from the demands of training and competition.
- Block or nonlinear periodisation incorporates blocks of highly specific and concentrated periods of work with more frequent variations in load. It is specialised and concentrated in its approach to each work block.
- Peaking and tapering are important considerations in the design of training programs. Peaking refers to the planning of training so that an athlete obtains their optimum state of readiness to perform at a particular predetermined time, such as a major event or competition. Tapering refers to a reduction in training loads, particularly the volume of training prior to a major event, to allow for complete recovery. The goal of peaking and tapering is to produce a fresh, rested, uninjured athlete who is ready to perform at their optimum level at a given time.
- The main goal of a training program is to prepare an athlete to be able to perform at their best. The concept of tapering is not appropriate for all sports, particularly sports which have weekly competitions; however, these athletes still require periods of recovery in order to perform at their peak.

Components of an exercise training session

- Each individual training session should consist of a warm-up, a conditioning phase and a cool-down.
- The warm-up is designed to prepare the body both physiologically and psychologically for the conditioning phase of the training session. A gradual increase in the intensity level of physical activity is performed in order to increase the heart rate, blood flow and ultimately the temperature of the muscles to be used. A warm-up provides the opportunity for the body to transition from a resting state to the higher physiological demands of the conditioning phase of training.
- The conditioning component is the main focus of the training session and it may include a skill development phase and/or a fitness conditioning phase.
- The cool-down transitions the body gradually from high intensity exercise back to resting levels. It involves completing low-intensity exercise, allowing for the maintenance of blood flow and the prevention of venous pooling.
- At the end of the cool-down component, stretching should take place in order to improve the flexibility of the muscles and reduce any stiffness or soreness. An athlete gains the most benefit from stretching when the muscles are still warm and the ligaments and joints are more elastic.

Strategies to monitor and record training

- There are many strategies available to athletes and coaches in order to monitor and record their physiological, psychological and sociological training data so as to reach a peak level of performance. The ultimate goal of a training program is to achieve the necessary chronic responses to improve an athlete's performance in a particular sport or activity and monitoring training is essential to keep the athlete on track to reaching this goal.

- It is important that monitoring is used to inform and evaluate training and not simply as a method of collecting data. The information provided can allow the athlete to incorporate the concepts of peaking and tapering effectively into their training program.
- Training diaries, digital activity trackers and apps are very useful monitoring tools that an athlete and coach can use in order to increase the effectiveness of a training program.
- A training diary is an athlete's personal monitoring tool that can record both objective and subjective training information and there are many physiological, psychological and sociological benefits to keeping a training diary.
- Sports science and analysis is a continually growing field and wearable technology or digital trackers are accessed by elite sportspeople and recreational athletes alike. There are many parameters that digital activity trackers can monitor.
- There are many and varied apps available that provide various features valued by both recreational athletes and elite sportspeople. The best fitness apps are the easiest to use and permit the user to set personal training goals, and monitor their physiological, psychological and sociological training data in order to keep them motivated and injury-free on the road to attaining their peak level of fitness and performance.

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 **(ACHPER Trial Exam 2013, question 10)**

The following graph represents the training load of an under-18 netball team from six weeks down to three weeks prior to the finals. Which training principle is demonstrated in the graph?

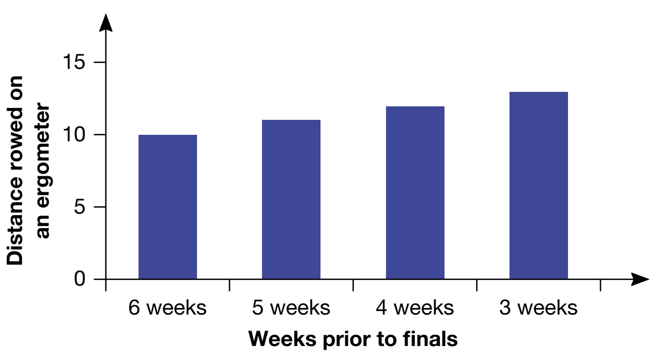


FIGURE 10.21 Training load prior to finals

(A) Specificity
(B) Tapering
(C) Overload
(D) Peaking

2 **(ACHPER Trial Exam 2006, question 19)**

As part of her training for the 400 m event, an elite athlete completes 4 × 250 m sprints in 30 seconds, with 60 seconds rest between each sprint. At the completion of her training session, the athlete should perform an active recovery in order to

(A) prevent venous pooling.
(B) assist in the breakdown and removal of accelerated metabolic by-products such as lactate and hydrogen ions.
(C) keep the heart rate elevated to assist oxygen delivery to skeletal muscles.
(D) All of the above.

3 An example of sociological training data that may be monitored is

(A) heart rate response.
(B) level of motivation.
(C) training environment.
(D) rate of perceived exertion (RPE).

eBook*plus*

Interactivity
Monitoring and planning a training program quiz
Searchlight ID: int-6822

studyon

Sit VCAA exam

4 One of the main purposes of a warm-up is to
(A) practise skills, game plans, tactics and strategies.
(B) increase blood flow to the muscles, which results in an increase in muscle temperature.
(C) prevent venous pooling.
(D) develop and maintain specific fitness components.

5 The three main phases involved in the traditional periodisation of a training program are
(A) the introductory phase, the competition phase and the transition phase.
(B) the preliminary phase, the competition phase and the conversion phase.
(C) the preparatory phase, the competition phase and the transition phase.
(D) the preparatory phase, the execution phase and the transition phase.

6 An example of psychological training data that may be monitored is
(A) breathing rate.
(B) level of arousal.
(C) training environment.
(D) rate of perceived exertion (RPE).

7 The general phase of a warm-up involves undertaking
(A) sport-specific skills training.
(B) activities that involve agility, speed and acceleration.
(C) dynamic stretching.
(D) low to moderate intensity cardiovascular continuous exercise.

8 The monitoring and recording of training is essential for
(A) assessing an athlete's strengths and weaknesses.
(B) informing and evaluating training progress.
(C) collecting data.
(D) using up-to-date sports science technology.

9 A training session should comprise of the following sequence:
(A) conditioning component, warm-up, cool-down, dynamic stretching.
(B) warm-up, static stretching, conditioning component, cool-down.
(C) warm-up, dynamic stretching, conditioning component, cool-down.
(D) conditioning component, cool-down, warm-up, dynamic stretching.

10 The term *peaking* refers to when an athlete
(A) is overtraining.
(B) reaches their optimum state of readiness.
(C) reduces their training load.
(D) reduces their aerobic conditioning.

TRIAL EXAM QUESTIONS

Question 1 **(adapted from ACHPER Trial Exam 2015, question 10)**

Michael Clarke is an Australian cricketer who hit a score of 128 off 163 balls in two days of play during a five-day test match against India. In the same summer season, Peter Handscomb hit a score of 103 off 64 balls in a Twenty20 game that was completed in three hours.

a. Discuss the importance of Michael Clarke and Peter Handscomb monitoring and recording their training data in the lead-up to their cricket games. Outline the types of data that may be monitored. **4 marks**

b. Recommend one appropriate training monitoring tool that both Michael Clarke and Peter Handscomb could adopt. **2 marks**

c. Justify why it would be important for both Michael Clarke and Peter Handscomb to include skill development as a part of their training session conditioning component. **2 marks**

Question 2 **(adapted from ACHPER Trial Exam 2012, question 11)**

In the lead-up to her school's cross-country run, Gertrude completes the following training program.

	Monday	Wednesday	Saturday
Week 1	20 minutes continuous running	20 minutes Fartlek	20 minutes continuous running
Week 2	22 minutes continuous running	20 minutes Fartlek	20 minutes continuous running
Week 3	22 minutes continuous running	20 minutes Fartlek	20 minutes continuous running
Week 4	24 minutes continuous running	20 minutes Fartlek	20 minutes continuous running
Week 5	24 minutes continuous running	20 minutes Fartlek	20 minutes continuous running
Week 6	20 minutes continuous running	20 minutes Fartlek	20 minutes continuous running
Event Week	20 minutes continuous running	Cross-country race	20 minute pool session
Week 8	Pilates	30 minutes of continuous cycling	20 minute pool session
Week 9	Pilates	30 minutes of continuous cycling	20 minute pool session

a. Prior to starting the above training program Gertrude should have completed two important steps. What were they? **2 marks**

b. Psychological data monitoring identified that Gertrude was losing motivation and wasn't enjoying undertaking the training program anymore. Provide a recommendation to Gertrude as to how you would modify her program to overcome this factor. **2 marks**

c. For Gertrude's 9-week training block, identify which week/s you would consider Gertrude to be undertaking the preparatory and transition phases of periodisation?

Preparatory phase — Week/s________________

Transition phase — Week/s________________ **2 marks**

d. Explain why Gertrude completes a transition phase as a part of her 9-week training block. **2 marks**

e. Gertrude was hesitant to perform a warm-up before every training session. Explain why you would recommend that Gertrude does complete a warm-up prior to every session. **2 marks**

INQUIRY QUESTION
Evaluate what training methods would be most appropriate to include in a Goal Keeper's training program and how you would apply the important training principles correctly to the training methods selected.

CHAPTER

11 Training program principles and methods

In order for a training program to achieve the goal of enhancing and/or maintaining fitness components, its design requires the correct application of training principles and methods.

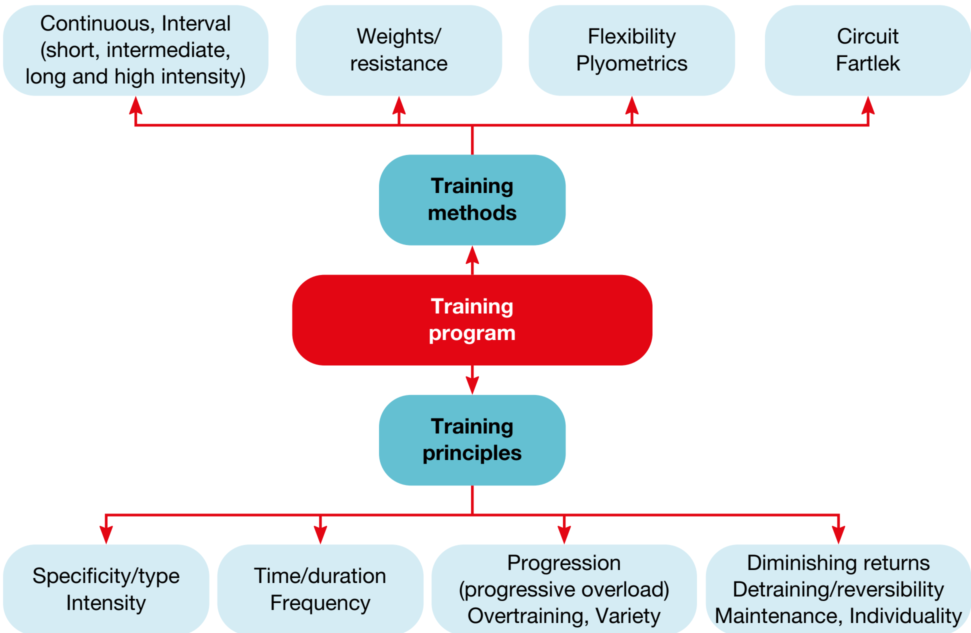
KEY KNOWLEDGE

- Training program principles, including frequency, intensity, time, type, progression, specificity, individuality, diminishing returns, variety, maintenance, overtraining and detraining
- Training methods including continuous, interval (short, intermediate, long and high intensity), fartlek, circuit, weight/resistance, flexibility and plyometrics

KEY SKILLS

- Design a training program that demonstrates the correct application of training principles and methods to enhance and/or maintain fitness components
- Evaluate and critique the effectiveness of different training programs

CHAPTER PREVIEW



11.1 Specificity, intensity and type of training

KEY CONCEPT Specificity, intensity and the type of training are training principles that are vital in achieving the overall goal of improved performance.

Specificity is the process of replicating the characteristics of physical activity in training to ensure it benefits performance.

Specificity

Of all the principles of training, **specificity** is the most important. Whether the aim of the training program is to improve general fitness or to become a better performer in a particular sport, it is essential that all training aspects are relevant to the overall purpose of the program.

The activity analysis provides information about the activity/sport that allows for the principle of specificity to be applied. The important aspects that are identified in an activity analysis are the following:

- the predominant energy systems required
- the fitness components used
- the muscle groups used
- the skills performed
- the fatiguing factors.

It would be pointless for a tennis player who requires agility, short sprints, skills work and resistance training to follow the training schedule of a marathon runner who completes 200 kilometres of continuous training per week. Obviously, the aspects identified above have different applications in the two sports, and the training for one would not be specific to what is needed for successful performance in the other.

FIGURE 11.1 It is essential that Thanasi Kokkinakis trains the specific energy systems, muscle groups and fitness components that are required for him to be competitive in tennis at the highest level.

It is also important to select training methods that are specific to addressing the identified needs for optimum performance levels. If the athlete needs to focus on upper body strength, anaerobic power and the ATP–CP energy system, it would be counterproductive to choose continuous training that is specifically for aerobic improvement and lower body local muscular endurance.

For team sports such as netball, Australian Rules football, rugby and soccer, an activity analysis on each particular position and/or player would reveal quite different physiological characteristics that are required for optimal levels of performance. The energy system and fitness component requirements of a striker in soccer would be very different to those of the goal keeper.

As discussed in chapter 7, the completion of an activity analysis is a critical step when applying the principle of specificity to a training program.

If an activity analysis of an elite tennis player such as Thanasi Kokkinakis revealed that leg power and agility are two important fitness components needed for optimum levels of performance, then the principle of specificity would require the athlete to:

- test these fitness components by using tests such as the vertical jump test and the 5-0-5 agility test (refer to chapter 9)
- design a training program that includes circuit training sessions that specifically work on muscular power and agility in the leg muscles

- select exercise stations that work specifically on leg power, such as squat jumps or drop jumps, and agility exercises such as speed and ladders
- ensure that the application of other training principles, such as type, intensity and time, are specific to the needs of the game of tennis.

If the tennis player trains the specific energy systems, fitness components, muscle groups and also accounts for the fatiguing factors relevant to the game of tennis, they will achieve the chronic adaptations that allow them to perform at their optimum fitness in a game situation. However, a very important aspect of the tennis player's game is the execution of a high level of motor skill. It is essential that the tennis player also includes a specific skill component into each training session. Appropriately targeting the physiological requirements of the sport will enhance the likelihood of the athlete performing to the best of their ability. There are other influences such as psychological factors, nutritional intake and hydration status that may also ultimately affect the player's performance and these are discussed in chapter 13.

The **SAID** principle is a well-known acronym in the sports science field and it stands for *Specific Adaptations to Imposed Demands*. This means that the specific training that is undertaken will determine the type(s) of physiological adaptations that will occur. For example, weight/resistance training specifically designed for strength improvements will result in an increase in motor unit recruitment, an increase in the rate and speed of neuromuscular firing, an increase in the size and number of myofibrils and an increase in the protein filaments actin and myosin as a result of the imposed demands placed on the muscles. Alternatively, long-interval training will result in an increase in the number of myoglobin stores in the muscles, which will enhance oxygen extraction and delivery to the mitochondria for energy production and improved aerobic efficiency. The chronic adaptations that occur are therefore defined by the specificity of the particular aspects of an athlete's training program.

The **SAID** principle stands for Specific Adaptations to Imposed Demands.

By identifying, through an activity analysis, the sport's requirements and targeting them specifically in a training program, the athlete can be more certain about meeting the overall goals of the training program. The principle of specificity should guide the appropriate application of all other training principles.

FIGURE 11.2 Activity trackers assist the athlete to make their training program specific to the requirements of their sport.

FIGURE 11.3 Adaptations specific to the sport — cycling

FIGURE 11.4 Adaptations specific to the sport — running

Intensity

Intensity is the exertion level or how hard the training is being performed. It is commonly measured as a percentage of maximum heart rate (MHR), which is determined by beats per minute (bpm).

In terms of fitness gains, **intensity** is the most important training principle. In rudimentary terms the following intensities are a guide to training each energy system:

- ATP–CP energy system — 95–100 per cent of maximum heart rate (MHR)
- anaerobic glycolysis energy system — 85–95 per cent of MHR
- aerobic energy system — 70–85 per cent of MHR.

Therefore, to improve the ATP–CP energy system by doing 50-metre sprints, the athlete needs to perform the sprints at 95–100 per cent intensity (maximum effort).

The intensity at which a person trains will determine the kind of adaptations that will be achieved.

There are a variety of methods/variables used to measure the intensity of exercise:

- percentage of maximum heart rate (% MHR)
- rating of perceived exertion (RPE)
- percentage of VO_2 maximum (% VO_2 max.)
- percentage of **heart rate reserve** (% HRR)
- **metabolic equivalents** (METs)
- blood lactate levels (mM).

The **heart rate reserve** is the difference between resting heart rate and maximum heart rate.

Metabolic equivalents is a system for classifying exercise intensity. 1 MET is equal to resting levels.

Commonly, measurements of intensity are referred to as a percentage of maximum heart rate and/or percentage of VO_2 maximum. Using VO_2 maximum as a tool to measure intensity requires a person to undertake a VO_2 max. test (such as the ones identified in chapter 9) to determine the maximum reference point that percentage exercise intensities can be defined by. However, it is difficult to actually determine oxygen consumption while training and that is why percentage of maximum heart rate is used. Heart rate and oxygen consumption increase linearly with exercise intensity increases and therefore % MHR as a measurement of intensity is justified.

A simple and general calculation for determining maximum heart rate is:

$$220 - \text{Age} = \text{Maximum Heart Rate}$$

A commonly recognised way to categorise the adaptations that occur at different intensities is the division of **training zones**.

A **training zone** describes the intensity range that is required for specific adaptations to occur.

eBook*plus*

Interactivity
Heart rates during exercise
Searchlight ID: int-6823

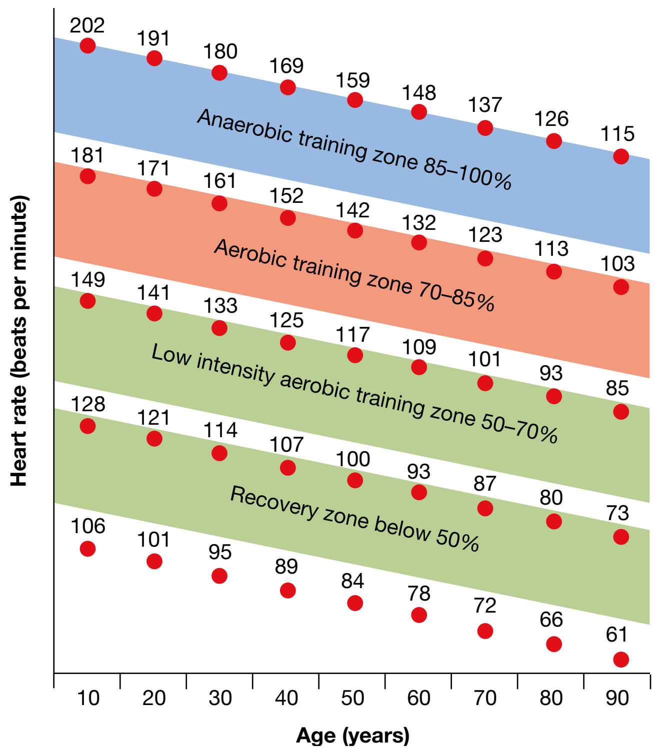


FIGURE 11.5 The various generic training zones according to age and heart rate

TABLE 11.1 The relationship between other variables and exercise intensity

Training zone	% MHR	% VO_2 max.	RPE	% HRR	Blood lactate (mM)
T6	NA	NA	Maximal	NA	NA
T5	>92%	>86%	Very hard	>86%	> 6.0
T4	90–92%	83–86%	Hard	83–86%	4.0–6.0
T3	85–90%	75–83%	Somewhat hard	75–83%	3.0–4.0
T2	70–85%	60–75%	Light	58–75%	2.0–3.0
T1	60–70%	36–60%	Very light	30–58%	<2.0

= Anaerobic training zone (T6–T3); = Aerobic training zone (T2); = Low intensity aerobic zone/recovery zone (T1)

Source: Adapted from https://www.visualcoaching.com/

METs categorise exercise intensities as:

Light	Moderate	Vigorous
<3.0 METs	3.0–6.0 METs	>6.0 METs

The limitation of using METs as a measure of exercise intensity is that they do not take into account individual fitness levels.

In general terms, a person's **lactate inflection point** (LIP) is thought to occur at an intensity of approximately 85% MHR.

Lactate inflection point is the highest intensity point where there is a balance between lactate accumulation and removal from the blood. It represents a person's highest steady state intensity.

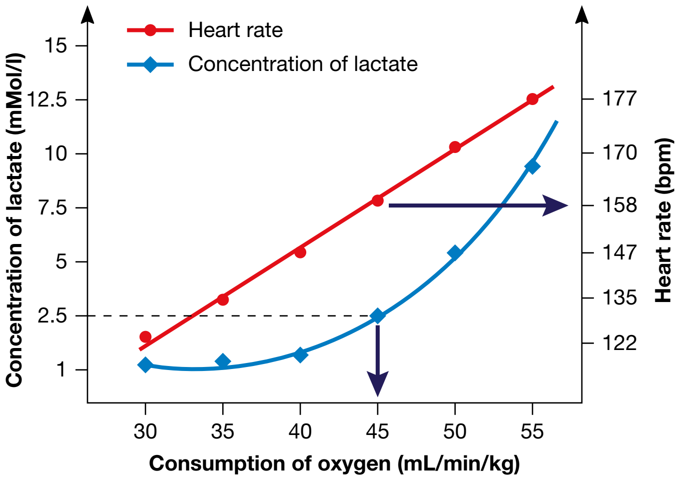


FIGURE 11.6 This graph represents the relationship between lactate concentration, heart rate and oxygen consumption for a successive bicycle ergometer test, with the exercise intensity starting at about 50–60% of VO_2 max.

It was determined that the athlete above had a maximal heart rate of 182 bpm, and a relative VO_2 max. of 61 mL/min/kg using a bicycle ergometer test.

Blood lactate concentration will accumulate faster than it can be removed when the athlete's VO_2 max. is 45 mL/min/kg; therefore their LIP occurs at about 74% of VO_2 max.

The heart rate at this point is 158 bpm; therefore their LIP occurs at about 85% of their MHR.

The intensity of a resistance training program will be determined by the load according to a percentage of **Repetition Maximum** (%RM).

The **Repetition Maximum** is the maximum amount of weight that a person can lift in one muscular contraction.

FIGURE 11.7 Michael Shelley, Australian Olympic marathon competitor, Rio 2016

Working at the correct intensity levels is critical to achieving the goals of a training program.

Type

The type of exercises, activities and/or training methods that are included into a training program will also determine the particular adaptations and performance gains achieved. It is important that the type of exercises, activities and/or methods selected are appropriate for achieving the overall training program goals. They should replicate the movement patterns, muscle groups/actions, energy systems and fitness components relevant for the particular sport or activity for which the person is training.

A marathon runner's training program would be predominantly running-based training, whereas a triathlete's training program would require a combination and balance of swimming, running and cycling. Both athletes would, however, need to select training methods that aim to improve their aerobic capacity.

studyon

Unit 4 | AOS 2 | Topic 2 | Concept 2

Time and type
Summary screen and practice questions

FIGURE 11.8 Aaron Royle leads the men's cycle leg of the World Triathlon.

TEST your understanding

1. Define specificity.
2. Outline the important aspects of an activity analysis that specificity must address.
3. What is the most common way to determine training intensity?
4. Identify another way to determine training intensity.
5. State the recommended heart rate training zone for aerobic training.
6. State the recommended heart rate training zone for recovery.

APPLY your understanding

7. Discuss why it is easier to use MHR as the means of assessing training intensity, rather than using maximum oxygen uptake.
8. Determine your aerobic training heart rate zone. Identify your parents' aerobic training heart rate zone.
9. Describe how you would correctly apply the *specificity* training principle to a training program of your choice.
10. Explain how you would correctly apply the principle of *type* to a training program of your choice.
11. Compare and contrast how you would apply the training principle of specificity to a training program for a 50 km road cyclist and an Olympic triathlete who completes the following distances: swim —1500 m, ride —40 km and run — 10 km.
12. **Practical activity: design a training session**
    Design a training session for a particular sport or activity of your choice that includes the correct application of the principles of specificity, intensity and type. Coach your classmates through the training session. You will need to consider the tool your classmates are going to use to monitor their intensity level.

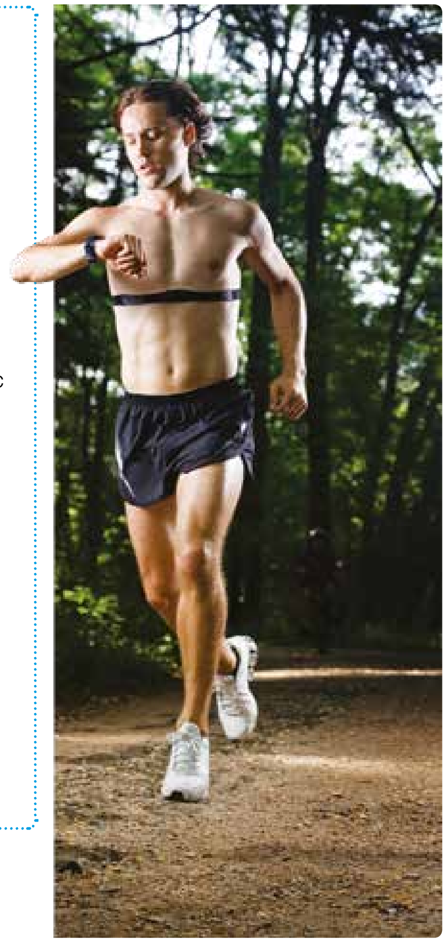


FIGURE 11.9 Heart rate monitors are a reasonably cheap, accurate and increasingly popular method of monitoring exercise intensity.

11.2 Time/duration and frequency

KEY CONCEPT The correct application of the principles of time/duration and frequency is required in order for a person to achieve specific training adaptations.

Time/duration

Time/duration can refer to the length of a training session, the length of a work interval within a training session and/or the length of the overall training program.

The **time/duration** principle is important to consider in combination with the principle of intensity. An athlete will not make fitness gains unless they are working at the required intensity for the required amount of time.

This is important for continuous aerobic training, for example, where improvement requires a minimum session of 20 minutes with the person operating at 70–85 per cent of their maximum heart rate. It is equally important if the desired outcome is improvement in the ATP–CP system. The work intervals within the training session should be short (approximately 10 seconds) and at maximum intensity.

The principle of time/duration also refers to the minimum length of time for a training program to result in improved fitness. This is dependent on the type of training methods undertaken and the intensity of training. Improvements in aerobic training will occur in about six weeks, but a greater amount of improvement is generally seen in about 12 weeks of training. Anaerobic training improvements are quite noticeable in about 6–8 weeks of training.

FIGURE 11.10 It is important to time the length of each work interval in order to achieve the appropriate fitness adaptations.

TABLE 11.2 Suggested guidelines for applying the training principles to aerobic and anaerobic training programs

Training principle	Aerobic training	Anaerobic training
Duration	6 weeks minimum 12–16 weeks	6 weeks minimum 8 weeks
Frequency	3–7 times per week	3–5 times per week
Intensity	70–85 per cent MHR	85–100 per cent MHR

Frequency

Frequency refers to the number of training sessions needed per week to ensure improvements are achieved in the desired fitness components and energy systems.

Generally the minimum number of training sessions per week for fitness gains to be possible is three. It is also generally acknowledged that to at least maintain a level of fitness, two training sessions per week are required.

An important consideration with **frequency** is the actual recovery time given following an exercise session before a similar session is undertaken. Other factors include the nature of the activity, the fitness level of the individual and the recovery facilities available.

Early in a training program, a positive training session may be followed by a poor or flat effort, usually because the untrained muscle has not recovered for the next exercise bout. Similarly, high-intensity and contact activities require longer recovery periods than needed for submaximal aerobic-type activity. This rule applies through to elite-level competition.

Therefore, the formula for gaining fitness is not to train as often as possible, but to find a balance between training frequency and recovery.

The minimum training frequency for improving aerobic fitness is three times per week, with up to five sessions being normal. Training can be even more frequent as the athletes aerobic fitness increases, especially for elite long-distance athletes. Simon Gerrans, one of Australia's most successful road cyclists, generally trains two long days (four to five hours), three × three-hour rides with intervals and two easy days per week.

FIGURE 11.11 Road cyclist Simon Gerrans (right) of team Orica-GreenEdge narrowly wins stage 3 of the 2016 Tour Down Under.

The minimum frequency for improving anaerobic fitness, including strength and power, is also three sessions per week, with four being normal as the individual consolidates. The nature and intensity of this type of activity means that muscle recovery is a more important factor, and it must be planned as an integral aspect of the training program.

You can certainly have too many training sessions per week, but you can also have too few.

TEST your understanding

1 Describe the three meanings of the principle of time/duration.
2 State the minimum time for which the heart rate should be in the required training zone for continuous training.
3 State what is generally recognised as the minimum number of weeks for a training program to show measurable fitness gains.
4 Outline how often you should train if you just want to maintain a certain level of fitness.
5 Evaluate whether there should be more recovery between aerobic or anaerobic training sessions.

APPLY your understanding

6 To show measurable fitness gains, does the duration of a training program vary according to your targeted energy systems? If so, in what way?

EXAM practice

7 **ACHPER Trial Exam 2010, question 2**

Austin is 16 years old and has been training for his school's 5 km cross country. The majority of his training involves continuous running sessions of between four and six kilometres. Every fortnight, he substitutes one running session for a 20 km bike ride.

(a) Identify two training principles evident in Austin's training. **2 marks**
(b) Differentiate the role of each of these training principles in helping to prepare Austin for his school's cross country. **2 marks**
(c) Justify which training principle identified in part (b) you believe to be more important to successful performance. **2 marks**
(d) To evaluate the effectiveness of this training program, outline two training principles you would require other than those mentioned in part (a). **2 marks**

studyon

Unit 4
AOS 2
Topic 2
Concept 1

Frequency and intensity
Summary screen and practice questions

11.3 Progression (progressive overload), overtraining and variety

KEY CONCEPT Progressive overload is crucial to improving fitness and performance and variety is essential in maintaining motivation.

Progressive overload

Progression is the systematic application of overload (progressive overload) in order to achieve the adaptations required to improve performance.

There can be no improvement in personal fitness levels without progressively increasing or overloading the existing training levels. The new levels of physical activity must exceed the level to which the individual is already accustomed. Any overload of physical activity is controlled by the manipulation of the FITT principle (Frequency, Intensity, Time, Type of exercise) which is discussed later in this chapter.

The human body responds to stress caused by physical work. Consequently, it adapts to cope with this stress or increased workload. Otherwise, there is a plateau in performance levels.

Progressive overload relies on four factors:

1. the existing workload is appropriate to the level of the individual's fitness
2. the amount of overload is sufficient to cause adaptation and improvement without causing the individual to feel unable to complete the session
3. the overload maintains the original aims of training
4. the variables of training (listed below) are not all revised at the one time, but rather, only one or possibly two variables are adjusted for the one session. This should lessen the chances of physical fatigue or joint and muscle soreness.

The variables of training that are available for progressive overload are:

- distance of work
- duration of work
- duration of recovery periods
- number of repetitions
- number of sets
- number of sessions per week
- amount of resistance
- range of motion.

The chosen variable must be manipulated for overload in a way that is consistent with the aim of the program. For example, an athlete aiming to improve their ATP–CP energy system by completing 5 × 70-metre running sprints could introduce overload by these methods:

- increase the number of repetitions of the 70-metre sprints
- moving from a 95 per cent effort sprint to a 100 per cent effort sprint
- increasing the distance sprinted, ensuring that the ATP–CP energy system remains the focused energy system.

This last point is crucial. If in this case the time of each sprint becomes longer and the effort moves from focusing on the ATP–CP system to focusing on the anaerobic glycolysis system, the overload will not continue to meet the aim of the training program.

The section on training methods later in this chapter further examines the more specific manipulation of variables for applying progressive overload. Progressive overload should be planned, but its application must be flexible. It may need to be applied after the first session if the prescription for the initial training bout is too low, or it may take several sessions. Progressive overload is particular to each individual and rigid application to all participants will not maximise training benefits.

FIGURE 11.12 Cate Campbell's correct application of progressive overload in her training program allowed her to obtain the world record in the 100 m freestyle at the 2016 Australian Swimming Grand Prix.

It is vital that the application of progressive overload is gradual and systematic, allowing for appropriate adaptations to occur and to avoid overtraining. It is generally accepted that a variable is increased by two to ten per cent.

Overtraining

Overtraining occurs when there is a long-term decline in performance and physical functioning. The ability of the body to continue to adapt to the training load is compromised when overtraining symptoms occur. Research suggests that there are both psychological and physiological causes of overtraining. Everyone will experience some level of fatigue following intense bouts of training, however overtraining is categorised by a decline in performance that cannot be remedied by a few days' rest.

While overtraining usually occurs when the amount and quality of recovery time is insufficient to fully recover from the stresses of training, there can be a number of other causes. These include:

- excessive training volume; for example, several training sessions every day of the week
- inappropriate increases in the frequency, duration and/or intensity of training; in other words, too much overload
- training when suffering from illness
- excessive increases in training loads following periods of enforced lay-off due to injury or illness
- excessive competition scheduling with maximum demands and frequent disturbance of daily routines
- poor nutritional state, especially inadequate carbohydrate, vitamin and mineral intake
- external stressors such as work and study demands, family responsibilities or difficulties in personal relationships.

It is important that adolescents who are physically active be aware of the dangers of overtraining a growing body.

The signs and symptoms of overtraining are listed in table 11.3 below and it is likely that they will vary according to the type of training undertaken.

studyon

Unit 4 | AOS 2 | Topic 2 | Concept 3

Progression and diminishing returns
Summary screen and practice questions

TABLE 11.3 Symptoms of overtraining

Physiological symptoms	Psychological symptoms	Miscellaneous symptoms
• Persistent feelings of fatigue • Chronic muscle soreness • Increased or decreased morning resting heart rate (beyond normal variation) • Increased heart rate during sub-maximal exercise at a given workload (beyond normal values) • Earlier onset of fatigue during exercise bouts • Decreased performance during strength and power testing • Decreased coordination and disturbances in rhythm of movement	• Decreased concentration span • Decreased motivation levels • Increased irritability and anger • Depression • Increased anxiety levels • Increased fear of competition • Increased sensitivity to emotional stress • Increasing tendency to give up and believe that the challenge is too difficult • Increased susceptibility to demoralising influences before and during competition	• More frequent illnesses • Loss of appetite • Increase in overuse injuries • Insomnia • Lack of enjoyment of training and competition

The key to avoiding overtraining is prevention. Well-planned training programs that include adequate rest and recovery periods are essential, as are gradual increases in training loads. The periodisation of training in which the training load varies in cycles with built-in mandatory rest phases is also a key factor in the avoidance of overtraining. Appropriate recovery methods are also important in ensuring that athletes gain maximum effectiveness from recovery sessions and rest periods. Tools such as training diaries, digital activity trackers and apps (outlined in chapter 10) are strategies that athletes can use to monitor their training stress and other training variables. Other recommendations for the prevention of overtraining include avoiding monotonous training by including some variety within the training program and also maintaining adequate nutrition. Vigorous exercise during the incubation period of a viral illness (e.g. the flu) may increase the duration and severity of that illness. Athletes who feel as if they are developing a cold should rest or reduce their training schedule for a few days.

If overtraining has occurred, the cure is relatively straightforward — reduce training loads and increase rest periods. A period of complete rest may be recommended. The longer the period of overtraining, generally the longer the period of time needed for recovery.

FIGURE 11.13 Digital activity trackers and apps are useful tools in preventing overtraining.

Variety

Variety is about providing different activities, formats and drills in training, while still addressing the aims of the training program. Its focus is to maintain the motivation levels of the performer and thereby optimise their fitness gains.

Training can become boring, and the athlete may drop out of the program if there is insufficient **variety**. Changes to training activities and drills stimulate and challenge participants, who are therefore more likely to train at optimal levels. But the use of variety must not diverge from the initial aims of the program.

Some examples of implementing variety include the following.

- Continuous training could be held at different venues or courses. This variable would work regardless of whether the continuous training was for running, cycling or swimming.
- Continuous running or cycling training could move venues to incorporate carefully introduced hill work.
- Continuous training sessions for one skill could be occasionally replaced with continuous sessions of running, cycling, swimming or even triathlons or biathlons.
- A program of resistance training could occasionally substitute free weights for machine weights or include a 'pump' or 'powerbar' session at the gym.
- A resistance training session could vary the order of exercise stations.
- Coaches should always be trying to vary warm-ups, drills and other aspects of their training sessions to promote enjoyment and improve the focus of their athletes.

studyon

Unit 4 | AOS 2 | Topic 2 | Concept 4

Variety, specificity and individuality
Summary screen and practice questions

TEST your understanding

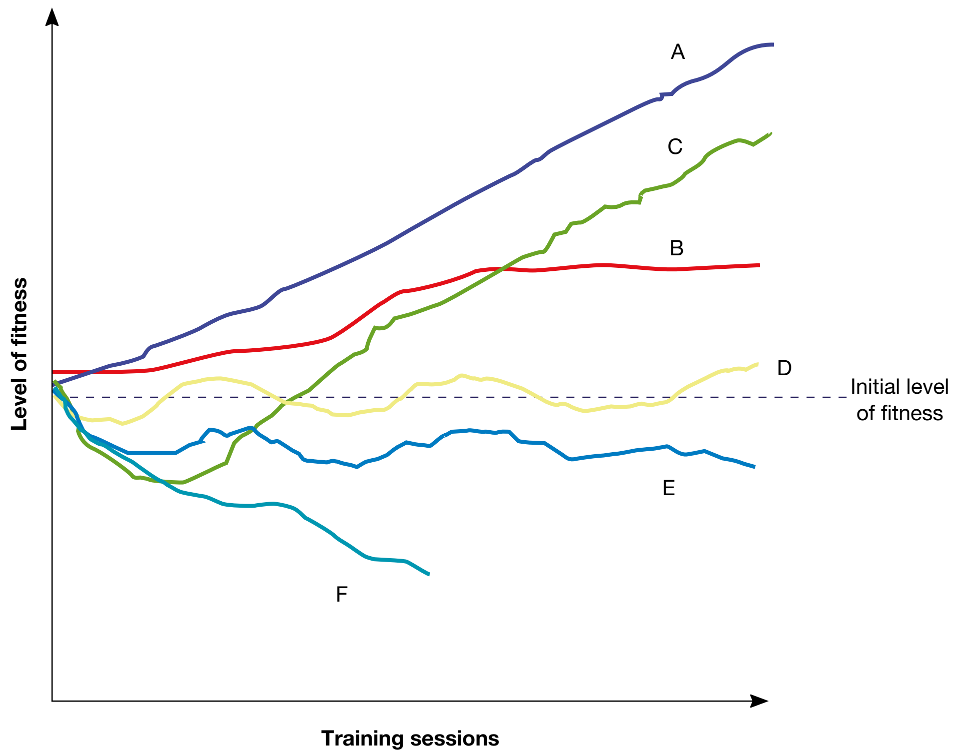
1 Define progressive overload.
2 Outline why it is important that overload is applied progressively.
3 Name the four factors on which overload relies.
4 Identify the variables with which training programs can be overloaded.
5 Define variety.
6 Explain the concept of overtraining.
7 List some of the signs and symptoms of overtraining.

APPLY your understanding

8 In the following training scenarios, suggest ways in which an athlete could introduce overload.
   (a) An 800-metre elite runner: one set of 6 × 300-metre intervals run at 75 per cent MHR with 1-minute walk recoveries between efforts
   (b) A 10 000-metre runner: three sessions per week of 15-kilometre runs around her local suburban streets
   (c) A pole vaulter: five sessions per week of two sets of 10 × 20-metre track sprints at 98 per cent MHR with 60 seconds of rest recovery between efforts and 10 minutes of walk recovery between sets
9 For the following sports, suggest ways in which variety could be introduced to training sessions: netball, swimming, tennis, basketball, water polo, cross-country running.
10 Examine the graph below and explain the progress of each of the six subjects in their application of progressive overload.
   Consider:
   (a) the appropriateness of the initial training load
   (b) adjustments made to the training load
   (c) no change to the training load
   (d) implications of a training load that is too easy or too hard.
11 Explain the factors that you would incorporate into your training program design that would prevent the likelihood of overtraining occurring.

EXAM practice

12 An athlete can use a variety of measures to monitor their progress. Oliver has felt ongoing fatigue during training. His coach refers to Oliver's training diary to gain a better understanding as to what might be causing the fatigue. She notices the following patterns in the recording of his daily information: ongoing muscle soreness, higher resting heart rates, lack of enjoyment, disturbed sleep patterns and a limited concentration span.
   (a) What do these symptoms indicate is occurring to Oliver? **1 mark**
   (b) Outline two factors that may have led to Oliver's ongoing fatigue. **2 marks**
   (c) Provide a recommendation as to how Oliver could best overcome this ongoing fatigue. **1 mark**
   (d) Explain how Oliver's coach could prevent him from developing ongoing fatigue in the future. **3 marks**



11.4 Diminishing returns, reversibility or detraining, maintenance and individuality

KEY CONCEPT All training principles need to be considered in the design of an effective training program.

Diminishing returns

The law of **diminishing returns** states that the rate of fitness improvement diminishes as a person approaches their genetic potential.

Fitness gains and improvements in performance occur most rapidly during the early stages of undertaking a training program and smaller margins of improvement occur as a person nears their optimal level of fitness and performance.

As an individual's fitness level increases, the rate of improvement lessens, thus creating **diminishing returns**. Someone who is unfit can make a large improvement in the first few weeks of a training program, while someone who is already fit can make only progressive, small gains despite training at a high level. An unfit older adolescent or adult sprinter who initially takes 16 seconds to sprint 100 metres may rapidly reduce their time to 11.5 seconds, but improvement from this point will take longer and be measured in tenths or hundredths of a second.

The application of overload must be kept in perspective as an individual reaches peak levels of fitness. When the athletes improvement begins to plateau, large or increasing amounts of overload may lead to injury or fatigue and loss of fitness.

The principle of diminishing returns suggests the rate of fitness gains diminishes over time as individuals approach their ultimate genetic potential (figure 11.14). Simply stated, as fitness improves, maintained levels of improvement cannot be expected. The fitter individuals are, the less likely they are to improve further.

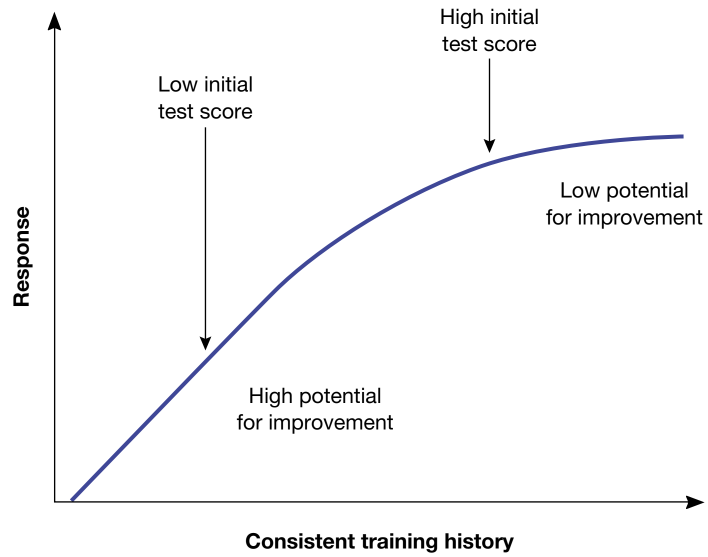


FIGURE 11.14 Recent training history determines an individual's future responsiveness to physical training.

Reversibility or detraining

Detraining is a period of time when training is ceased or there is a reduction in training load beyond what is required for fitness to be maintained.

Reversibility describes the fitness and/or performance loss after a period of detraining.

When training stops or is reduced, the reversal of fitness gains occurs much more quickly than they were achieved. The extent of performance loss is dependent upon the length of the **detraining** and the type of activity. Generally, aerobic endurance gains are lost quickly, in the first two to four weeks, while muscular strength degeneration tends to be much slower. Research has found that aerobic capacity declines between 4 and 20 per cent during the initial eight weeks of detraining and the degree of **reversibility** tends to be greater in highly trained aerobic athletes.

The extent of decline in strength and power during a period of detraining is dependent upon training experience, the length of training time prior to detraining and specific muscle groups. Izquierdo and colleagues (2007) found a decrease of 6 per cent in squat strength and a decrease of 9 per cent in bench press strength following a four-week detraining period in athletes who had undertaken a 16-week resistance training program.

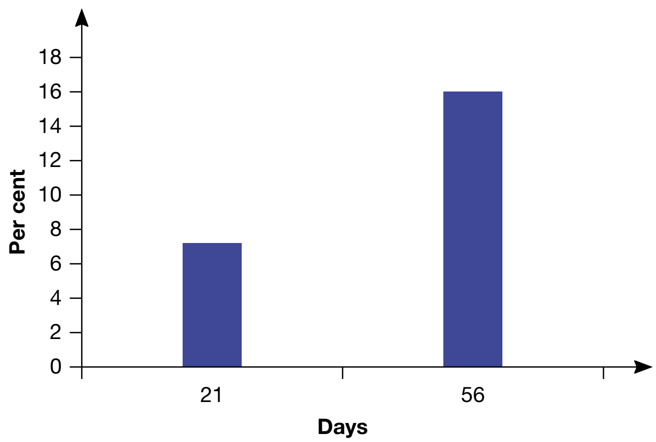


FIGURE 11.15 Loss of aerobic capacity dependent on duration of detraining period

This principle suggests that consistency and regularity of physical activity are critical determinants of both fitness maintenance and improvement. All the hard work put in over weeks of training to make measurable fitness gains can be easily reversed in just a couple of weeks.

Maintenance

Acquired fitness levels can be **maintained** by carefully altering the FITT principle (Frequency, Intensity, Time, Type of exercise).

By maintaining the intensity of training and decreasing the volume or frequency of training by around one-third, the attained fitness levels should be maintained. The amount of reduction of training load will be different from one person to the next.

A general understanding is that moving from a minimum of three quality training sessions per week to two should maintain an attained level of fitness. The training intensity is vital for maintaining fitness and performance. The principle of reversibility supports the saying 'use it or lose it' and therefore a strategic approach to training must be undertaken in order to maintain current fitness levels.

The principle of **maintenance** suggests that once a required level of fitness has been achieved, the level of effort to maintain that level of fitness is not as great as was required to achieve it.

Individuality

No two individuals react in exactly the same way to a similar physical activity program. Regardless of the training programs being used, some people will achieve significant gains, while others will only improve slowly.

The principle of **individuality** is strongly influenced by heredity.

The principle of **individuality** suggests that individual responses to physical activity are highly varied.

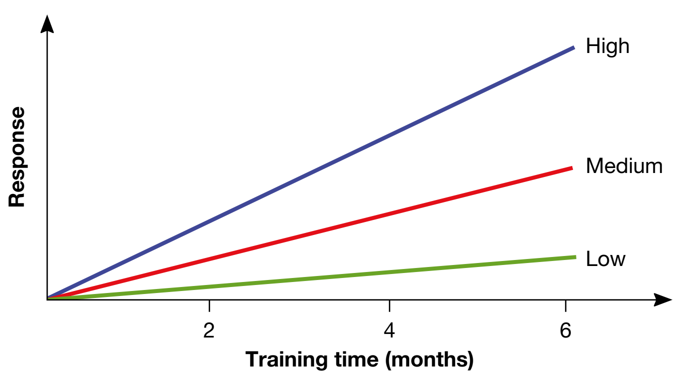


FIGURE 11.16 Individual response to training varies widely.

Source: Bouchard, C & Rankinen, T 2001, 'Individual differences in response to regular physical activity', *Medicine and Science in Sports and Exercise,* vol. 33, no. 6, pp. S446–S451.

It is essential that a training program is designed to cater for the specific needs, goals and abilities of the individual.

studyon

Unit 4 | AOS 2 | Topic 2 | Concept 5

Maintenance, over-training and detraining
Summary screen and practice questions

TEST your understanding

1 Outline what other training principle is important to consider when a training program begins to show signs of diminishing returns.
2 Define the principle of reversibility.
3 Explain what the term *detraining* means.
4 Identify which of the FITT factors must stay the same if maintenance of training gains is desired.
5 Define the principle of individuality.

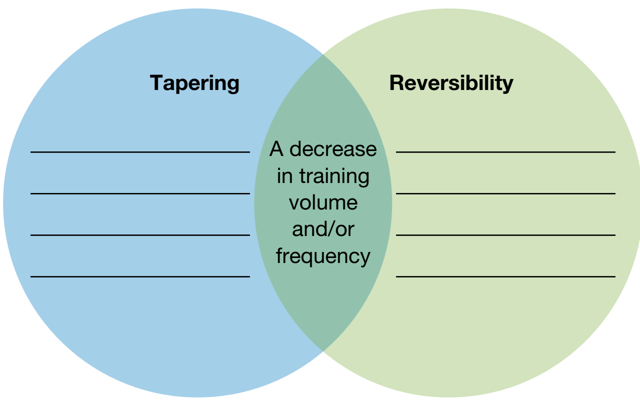
APPLY your understanding

6 Are there differences in the speed of reversibility of fitness gains between aerobic and anaerobic training programs? Explain these.
7 Discuss how a training program can be adapted to delay the principle of reversibility.
8 For the following training scenario, suggest ways to adjust the FITT factors to allow this athlete to achieve maintenance.
A pole vaulter: five sessions per week of two sets of 10 × 20-metre track sprints at 98 per cent MHR with 60 seconds of rest recovery between efforts and 10 minutes of walk recovery between sets.
9 Discuss how a trainer or coach prepares for the effects of the principle of individuality on each of their participants in a training program.

EXAM practice

10 **ACHPER Trial Exam 2011, question 11**
Outline two training principles a coach should ensure his or her athletes are aware of during their 'off season'. **2 marks**

11 **adapted from ACHPER Trial Exam 2012, question 2**
Tapering and reversibility may be demonstrated with a training program. Complete the Venn diagram below to distinguish between tapering and reversibility.



2 marks

11.5 Continuous and interval training

KEY CONCEPT Both continuous and interval training provide benefits in improving performance; however, they each achieve this differently.

Continuous training

Continuous training leads to an improvement in aerobic capacity and local muscular endurance, and improves the lactate inflection point. You reach your aerobic steady state faster, accumulate lactic acid more slowly and recover more quickly.

This type of training can be adapted to any activity that requires the use of the aerobic energy system as the dominant provider of ATP. It is not restricted to running; continuous training can also be applied to swimming, cycling, cross-country skiing and kayaking, for example:

- a 5-kilometre run
- a 500-metre swim
- a 20-kilometre bike ride
- a 5-kilometre cross-country skiing trip
- a 2-kilometre rowing session.

Continuous training is also commonly used in team sports as a pre-season training method to establish a sound aerobic base from which athletes improve their other fitness components and in the off-season for the purpose of aerobic maintenance.

To gain the most out of continuous training, follow the FITT formula:

- Frequency (at least three sessions per week for aerobic improvements)
- Intensity (in the aerobic training zone between 70–85 per cent MHR as indicated in figure 11.5)
- Time (minimum of 20 minutes continuous activity is required)
- Type (whole-body activities that use large, major muscle groups, such as walking, running, cycling, rowing, swimming and aerobics).

All aspects of the FITT formula should be used.

Also often known as long, slow distance training, **continuous training** involves continuous activity that lasts a minimum of 20 minutes at the required intensity using the aerobic energy system. It is submaximal and requires an intensity of 70–85 per cent of maximum heart rate.

studyon

Unit 4	**Continuous and fartlek training**
AOS 2	Summary screen and practice questions
Topic 3	
Concept 1	

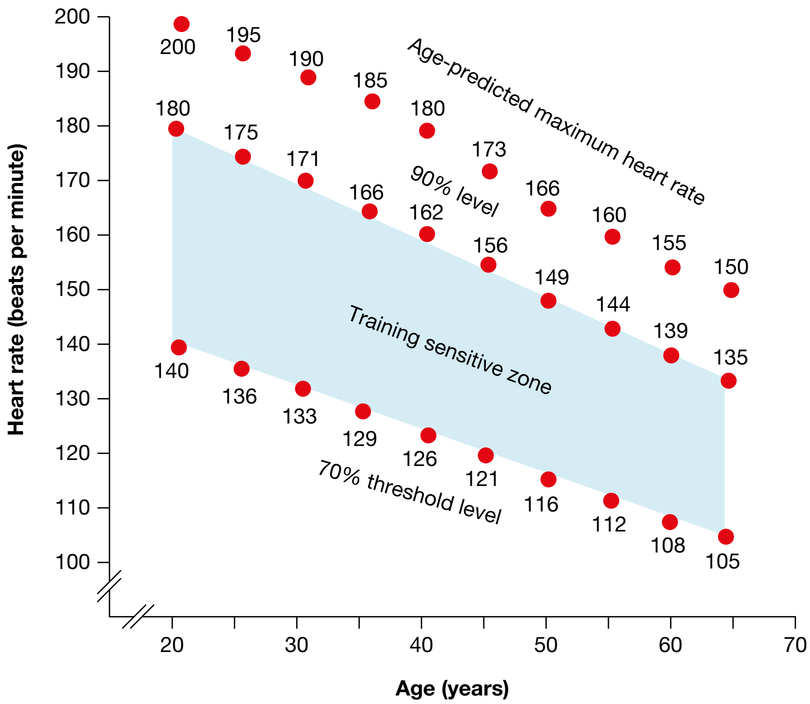


FIGURE 11.17 Target training zone for aerobic fitness improvement

Long, slow distance training is generally the most common and safest type of training adopted by recreational athletes in order to attain health-related benefits.

It is important to note that continuous training can also include high-intensity endurance training that is performed at intensities of 85–95 per cent MHR. The purpose of high-intensity endurance training is to perform at intensities that allow the athlete to improve their lactate inflection point.

Interval training

Interval training consists of repeated periods of work followed by periods of rest or recovery.

Interval training consists of repeated periods of work followed by periods of rest or recovery.

Interval training is a versatile training method that can be tailored to the specific energy system needs. It requires careful planning, and several variables must be considered when planning both the initial exercise bout and the application of progressive overload (table 11.4).

TABLE 11.4 Planning interval training

Variable	Description	Examples
Work interval distance	The distance of the work	60 metres
Work interval time	The time in which the work must be completed	8 seconds
Rest interval duration	The time between work intervals	40 seconds
Rest interval type	The nature of the rest between work intervals	Walk
Work intensity	How hard the work is to be done (usually a percentage of the maximum heart rate)	95 per cent
Repetitions	The number of work periods in a sequence	8
Sets	The number of repetition sequences	3
Frequency	The number of training sessions per week	3

studyon
Unit 4
AOS 2
Topic 3
Concept 2
Short-interval training
Summary screen and practice questions

studyon
Unit 4
AOS 2
Topic 3
Concept 3
Intermediate-interval training
Summary screen and practice questions

Interval training and work-to-rest ratio

In planning interval training, a knowledge of the work-to-rest ratio is important because this determines the setting of the variables. The work-to-rest ratio is established by analysing and breaking an activity into work and rest components. It indicates how much work is completed in an activity in proportion to how much rest is available.

An important fact to establish is what is classified as work and what is classified as rest.

Although work-to-rest ratios cannot be used in isolation to determine energy system usage, the following examples show the general relationship:

- A work-to-rest ratio of 1:5 and greater indicates that the ATP–CP energy system is the system predominantly used.
- A ratio of 1:3 would suggest the use of the anaerobic glycolysis energy system.
- A ratio of 1:1 would use aerobic energy.

Once the work-to-rest ratio is established for an activity, it can be replicated in the interval training schedule (the principle of specificity). Examples of interval training for the three energy systems are outlined in table 11.5.

TABLE 11.5 Examples of interval training variables for running

Type of interval training	Energy system	Work interval time	Work intensity	Reps	Sets	Rest/recovery interval time	Work:rest ratio	Training frequency per week
Short	ATP–CP	3–10 sec	Maximal	6–15	3	3–50 sec	1:5+	3
Intermediate	Anaerobic glycolysis	10–60 sec	85%–95% of max HR	6–10	2	30–180 sec	1:3	3
Long	Aerobic	30 sec–4 min	70–85(+)% of max HR	2–4	2	30 sec–4 min	1:1 1:0 2:1	4–5

With sports science's understanding of the contribution of the energy systems to athletic performance, we now acknowledge that interval training can facilitate the development of all three energy systems, depending upon how the variables are manipulated.

Long-interval training has traditionally been the type of interval training adopted in order to improve aerobic power; however, there has been growing evidence that suggests that **high-intensity interval training (HIIT)** is a very time-efficient training method to elicit chronic aerobic adaptations. HIIT involves repeated work intervals with sessions that are relatively brief in duration, performed at a high level of intensity close to VO_2 maximum. A single work interval may be a few seconds to several minutes in duration, separated by up to a few minutes of rest or recovery exercise.

Research indicates that for athletes who already have a high level of aerobic capacity, further improvements are best obtained through high-intensity interval training.

FIGURE 11.18 HIIT training session on cycle ergometer

High-intensity interval training (HIIT) involves repeated work intervals that are relatively brief in duration, performed at a high level of intensity close to VO_2 maximum followed by less intense recovery/rest intervals.

TABLE 11.6 A typical example of a HIIT training program on a cycle ergometer

Work interval time	Work intensity	Reps	Sets	Rest/recovery time	Frequency
30 seconds	Maximum	4–6	1	2–3 minutes	3 per week

Total work period for each training session = 2–3 minutes
Total training session time including rest/recovery time = 20 minutes.

studyon
Unit 4
AOS 2
Topic 3
Concept 4
Long-interval training
Summary screen and practice questions

The American College of Sports Medicine (ACSM) provides further information about HIIT training:

ACSM information on …
HIGH-INTENSITY INTERVAL TRAINING

The popularity of high-intensity interval training is on the rise. High-intensity interval training sessions are commonly called HIIT workouts. This type of training involves repeated bouts of high-intensity effort followed by varied recovery times.

A complete physical activity program
A well-rounded physical activity program includes aerobic exercise and strength training exercise, but not necessarily in the same session. This blend helps maintain or improve cardiorespiratory and muscular fitness and overall health and function. Regular physical activity will provide more health benefits than sporadic high-intensity workouts, so choose exercises you are likely to enjoy and that you can incorporate into your schedule.

ACSM's physical activity recommendations for healthy adults, updated in 2011, recommend at least 30 minutes of moderate-intensity physical activity (working hard enough to break a sweat, but still able to carry on a conversation) five days per week, or 20 minutes of more vigorous activity three days per week. Combinations of moderate- and vigorous-intensity activity can be performed to meet this recommendation.

Examples of typical aerobic exercises are:

- Walking
- Running
- Stair climbing
- Cycling
- Rowing
- Cross-country skiing
- Swimming

In addition, strength training should be performed a minimum of two days each week, with 8–12 repetitions of 8–10 different exercises that target all major muscle groups. This type of training can be accomplished using body weight, resistance bands, free weights, medicine balls or weight machines.

The intense work periods may range from 5 seconds to 8 minutes long, and are performed at 80% to 95% of a person's estimated maximal heart rate, the maximum number of times your heart will beat in a minute without overexerting yourself. The recovery periods may last equally as long as the work periods and are usually performed at 40% to 50% of a person's estimated maximal heart rate. The workout continues with the alternating work and relief periods totaling 20 to 60 minutes.

What are the benefits of HIIT?
HIIT training has been shown to improve:

- aerobic and anaerobic fitness
- blood pressure
- cardiovascular health
- insulin sensitivity (which helps the exercising muscles more readily use glucose for fuel to make energy)
- cholesterol profiles
- abdominal fat and body weight while maintaining muscle mass.

Why is HIIT training so popular?
HIIT training can easily be modified for people of all fitness levels and special conditions, such as overweight and diabetes. HIIT workouts can be performed on all exercise modes, including cycling, walking, swimming, aqua training, elliptical cross-training, and in many group exercise classes. HIIT workouts provide similar fitness benefits as continuous endurance workouts, but in shorter periods of time. This is because HIIT workouts tend to burn more calories than traditional workouts, especially after the workout. The post-exercise period is called 'EPOC', which stands for excess postexercise oxygen consumption. This is generally about a 2-hour period after an exercise bout where the body is restoring itself to pre-exercise levels, and thus using more energy. Because of the vigorous contractile nature of HIIT workouts, the EPOC generally tends to be modestly greater, adding about 6 to 15% more calories to the overall workout energy expenditure.

How do you develop a HIIT exercise program?
When developing a HIIT program, consider the duration, intensity, and frequency of the work intervals and the length of the recovery intervals. Intensity during the high intensity work interval should range ≥ 80% of your estimated maximal heart rate. As a good subjective indicator, the work interval should feel like you are exercising 'hard' to 'very hard'. Using the talk test as your guide, it would be like carrying on a conversation, with difficulty. The intensity of the recovery interval should be 40–50% of your estimate maximal heart rate. This would be a physical activity that felt very comfortable, in order to help you recover and prepare for your next work interval.

The relationship of the work and recovery interval is important. Many studies use a specific ratio of exercise to recovery to improve the different energy systems of the body. For example, a ratio of 1:1 might be a 3-minute hard work (or high intensity) bout followed by a 3-minute recovery (or low intensity) bout. These 1:1 interval workouts often range about 3, 4, or 5 minutes followed by an equal time in recovery. Another popular HIIT training protocol is called the 'spring interval training method'. With this type of program the exerciser does about 30 seconds of 'sprint or near full-out effort', which is followed by 4 to 4.5 minutes of recovery. This combination of exercise can be repeated 3 to 5 times. These higher intensity work efforts are typically shorter bouts (30 seconds with sprint interval training).

What are the safety concerns with HIIT training?
Persons who have been living rather sedentary lifestyles or periods of physical inactivity may have an increased coronary disease risk to high intensity exercise. Family history, cigarette smoking, hypertension, diabetes (or pre-diabetes), abnormal cholesterol levels and obesity will increase this risk. Medical clearance from a physician may be an appropriate safety measure for anyone with these conditions before staring HIIT or any exercise training. Prior to beginning HIIT training a person is encouraged to establish a foundational level of fitness. This foundation is sometimes referred to as a 'base fitness level'. A base fitness level is consistent aerobic training (3 to 5 times a week for 20 to 60 min per session at a somewhat hard

intensity) for several weeks that produces muscular adaptations, which improve oxygen transport to the muscles. Establishing appropriate exercise form and muscle strength are important before engaging in regular HIIT to reduce the risk of musculoskeletal injury.

Regardless of age, gender and fitness level, one of the keys to safe participation of HIIT training is for all people to modify the intensity of the work interval to a preferred challenging level. Safety in participation should always be primary priority, and people should focus more on finding their own optimal training intensities as opposed to keeping up with other persons.

How many times a week can you do a HIIT workout?
HIIT workouts are more exhaustive then steady state endurance workouts. Therefore, a longer recovery period is often needed. Perhaps start with one HIIT training workout a week, with your other workouts being steady state workouts. As you feel ready for more challenge, add a second HIIT workout a week, making sure you spread the HIIT workouts throughout the week.

Final HIIT message
Interval training has been an integral part of athletic training programs for many years because a variety of sport and recreational activities require short bursts of movement at high intensities. Interval training is becoming an increasingly recognised and well-liked method of training. The incorporation of interval training into a general conditioning program will optimise the development of cardiorespiratory fitness as well as numerous other health benefits. Give HIIT a try.

Staying active pays off!
Those who are physically active tend to live longer, healthier lives. Research shows that moderate physical activity — such as 30 minutes a day of brisk walking — significantly contributes to longevity. Even a person with risk factors like high blood pressure, diabetes or even a smoking habit can gain real benefits from incorporating regular physical activity into their daily life.

As many dieters have found, exercise can help you stay on a diet and lose weight. What's more — regular exercise can help lower blood pressure, control blood sugar, improve cholesterol levels and build stronger, denser bones.

The first step
Before you begin an exercise program, take a fitness test, or substantially increase your level of activity, make sure to answer the following questions. This physical activity readiness questionnaire (PAR-Q) will help determine if you're ready to begin an exercise routine or program.

- Has your doctor ever said that you have a heart condition or that you should participate in physical activity only as recommended by a doctor?
- Do you feel pain in your chest during physical activity?
- In the past month, have you had chest pain when you were not doing physical activity?
- Do you lose your balance from dizziness? Do you ever lose consciousness?
- Do you have a bone or joint problem that could be made worse by a change in your physical activity?
- Is your doctor currently prescribing drugs for your blood pressure or a heart condition?
- Do you know of any reason you should not participate in physical activity?

If you answered yes to one or more questions, if you are over 40 years of age and have recently been inactive, or if you are concerned about your health, consult a physician before taking a fitness test or substantially increasing your physical activity. If you answered no to each question, then it's likely that you can safely begin exercising.

Prior to exercise
Prior to beginning any exercise program, including the activities depicted in this brochure, individuals should seek medical evaluation and clearance to engage in activity. Not all exercise programs are suitable for everyone, and some programs may result in injury. Activities should be carried out at a pace that is comfortable for the user. Users should discontinue participation in any exercise activity that causes pain or discomfort. In such event, medical consultation should be immediately obtained.

Brochure content provided by Len Kravitz, Ph.D.

HIIT has been found to be a very time-efficient training method that enables skeletal muscle adaptations similar to those achieved by other forms of endurance training. In as little as two weeks including six sessions of HIIT, which encompasses a total of only 12–15 minutes of maximum-intensity work intervals, there can be increases in skeletal muscle oxidative capacity and noticeable improvements in performance during activities that require aerobic energy metabolism.

Interval training can and should be designed to cater for the particular requirements of the sport or activity for which the athlete is training. Sarah Wall, creator of NETFIT Netball, incorporates netball-specific skills and movements into a HIIT session as outlined in figure 11.19.

eBook*plus*
Weblink
Fit in 6 minutes a week

studyon
Unit 4 | AOS 2 | Topic 3 | Concept 5
High-intensity interval training
Summary screen and practice questions

FIGURE 11.19 Netball specific HIIT session by NETFIT

eBookplus

Weblink
Netball-specific movements HIIT

Applying progressive overload to interval training

The training example used in table 11.5 could involve manipulating the following variables to overload:

- work interval distance
- work interval time
- rest interval time
- rest interval type
- number of repetitions
- number of sets.

However, it is also important to maintain the original aim of training. Table 11.7 summarises the impact of variable manipulation when applying progressive overload with the aim of improving ATP–CP energy system efficiency.

Many team sport coaches adopt interval training as the most effective means of conditioning athletes. For example, Australian Rules football teams long ago moved away from an emphasis on continuous training to interval work because the work-to-rest relationship closely resembles that of the game situation.

TABLE 11.7 The impact of variable manipulation

Variable	Current training	Manipulation to cause overload	Impact
Work interval distance	100 metres	Longer	Changes the predominant energy system to anaerobic glycolysis
Work interval time	15 seconds	Shorter	Creates higher intensity, requiring more phosphate energy
Rest interval time	45 seconds	Shorter	Changes the work-to-rest ratio to less than 1:3, so anaerobic glycolysis becomes the predominant energy system
Rest interval type	Rest	Slow jog	Appropriate as long as the intensity of jogging remains low
Number of repetitions	8	Increase	Appropriate, although too many will lead to gradual depletion of adenosine triphosphate and reliance on anaerobic glycolysis
Number of sets	2	Increase	More appropriate than a continual increase in repetitions

TEST your understanding

1 Define the continuous training method.
2 Explain why continuous training is often the chosen method of training used for improving aerobic power in recreational athletes.
3 Outline the best ways to manipulate the FITT principle to promote effective continuous training.
4 Define interval training.
5 Outline the recommendations in the variables associated with short-, intermediate- and long-interval training.
6 Reflect why it is beneficial to adopt HIIT as a method of improving aerobic power.

APPLY your understanding

7 Explain a scenario where continuous training would be most appropriate to adopt into a training program. Give reasons for your response.
8 (a) Choose a particular case study and design an appropriate interval (short, intermediate, long or high intensity) training program using the following variables:
- work interval time
- work intensity
- number of reps
- number of sets
- rest/recovery time
- work-to-rest ratio
- frequency per week.

(b) Justify the selection of each of the variables into your training program design.
9 Explain some ways in which you could incorporate variety into continuous and interval training program design.
10 **Practical activity: interval training**
Organise your class group to participate in an individual interval training session that would be appropriate to include in the training program you outlined in question 10.
11 **Practical activity: continuous training**
Participate in a 20-minute continuous training session, ensuring that your heart rate remains in the recommended target zone.

studyon

Unit 4
AOS 2
Topic 3
Concept 6

Circuit training
Summary screen and practice questions

EXAM practice

12 **ACHPER Trial Exam 2010, question 15**

(a) The following is an example of an interval training session. In the table below, fill in the rest period required for the anaerobic glycolysis energy system.

Energy system	Sets	Repetitions	Exercise	Work time (Secs)	Intensity	Rest time (Secs)
ATP-CP	2 (10 mins rest between each set)	6	50 m Sprints	7	Maximal	70
Anaerobic glycolysis	2 (10 mins rest between each set)	6	50 m Sprints	7	High	

1 mark

(b) For the same program as in part (a), demonstrate how you would apply overload to the ATP–CP system by completing the following table.

Energy system	Sets	Repetitions	Exercise	Work time (Secs)	Intensity	Rest time (Secs)
ATP-CP	2 (10 mins rest between each set)	6	50 m Sprints	7	Maximal	70
ATP-CP						

1 mark

(c) Differentiate between *sets* and *repetitions*. **2 marks**

11.6 Resistance (or weight) training

KEY CONCEPT Resistance training improves the strength and functionality of skeletal muscles.

There are different types of **resistance training**:

- isoinertial (free weights)
- isometric (fixed resistance)
- isokinetic (variable resistance provided by a machine)
- eccentric overload training (flywheel and versapulley)
- core strength training (pilates and swissball).

Isoinertial resistance training is the traditional form of resistance training, using free weights such as barbells and dumbbells, or resistance machines that use weight stacks for adjusting resistance. It is dynamic and involves lifting a set weight through the range of motion of the joint. This training has two distinct phases that can be completed independently of each other.

These phases are:

- *the concentric phase*, where the muscle contracts against the force of gravity
- *the eccentric phase*, where the muscle lengthens under tension with the force of gravity.

The criticism of this method has been that the maximum weight that can be used in free weights is that which can be lifted at the weakest points (the start and finish) of the range of motion. Muscle is not being trained by an appropriate resistance in the mid-section of the lift (approximately 115 degrees), which is the strongest point of the contraction. For example, when lifting the weight in a bicep curl, at the start of the exercise, the weight of the dumbbell must be overcome. Initially the involved muscles contract isometrically in order to produce enough tension to begin to overcome the load of the dumbbell. As soon as the force produced by the muscle is greater than the resistance, the muscle contracts concentrically, and causes acceleration of the bicep curl exercise.

Isometric resistance training involves holding the muscle in one position while it contracts against the resistance. Tension in the muscle increases but the muscle stays the same length. Examples are pushing against a wall, performing a handstand and holding a crucifix (or Iron Cross) position on the Roman rings. This method is effective in increasing strength but only in the static position held, so it has minimal use in dynamic activities. If the arm, for example, is flexed at 90 degrees against an isometric resistance (see figure 11.21(a)) strength would improve for that position. Adjusting the flex to 120 degrees (see figure 11.21(b)) would produce isometric strength gain for that position only.

Resistance training aims to build muscle strength, muscle power or local muscular endurance by exercising muscles or muscle groups against a resistance.

An **isoinertial** contraction is a type of dynamic muscle contraction where the resistance against the muscle remains constant.

An **isometric** contraction is when the muscle length remains the same as it contracts under tension.

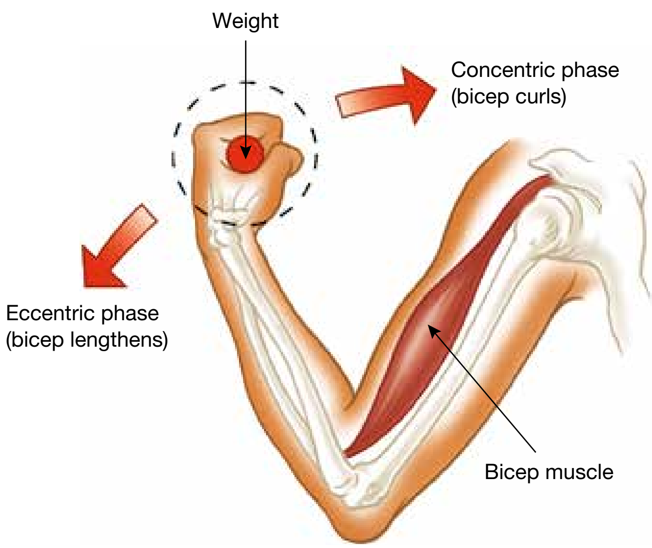


FIGURE 11.20 Concentric and eccentric phases of the biceps curl

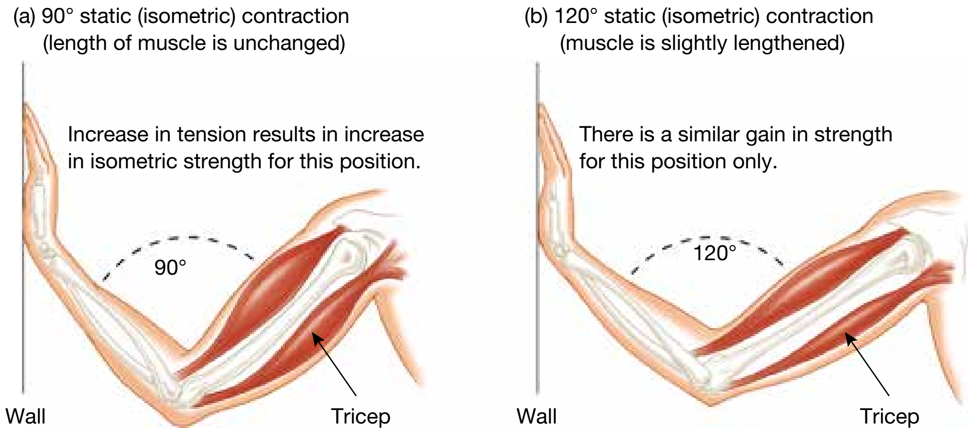


FIGURE 11.21 The impact of isometric training on muscular strength for the tricep is limited to the angle of joint flexion.

You may be surprised at how often the sport you play requires some form of isometric strength. Whether it is gripping a racquet, ball or opponent, or just holding a particular body position, these movements all require isometric strength. Specific sporting examples where isometric strength is required and therefore would gain from this form of training are Olympic wrestling, rugby scrums, Australian Rules football tackling, rock-climbing, sailing, and sports that require grip and strength to hold equipment.

Isokinetic resistance training is undertaken on machines such as a Cybex, Kincom, Biodex or Hydragym, which can adjust the load as the body part moves through the range of motion. This is called accommodating resistance adjusting the resistance to a greater or lesser amount as the body parts work through the full range of motion.

Research shows that improvements in strength using isokinetic resistance training occur only at or below the velocity at which the resistance allows the joint to move. More advanced machines have adjustable resistance to allow higher velocity movements that result in greater benefits.

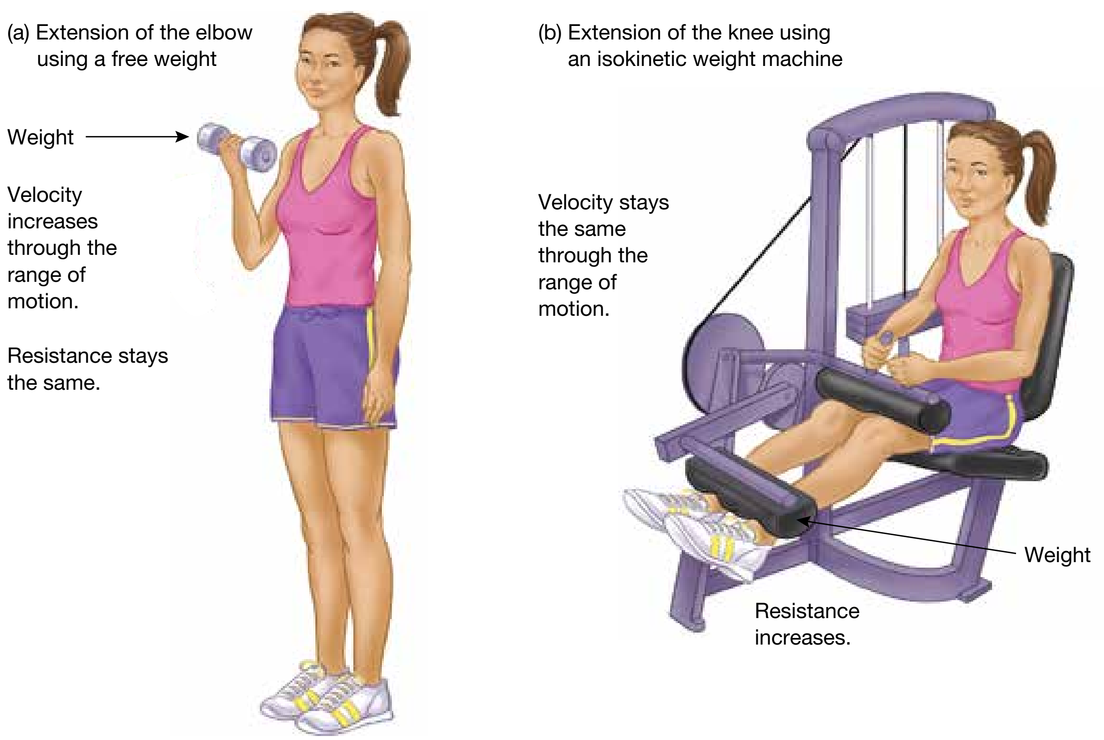


FIGURE 11.22 The difference between isoinertial and isokinetic muscle contraction

Eccentric overload training is a form of dynamic resistance training that emphasises the eccentric phase of the muscle contraction. A resistance program that includes an emphasis on both eccentric and concentric contraction phases will maximise the gains in muscular strength and size. Flywheel and Versapulley technology allows for an isoinertial eccentric contraction overload as they work on the basis of inertia opposing the force exerted by the muscle rather than simply gravity (see figure 11.23). Your muscles are generally stronger in the eccentric phase of contraction than the concentric phase of contraction. In standard loading resistance training, the maximal load can be lifted is limited by the concentric phase of contraction, and the eccentric phase of contraction is therefore underloaded. Eccentric overload training leads to greater neuromuscular and strength adaptations compared with standard loading.

An **eccentric** contraction is when the muscle lengthens as it contracts.

FIGURE 11.23 Eccentric training with inertia opposing the contraction

Core strength training

The aim of core strength (or stability) training is to effectively use the trunk musculature and to control the position of the lower back (or lumbar spine) during sport or recreation-based movements. The major abdominal and hip area muscles are central in the active support of the lumbar spine. The teamwork of these muscles stabilises the lumbar spine and acts directly to resist all the forces acting on the lumbar spine. The strength and coordination of these muscles is significant in creating a safe, successful and enjoyable movement. Improving the muscular strength of the postural muscles will reduce the risk of injury and improve performance. Strength of the core muscles becomes very important when fatigue sets in and form needs to be maintained in order to execute skills well. Core strength exercise should target the abdominals, gluteals and lumbar extensors.

As with all fitness training, the training procedure for core strength must be specific to the task required. The deep-trunk muscles act as stabilisers and provide isometric strength of varying degrees during all movements.

Some common core strength exercises are the plank, bridge and superman. Pilates, yoga and gym ball training all have a focus on strengthening core stability.

Core strength training should be undertaken 2–3 times per week and include rest days so as to allow muscle recovery. As core strength develops, the load can be gradually increased by increasing the number of repetitions, number of sets, the difficulty of each exercise or frequency of training.

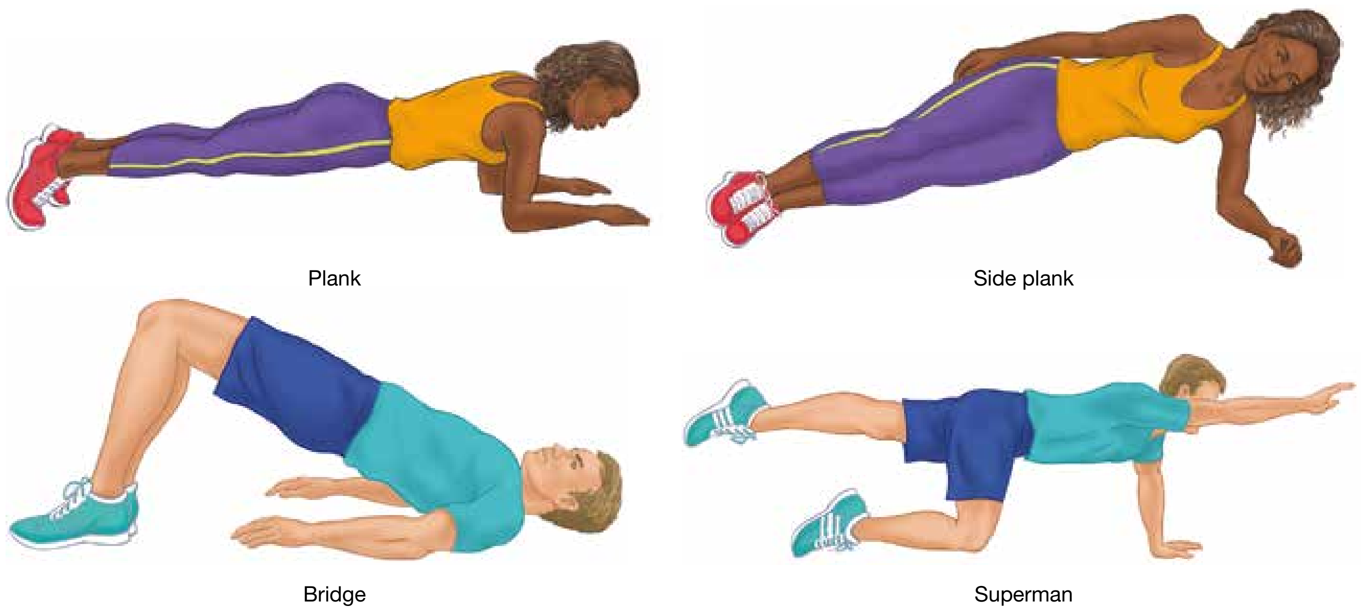


FIGURE 11.24 Core stability exercises can be performed with no or minimal equipment.

FIGURE 11.25 Core strength training with the assistance of a gym ball

Core stability has become recognised as an important part of modern fitness training philosophies. It is used by almost all elite sporting teams and individuals to heighten total body stability during competition.

Specificity in resistance training

One of the main reasons for resistance training being central to just about all sport training is that its movements can be designed to mimic most sporting actions. This means that muscles used in a movement, the energy systems employed in that movement, the angles of joint movement used and the force required for the movement can all be replicated in a resistance training exercise.

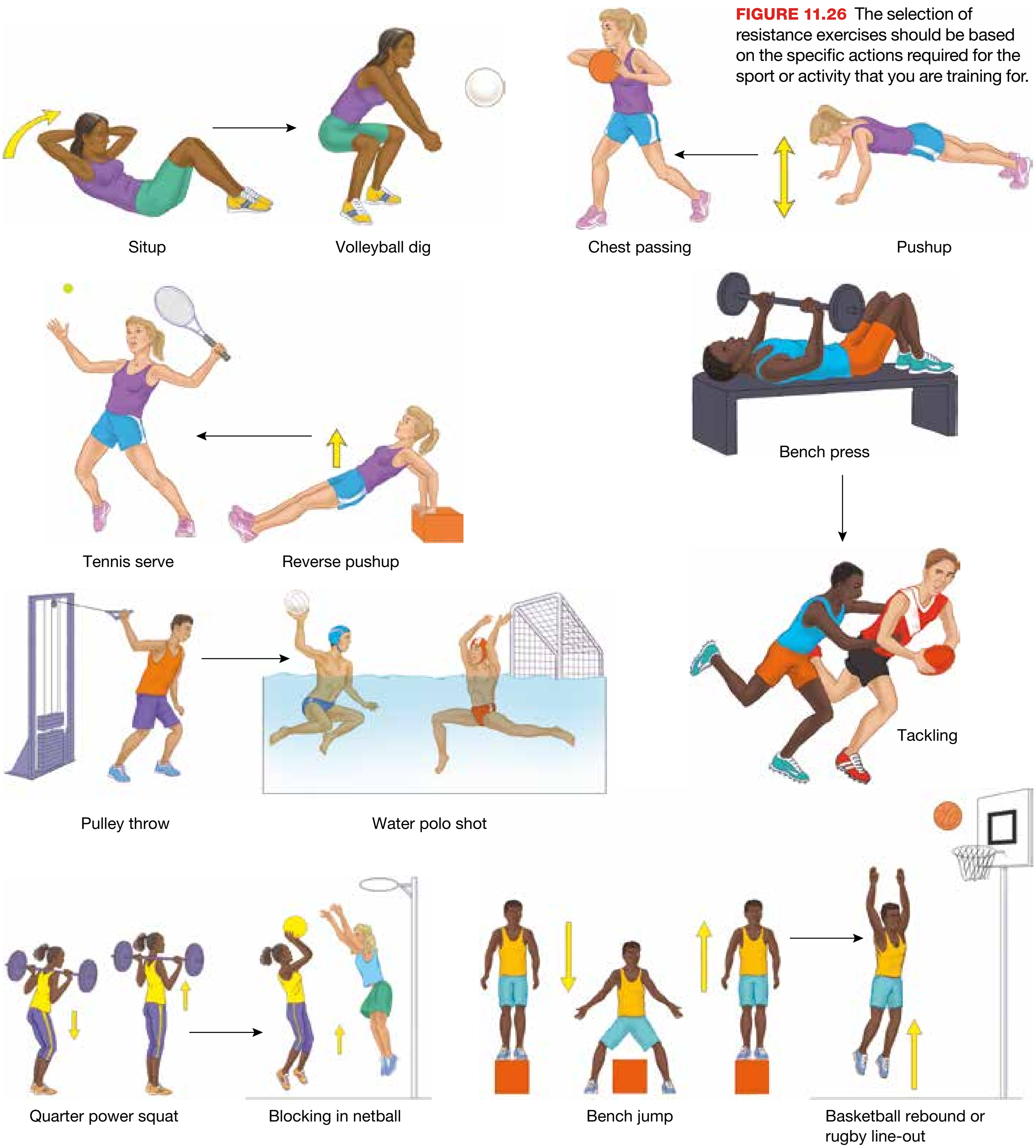


FIGURE 11.26 The selection of resistance exercises should be based on the specific actions required for the sport or activity that you are training for.

Some examples of this specificity are:

- bicep curls for handballs in Australian Rules football
- flies for tackling
- bench presses for netball or basketball chest passes
- quarter squats for basketball rebounds, long jump take-offs, sprint starts
- calf raises for running

eBook*plus*

eLesson
Resistance training basics
Searchlight ID: eles-0509

- tricep extensions for throwing
- sitting leg extensions for kicking in Australian Rules football
- various pulley resistance training for hockey long hits, groin strengthening work for specific throwing movements to avoid osteitis pubis.

Resistance training terminology

The language of resistance training is important for understanding resistance training and for applying it to your own training. Definitions of variables used in resistance training are provided in table 11.8.

eBook*plus*

Interactivity
Resistance training variables
Searchlight ID: int-6824

TABLE 11.8 Definitions of variables in weight training

Variable	Definition
Repetition	A single effort or performance of an exercise
Repetition maximum (RM)	The heaviest load that can be successfully completed in one contraction
Set	The number of exercise repetitions performed in a sequence without rest
Resistance or load	The weight that must be moved in the exercise or effort
Contraction speed	The velocity at which a muscle contracts

studyon

Unit 4	**Weight and resistance training**
AOS 2	Summary screen and practice questions
Topic 3	
Concept 7	

Resistance training and training principles

The principles of training are most important in weight training:

- Specificity in relation to the relevant muscle groups is the first consideration of any weight-training program.
- Overload is applied using the variables outlined earlier. There are no set rules as to which variable is more appropriate because research and studies on the matter are inconclusive. The most important consideration is to use gradual overload, remembering that too little is much safer than too much.
- Frequency should be one to three times per week depending on other training methods being used, recovery strategies and level of desired performance.
- The duration of the program should be a minimum of six weeks to obtain significant gains.
- The exercises within the weight program should be ordered in a way that does not use the same muscle or muscle group twice in a row. Cycling of muscle or muscle groups is required to avoid excessive stress on the muscles and allow recovery.
- When devising a weight-training program, first decide the aim of your program — is it to develop muscular strength, muscular power or muscular endurance?

Only one component can be developed at one time. Once decided, ensure you develop the specific fitness component in the following order: muscular endurance, muscle size or hypertrophy, strength and finally power. In order to develop a strength or power weights program, weight training should be carried out in phases. This means that endurance must be developed in the muscle before you progress to the next phase.

There has been much discussion and difference of opinion on the most appropriate number of sets, weights and repetitions to maximise strength, power or muscular endurance. Traditionally, high weights and low repetitions equated to strength training, while higher repetitions and lower weights equated to muscular endurance training. There is also no doubt that a program designed for strength will indirectly help improve muscular endurance and power, and vice versa.

Table 11.9 outlines weight-training variables recommended by the American College of Sports Medicine for improving strength, power, endurance and hypertrophy of muscles.

TABLE 11.9 Muscular strength resistance training

Training level	Load %RM	Reps	Sets	Contraction speed	Rest/recovery	Frequency (days per week)
Novice	60–70%	8–12	1–3	Slow/ moderate	2–3 min heavy loads 1–2 min light loads	2–3
Intermediate	70–80%	6–10	2–6	Moderate	2–3 min heavy loads 1–2 min light loads	3–4
Advanced	80–100%	1–12	2–6	Slow to fast	2–3 min heavy loads 1–2 min light loads	4–6

Muscular power resistance training

Training level	Load %RM	Reps	Sets	Contraction speed	Rest/recovery	Frequency (days per week)
Novice	30–60%	3–6	1–3	Moderate	2–3 min heavy loads 1–2 min light loads	2–3
Intermediate	30–60%	3–6	1–3	Fast	2–3 min heavy loads 1–2 min light loads	3–4
Advanced	85–100%	1–6	3–6	Fast	2–3 min heavy loads 1–2 min light loads	4–5

Muscular endurance resistance training

Training level	Load %RM	Reps	Sets	Contraction speed	Rest/recovery	Frequency (days per week)
Novice	50–70%	10–15	1–3	Slow for moderate reps Moderate for high reps	1–2 min for high-rep sets	2–3
Intermediate	50–70%	10–15	1–3	Slow for moderate reps Moderate for high reps	1–2 min for high-rep sets	3–4
Advanced	30–80%	10–25+	Multiple	Slow for moderate reps Moderate for high reps	>1 min for 10–15 reps	4–6

Muscular hypertrophy resistance training

Training level	Load %RM	Reps	Sets	Contraction speed	Rest/recovery	Frequency (days per week)
Novice	70–80%	8–12	1–3	Slow to moderate	1–2 min	2–3
Intermediate	70–80%	8–12	1–3	Slow to moderate	1–2 min	4
Advanced	70–100%	1–12	3–6	Slow, moderate, fast	2–3 min for heavy loads 1–2 min for medium loads	4–6

Source: Adapted from the American College of Sports Medicine, 2013.

The differentiating factors between the types of resistance training can be summarised as follows.

Muscular strength — high load (%RM) and low volume (reps)
Muscular power— moderate load (%RM) with fast contraction speed
Muscular endurance — low load (%RM) and high volume (reps)
Muscular hypertrophy — moderate relative loads (%RM) and high volume (reps)

Guidelines for undertaking resistance training safely and effectively

When developing a resistance training program, it is necessary to consider the following general guidelines.

BASIC GUIDELINES FOR WEIGHT TRAINING

- Always properly warm-up and cool-down the muscles that are used in each resistance training session.
- Make sure that you concentrate on performing each exercise using correct body posture and complete each range of movement smoothly so as to avoid injury and prevent the development of bad habits.
- Stay in control of the movement and work at a good tempo.
- It is best to start a program with lower weights and higher repetitions.
- Think about your breathing technique. Exhale as you work against the resistance and inhale as you are releasing the resistance.
- Try to work different muscle groups with sequential exercises.
- Gradually increase the load by between 2 per cent and 10 per cent when you can comfortably perform the current workload over two consecutive training sessions, so as to avoid overtraining. Remember that you should be able to do all the repetitions using good form and the muscles should feel tired by the last two repetitions.
- Train the larger muscle groups first, progressively working towards training the smaller muscle groups in one session and ensure exercises targeting core strength are completed towards the end of the session.
- Ensure adequate rest and recovery of the muscles between training sessions. Strength training causes tiny tears in muscle tissue which is important for achieving anabolic adaptations during recovery. Your muscles should have at least 48 hours to recover between each strength training session.
- Use a spotter for free weight activities such as squats and bench presses.

TEST your understanding

1 Define resistance training.
2 Outline some of the different types of resistance training.
3 Describe isoinertial resistance training.

APPLY your understanding

4 List some specific sporting examples of movements that would benefit from isometric resistance training. Justify your choices.
5 Explain the value of isokinetic resistance training machines.
6 Explain why core stability training is important.
7 Discuss the benefit of incorporating eccentric overload training into a resistance program.
8 With reference to a sport or activity of your choice, explain whether you would select to train for strength, power or endurance. Justify your selection with examples.
9 **Practical activity: resistance training session**
Design a resistance training session that is appropriate for a particular sport or activity and guide your class group through the session. Make sure that your session includes the appropriate variables that are required to train strength, power or endurance and that you target your session at a level that is suitable for all participants.

EXAM practice

10 **ACHPER Trial Exam 2014, question 5**
Research has proven that resistance training is an effective training method to use in order to increase muscular strength. Complete the table below to show an appropriate overload for a leg press exercise in a resistance training program for an elite athlete.

Exercise	Repetition Maximum (RM)	Number of repetitions	Number of sets	Duration of rest
Leg press	80% RM	5	6	2 minutes
Overload			6	

1 mark

11 **ACHPER Trial Exam 2010, question 9**

The following program is being performed by a beginner trying to improve the muscular power of their legs.

Exercise	1RM Max (kgs)	Weight to lift	Sets	Reps	Rest	Speed of contraction
Squat	50	15–30	3	4	1 min	As fast as possible
Leg press	50	25	6	4	2 mins	As fast as possible
Bent knee deadlifts	30	9–18	3	6	3 mins	As fast as possible
Leg extension	25	20	2	8	2 mins	As fast as possible
Leg curl	25	15	2	6	2 mins	As fast as possible

(a) Outline two errors in the above program. **2 marks**

(b) For each error identified in part (a), suggest a modification that will enable the exercise to meet the intended aim of the program. **2 marks**

11.7 Flexibility and plyometrics

KEY CONCEPT Flexibility is an essential component of fitness in all active sports and plyometrics is an effective method to develop muscular power.

Flexibility

Flexibility refers to the ability of specific joints to move through the full range of motion.

Flexibility is specific to each joint; an individual can be high in flexibility in some joints and not so high in others. A very flexible person has a full range of motion for a given joint. Flexibility training is about improving the range of motion at the desired joints that are important for maximum performance in the designated activity.

For gains in flexibility, an athlete needs to undertake a stretching program three or four times per week for three weeks. If they stop training, their flexibility reverses at about the rate of improvement. There is insufficient evidence from research about the role of stretching in preventing injury, however stretching does improve flexibility, posture and body awareness (proprioception), and also helps to relieve stress.

The ideal timing in which to include any stretching aimed at improvement is after any training or exercise session. Many studies have proven that the benefits of post-exercise stretching outweigh those of pre-exercise stretching in terms of developing flexibility.

Before any flexibility training, the participant should undertake a thorough and general aerobic warm-up to increase blood temperature and circulation and thus minimise injury and maximise the potential to improve performance. It is good practice to include flexibility training at the end of every training session; however, flexibility training can also be the main focus of a session or program.

Methods of stretching that may be incorporated into a training program

There are a variety of recognised methods of stretching, including:

- static (or passive)
- slow active
- proprioceptive neuromuscular facilitation (PNF)
- dynamic
- ballistic
- myofascial release.

Static (or passive) stretching

Static stretches involve holding the end point of a stretch for up to 30 seconds.

Static stretching is the safest and easiest method to practise. It involves a thorough, adequate and total body warm-up, then gradually stretching the muscle groups across a joint to the full range of motion and holding for 15–30 seconds (figure 11.27). This is also the most effective stretching method in a cool-down following the most exhaustive part of an exercise bout.

Hamstring stretch | Groin stretch | Shoulder stretch

FIGURE 11.27 Some commonly used passive stretches

Slow active stretching

Slow active stretching involves slowly moving the joints through the range of motion, relaxing the agonist and repeating the stretch. This type of stretching is common in aerobics classes and is considered low risk because it is controlled by internal rather than external forces.

PNF (proprioceptive neuromuscular facilitation) stretching

PNF stretching is considered to be 20 per cent more effective than other methods, if undertaken correctly. PNF involves the use of muscle isometric contraction before the stretch in an attempt to achieve maximum muscle relaxation.

If the muscle is first moved to isometrically contract against an immovable resistance, it develops a greater ability to stretch through its range of motion. These steps should be followed:

1. You thoroughly warm-up first.
2. You move into the stretch position so that you feel the stretch sensation.
3. Your partner holds the limb in this stretched position.
4. You then push against your partner by isometrically contracting the antagonistic muscles for 6–10 seconds and then relax. During the contraction, your partner aims to resist any movement of the limb.
5. Your partner then moves the limb further into the stretch until you feel the stretch sensation. Hold for 10–15 seconds.
6. Repeat steps 4 and 5 three or four times before the stretch is released.

PNF stretches can also be undertaken individually, as shown in figure 11.28.

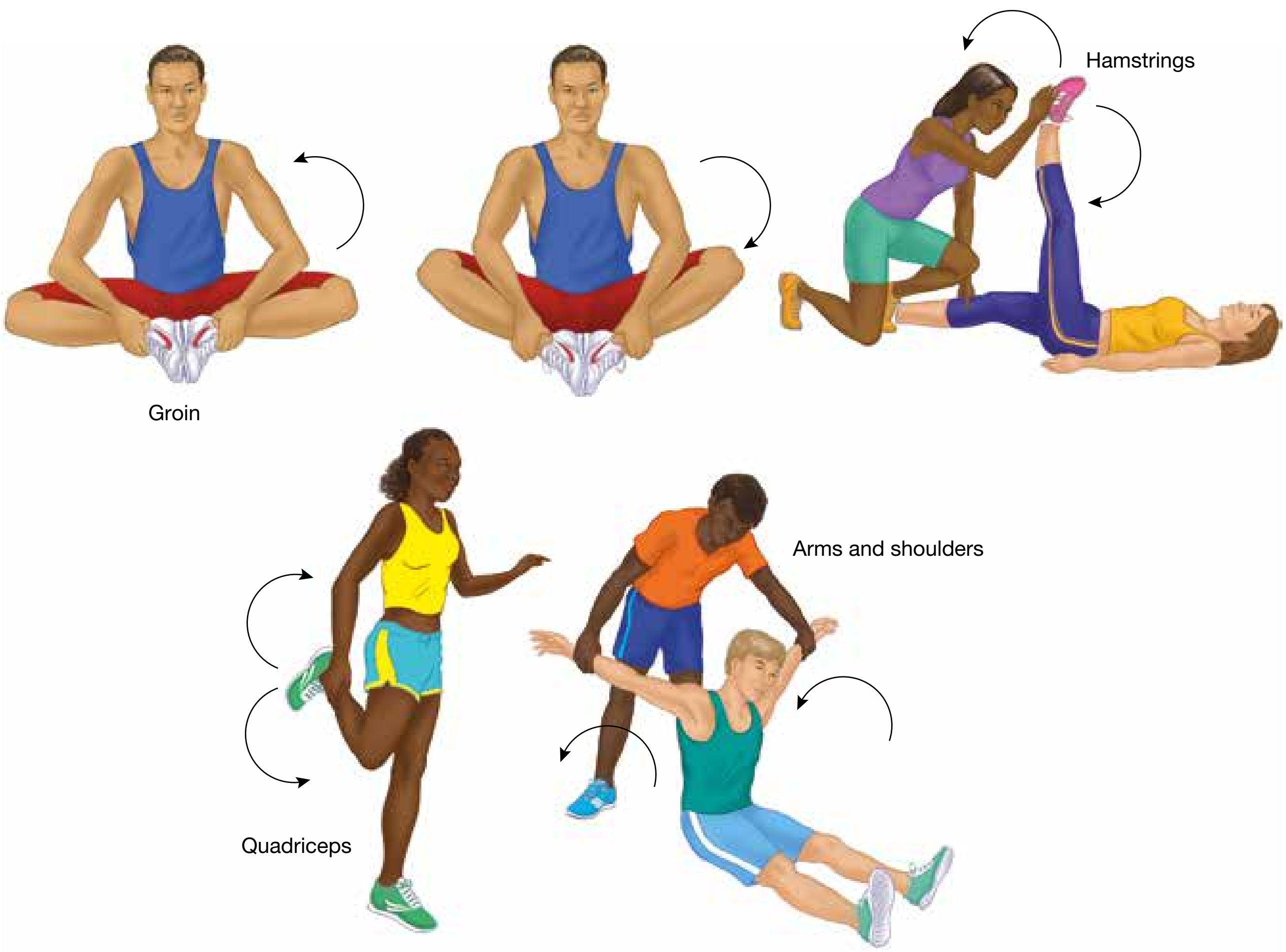


FIGURE 11.28 PNF stretches — individual and partnered

Dynamic stretching

Dynamic stretching consists of slow, controlled movements through the full range of motion. For example, controlled leg and arm swings that take you gently to the limits of your range of motion.

Where the event requires a dynamic movement, then it is appropriate and perhaps necessary to conduct dynamic stretching exercises. Start with the movement at half speed for a couple of repetitions and then gradually work up to full speed.

Dynamic stretching and mobility exercises could form part of the warm-up in a training session. The dynamic exercises you use should be similar to or the same as the movements you would experience in your sport or event. Current research suggests that the use of dynamic stretches is more appropriate than static ones for the warm-up.

Basic examples of dynamic stretching are seen when players warm-up before a game. Their hitting, kicking, running and throwing is taking various and relevant body parts through the ranges of motion needed in the game.

Ballistic stretching

Ballistic stretching is a controversial, higher risk type of stretching because it involves moving through the range of motion using the momentum created rather than the muscle contraction. Only specifically conditioned athletes such as experienced dancers, high-level team players and gymnasts are recommended to use ballistic stretching. Ballistic stretching uses the momentum of a moving body or a limb in an attempt to force it beyond its normal range of motion.

A common example of ballistic stretching is bouncing down repeatedly to touch your toes. This type of stretching does not allow your muscles to adjust to, and relax in, the stretched position. It may instead cause them to tighten up by repeatedly activating the stretch reflex. However, if there are ballistic movements in the particular sport or activity that a person is training for, then it may be appropriate and even necessary to conduct ballistic stretching exercises as part of preparation.

The stretch reflex (also called the myotatic stretch reflex) attempts to resist the dynamic stretch's sudden change in muscle length by calling on the stretched muscle to contract. It is the body's attempt to prevent the suddenly stretched muscle from tearing. The more sudden the change in muscle length, the stronger the muscle's answering contractions will be.

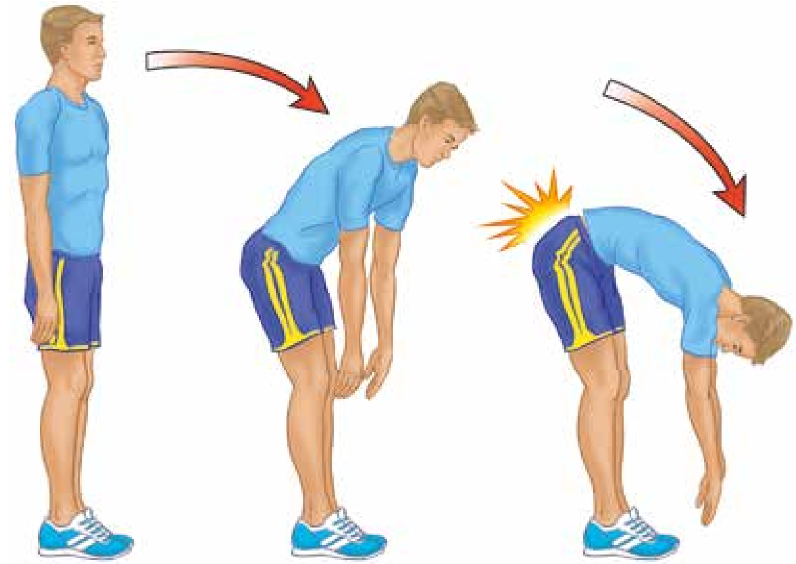


FIGURE 11.29 Inexperienced performance of ballistic stretching can result in severe lower back problems.

Myofascial release

Myofascial release is a technique that is used to apply pressure to tight areas of the **fascia** that underlies the muscle. This technique aims to relieve tension and improve the flexibility of the targeted joint. The most common method of myofascial release involves the use of a foam roller and the combination of gravity and body weight controls the pressure on the particular area. The technique reduces soft tissue tension, restoring normal muscle length and therefore providing an overall improvement of the muscle function.

Fascia is a densely woven connective tissue that covers and bonds internal sections of the body.

FIGURE 11.30 Myofascial release of the iliotibial band using a foam roller

studyon

Unit 4
AOS 2
Topic 3
Concept 8

Flexibility training
Summary screen and practice questions

Plyometrics

Plyometrics is an excellent way for conditioned athletes to increase and develop their force production, velocity and power output.

It is also known as depth jumping or rebounding, in which an eccentric contraction is immediately followed by a concentric contraction.

The eccentric stretching of the muscle prior to the rapid concentric contraction allows for a more forceful contraction, recruiting more motor units than if no pre-stretch occurred. During the eccentric phase, **potential energy** is stored in the elasticity of the muscle and then released at the start of the concentric phase of contraction.

Think of an elastic band: the elastic proteins of a muscle fibre act in a similar manner as an elastic band when it is stretched and released. There are three phases of plyometrics:

1. The eccentric pre-stretch phase — during this phase, the muscles are stretched rapidly, which activates the **stretch reflex** causing a powerful concentric contraction to protect the muscle from overstretching.
2. The amortisation phase — the very short phase between the eccentric and concentric contraction.
3. The concentric shortening phase — during this phase, the muscles contract forcefully with assistance from the stored potential energy (elastic energy) gained from the eccentric and amortisation phases.

Plyometric actions occur in many sporting activities. Leg muscles in each running stride are actually performing plyometrics as each leg lands on the running surface.

Plyometrics involves the use of the stretch-shortening muscle cycle to produce powerful and explosive movements.

Potential energy is the capacity of the muscle to do work based upon its position. This happens in the eccentric phase of contraction. The greater the stretch, the greater the capacity of the concentric muscle contraction.

The **stretch reflex** occurs when an impulse is immediately sent to the spinal cord for a muscle to contract when it is stretched in order to prevent overstretching.

A baseball player, must first swing the bat back, stretching the muscle, before contracting the muscle to hit the ball. If the player stops in the back swing or simply swings at the ball without a back swing, they either lose power or do not even generate it.

Because plyometric exercises can create so much muscular power, there is understandable concern about their safety and appropriateness. They place considerable pressures on both the body and joints and are not recommended for persons of poor or average fitness abilities. Table 11.10 outlines the different stress levels and recovery times for various plyometric exercises.

An athlete's number of training years is important. Those with little foundation training should start with low-stress or low-impact activities, which have low demand on the nervous system and low motor complexity.

TABLE 11.10 The impact of varying intensity plyometric training programs

Rating	Recovery time	Example
1 = very low stress	Recovery very rapid	Jump rope or ankle bounces or other similar low-amplitude jumps
2 = low stress	Recovery rapid; one day required	Tuck jump or other similar activity in place of jumps
3 = moderate stress	One to two days required	Stair jumps or other similar short jumps
4 = high stress	Recovery slow; two days required	Hops or bounds for distance or other similar long jumps
5 = very high stress	Recovery very slow; three days required Highest nervous system demand	Depth jumps or other similar shock-type jumps

Source: Gambetta V 1998, 'Plyometrics: myths and misconceptions', *Sport Coach*, summer, p. 7.

Plyometric training guidelines

1. An adequate warm-up must be performed, consisting of general aerobic activities progressively increasing in intensity and including dynamic flexibility.
2. The development of a good strength base should precede plyometric training.
3. Begin with low to moderate level plyometric exercises and progress to higher levels when sufficient strength and power have been developed.
3. Plyometric exercises should be performed in a controlled manner using good postural technique.
4. Footwear that has good ankle and foot support is recommended.
5. Plyometric exercises should be undertaken on shock-absorbing surfaces.
6. Plyometric exercises should be undertaken early in a training session so that the exercises aren't being performed when the person is fatigued.
7. There should be at least 48 hours recovery between each plyometric session and a maximum of two sessions per week for beginners.

studyon

Unit 4 | AOS 2 | Topic 3 | Concept 9

Plyometrics
Summary screen and practice questions

Low-impact vs high-impact plyometric exercises

Examples of low-stress or low-impact plyometric drills are:

- skipping with and without a rope
- doing low hops, steps and jumps
- throwing light objects such as cricket balls and frisbees
- throwing a light (2.5 kilogram) medicine ball
- jumping 360 degrees.

The height for low-impact exercises is 25 centimetres or less, and the beginner should start with repetitions of 10 × 1–5 sets. The appropriate rest and recovery time between sets is 3 minutes.

Examples of high-stress or high-impact plyometric drills are:

- bounding with alternate legs
- bounding with both legs
- speed hopping on a single leg

- doing clap pushups
- jumping over, on and from benches that are 35 centimetres high
- triple jumping
- throwing a heavy medicine ball (above 4 kilograms).

The height for high-impact exercises is 35 centimetres and above, and the athlete should perform repetitions of 10–25 × 1–5 sets. The appropriate rest and recovery time between sets is 10 minutes.

eBook*plus*

Interactivity
Plyometric exercises
Searchlight ID: int-6825

FIGURE 11.31 Plyometric excercises

TEST your understanding

1. Define flexibility.
2. What must be done before any form of flexibility training is carried out?
3. Define static stretching.
4. Define PNF stretching. What does PNF stand for?
5. List some examples of dynamic stretching movements seen before a sport of a choice.
6. List some activities where ballistic stretching would be expected and acceptable.
7. Explain the stretch reflex and how it applies to plyometrics.
8. Discuss what is meant by the term *myofascial release*.

APPLY your understanding

9. Explain the differences between static and slow active stretching.
10. Describe some PNF stretches that would increase the flexibility of the following muscle groups:
    (a) pectorals
    (b) hamstrings
    (c) quadriceps
    (d) triceps
    (e) calves.
11. Discuss the importance of three recommended guidelines when undertaking plyometric training.
12. List and justify five plyometric exercises for a sport of your choice.
13. **Practical activity: flexibility**
    (a) Carefully complete a flexibility test, prior to and after an aerobic warm-up.
    (b) What were the results?
    (c) Explain the reasons for the results obtained.
    (d) Design and implement a flexibility session using static and PNF stretches.
14. **Practical activity: plyometric training session**
    (a) Design a safe and effective training session for your class to undertake. Your training session template needs to include an appropriate warm-up, four plyometric exercises that are suitable for your class group (2 upper body and 2 lower body) to perform and an adequate cool-down.
    (b) Provide a justification of your selection of plyometric activities.

EXAM practice

15. **ACHPER Trial Exam 2011, question 11**
    Sally Pearson is a track and field athlete who competed in three events at the 2010 Delhi Commonwealth Games: the 100 metre hurdles, 100 metre sprint, and she was a late inclusion in the 4 x 400 metre relay. Sally won gold in the 100 metre hurdles event. Plyometrics is a training method that Sally regularly uses to improve her skill in the hurdle event.
    (a) Describe one plyometrics exercise that Pearson may use to improve her performance in the 100 metre hurdles. **1 mark**
    (b) Plyometrics training is used no more than two to three times per week. Outline a likely reason as to why plyometrics would be utilised less frequently. **2 marks**
    (c) Other than plyometrics training, identify one suitable training method Pearson could use when training for the 100 metre hurdles. **1 mark**
    (d) Pearson was controversially included in the team for the final of the women's 4 x 400 metre relay, an event she had not trained for, and collapsed after running her leg of the race. The Australian team finished in fifth place. Outline a training method that Pearson might have undertaken if she was training for the 400 metre event that would be different to her hurdles training. **2 marks**
    (e) Outline two training principles a coach should ensure his athletes are aware of during their 'off season'.
    Training principle 1 ___________________________
    Training principle 2 ___________________________
    2 marks
16. **ACHPER Trial Exam 2005, question 13**
    The coach of the Australian rugby team devotes approximately 30–45 minutes of each training session to 'flexibility work'.
    (a) Explain how slow active stretching potentially delivers greater increases to flexibility than static stretching does. **2 marks**
    (b) PNF stretching includes isometric muscle contractions. Briefly discuss how isometric contractions are different from isokinetic contractions. **2 marks**

11.8 Circuit and fartlek training

KEY CONCEPT Both circuit training and fartlek training can be designed to train the aerobic and anaerobic energy systems.

Circuit training

Circuit training involves working at a variety of activity stations in sequence, training a number of fitness components at once.

Circuit training can have 5 to 15 stations that focus on specific components of fitness from the selected activity. An athlete can plan to train any of the fitness components in a circuit training session. Circuit training is a very versatile training method as it can be planned with minimal use of equipment, be performed indoors or outdoors and target a variety of aspects that are relevant to the activity or sport for which a person is training.

In circuit training the athlete completes one set of exercises and then moves on to the next. When the athlete has completed each exercise station once, they have completed one lap of the circuit.

Exercise stations should be arranged so that body parts are cycled or distributed. One body part should not be repeated twice in a row. For example, a leg station such as stepups could be followed by situps. This allows for specific muscle group recovery to take place.

Circuits also allow for specific skill drills to be included as exercise stations. In this way both the physical and skill requirements of the sport are being specifically trained at the one time. For example, a field-hockey player could include push passes against a rebound wall or to a team mate as an exercise station.

The circuit can also be designed to focus on general aerobic fitness. This type of training allows a large number of participants to work in a confined area with minimal equipment, so it is inexpensive and efficient. Each training session should be designed to reflect the energy systems, muscle groups, fitness components and fatiguing factors of the game or activity.

Types of circuit training

Fixed time

- Each person completes as many repetitions of an exercise as they can at each station in an allocated time (30–60 seconds).
- Work-to-rest ratios are designed in relation to the requirements of the activity or sport.
- Easy to administer to large groups as everyone moves from station to station at the same time.

Fixed load

- Each person completes a predetermined number of repetitions at each station.
- Individual strengths and weaknesses are not taken into account.
- Each person will complete each station at different times so quite impractical for large groups.

Individual load

- Each person will have undertaken a pre-test to determine the maximum number of repetitions that can be performed in 60 seconds at each station and then work at a percentage of these repetitions.
- Each person will be completing different repetitions so it is likely that some wait time will be experienced between stations.
- Individualised to each person's strengths and weaknesses.

Overload implementation in circuit training can be done by:
- increasing the repetitions
- increasing the number of circuits
- increasing the weights
- changing the length and nature of their recovery periods.

For fixed interval circuits the athlete could also lengthen the work period.

An example of an individual circuit record sheet working at 50 per cent of 1-minute repetitions is shown in table 11.11.

TABLE 11.11 Example of an individual circuit record sheet

Stations	Score for 1 minute	Half score	Time and date	Time and date	Time and date
Skipping	50	25			
Situps	60	30			
Pushups	50	25			
Agility run	6	3			
Basketball throw	20	10			
Stepups	50	25			
Medicine ball throw	20	10			
Ladder climb	6	3			
Shuttle run	10	5			
Initial time (three circuits)		21 minutes			
Target time		14 minutes			

There are any number of potential circuit training exercises that can be used in a particular training session; however, the principle of specificity means that the exercises selected should train particular aspects required in the sport or activity that the person is training for.

Fartlek training

Fartlek training works both the aerobic and anaerobic energy systems by interspersing continuous low/medium intensity efforts with high intensity efforts.

Fartlek training, a variation of continuous training, involves changes of intensity throughout the training sessions. These changes of intensity can be simply an increase in pace or running up a hill, and involve the addition of the anaerobic glycolysis energy system to help produce the increased amount of ATP needed for the increased intensity. As a result, it stimulates the interplay between the aerobic and anaerobic energy systems used in individual sports (such as sprinting to gain a better position within the field of runners), and in team games (when involved in a sprint to the ball, followed by jogging to a new position on the field).

Team game players need to build into a fartlek session all the variations of effort and directions of effort that are evident in their activity analysis.

Individuals or groups at varying fitness levels can undertake fartlek training, which can be completed in a relatively confined space such as an oval or around local streets.

Fartlek is mainly used by runners, but the concept is equally useful for swimming, cycling, rowing and skiing basically any sport where a combination of aerobic and anaerobic energy is important. Ways to overload using fartlek training include:

- increasing the frequency of the high intensity efforts
- increasing the duration of the high intensity efforts
- increasing the overall distance covered
- including more hills and variety in terrain
- shortening the time to cover the same distance.

FIGURE 11.32 Elite track athletics runners use various forms of fartlek training to optimise their tactical surges during races.

TEST your understanding

1 Define circuit training.
2 Explain the major benefit of circuit training.
3 Name the three methods of designing a circuit training session.
4 Define fartlek training.
5 Identify which sports are best suited to fartlek training.

APPLY your understanding

6 Discuss which of the five main principles of training is most important when designing a circuit training program. Why?
7 List five exercises that would be appropriate to be included in a circuit training session designed for each of these sports:
(a) netball
(b) soccer
(c) Australian Rules football
(d) water polo
(e) rowing
(f) volleyball.
8 Justify your selection of exercises in question 7.
9 Explain how you could progressively overload a fartlek training program.
10 **Practical activity: design a circuit training program**
Choose one of the following team sports:
- netball
- soccer
- Australian Rules football
- lacrosse
- rugby
- volleyball
- hockey.

(a) Design a circuit that has eight relevant fitness stations.
(b) Have your class complete the circuit in either of the two fixed types of circuit training.
(c) Complete the circuit using both the fixed and individual load methods.

11 **Practical activity: design a fartlek training session**
Design a fartlek training session, for your class group to participate in. Try designing one that uses the space of a basketball court. Be sure to be creative and include different intensities and movements relevant to a sport of your choice. Draw your session as a map in order to explain it to your class group easily.

KEY SKILLS TRAINING PROGRAM PRINCIPLES AND METHODS

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

KEY SKILLS

- Design a training program that demonstrates the correct application of training principles and methods to enhance and/or maintain fitness components
- Evaluate and critique the effectiveness of different training programs

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- Be able to select the most appropriate training methods to train the relevant fitness components for a variety of sports
- Know how to correctly apply each of the training principles to each type of training method
- Be able to identify the aspects of a training program that make it successful
- Know how to use different monitoring strategies to assess the effectiveness of a training program

PRACTICE QUESTION

1 **(adapted from ACHPER Trial Exam 2015, question 12)**

Bobby is an Australian nationally ranked 16-year-old male swimmer in the 400 m freestyle event. His personal best time is 3 minutes 53 seconds. Two training methods that Bobby participates in as part of his training program are long-interval training and intermediate-interval training. With specific reference to lactate tolerance and the lactate inflection point, **justify** the inclusion of each of these training methods in Bobby's training program.

8 marks

SAMPLE RESPONSE

Intermediate-interval training would require Bobby to train with a W:R ratio of 1:3, therefore targets the use of the anaerobic glycolysis energy system, which produces lactic acid as a by-product. Training under these physiological conditions results in the chronic adaptation of improving lactic acid buffering capacity and also improves lactate tolerance, which is the ability to withstand larger amounts of lactic acid in the muscles. This will enable Bobby to increase his ability to work maximum intensity by increasing the capacity of the anaerobic energy systems usage when racing to the wall in the last 100m of the event.

Long-interval training would require Bobby to train with a W:R ratio of 1:1 or less and therefore target the aerobic energy system with a chronic adaptation of increasing mitochondrial size and density. These adaptations increase the lactate inflection point (LIP), which is the highest intensity point where there remains a balance between lactate accumulation and removal or highest steady state exercise intensity. Lactic acid breakdown results in hydrogen ions being produced and when an athlete exercises at an intensity above their lactate inflection point (LIP), fatigue results. The increased mitochondrial size and density allows for the aerobic energy system to meet the demands at higher intensities before the anaerobic glycolysis system is required to increase its contribution and therefore less lactic acid is being produced at a higher intensity. Bobby is able to work at higher intensity for longer when pacing in the middle of the race and produce a faster time overall for his freestyle event.

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:** **Justify** — explain why the option you chose is the **best** option
- **Key terminology:** Long-interval training and medium-interval training — outline the characteristics/components of long- and medium-interval training
  Lactate tolerance and lactate inflection point — explain what is meant by lactate tolerance and lactate inflection point
- **Key concepts:** Inclusion of each of these training methods in Bobby's training program — discuss the physiological benefits that each training method has in relation to improving performance
- **Marking scheme:** *8 marks* — always check marking scheme for the depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

- **1 mark each (2 marks)** for describing long- and medium-interval training and the energy systems that they train
- **1 mark each (2 marks)** for defining lactate tolerance and lactate inflection point
- **1 mark** for explaining how medium-interval training method improves lactate tolerance
- **1 mark** for explaining how long-interval training method improves lactate inflection point
- **1 mark each (2 marks)** for providing examples of how increased lactate tolerance and LIP would benefit Bobby's performance

CHAPTER REVIEW TRAINING PROGRAM PRINCIPLES AND METHODS

CHAPTER SUMMARY

- Training principles refer to the rules or guidelines that ensure the training session is relevant to the initial aim. The five primary training principles are as follows.
  1. Specificity: a replication of the requirements of an activity in the training for that activity.
  2. Intensity: the level of demand of the work rate on the working muscle, usually measured as a percentage of maximum heart rate.
  3. Time: the length of the training program or session.
  4. Frequency: the number of sessions trained per week with appropriate periods of rest.
  5. Progressive overload: the application of increased physical workload in training so the human body can adapt to higher levels of stress or workload.
- Other training principles for the success of a training program include:
  - variety, where the range of different activities, the order of exercises and the venues can all improve player motivation
  - diminishing returns, where the rate and amount of improvement reduce as fitness levels increase
  - detraining, where the loss of fitness increases as the period of time without training becomes greater
  - maintenance, where current levels of fitness can be maintained with less frequency than that required to improve fitness (although the intensity levels must remain the same)
  - individuality, where the rate and amount of improvement varies from one individual to the next
  - overtraining, where there is a long-term decline in performance and physical functioning. The ability of the body to continue to adapt to the training load is compromised when overtraining symptoms occur.
- Training methods are specific activities or groups of activities that cause an improvement in particular fitness components and energy systems.
  - Continuous training: slow-distance activities, such as running, that are designed to improve aerobic fitness.
  - Interval training: periods of work followed by periods of rest and recovery. This method is excellent for team games and individual activities where the interplay and recovery of energy systems are important.
  - Resistance (weight) training: movement of a load by a particular muscle group or groups to improve strength, power endurance or hypertrophy. There are different forms of resistance training.
  - Flexibility training: the stretching of individual muscle groups to allow an increase in the range of motion for the joint. There are different types of flexibility training — PNF, static, slow active, ballistic and myofascial release.
  - Plyometrics: an explosive movement, such as skipping, that results from lengthening then shortening the muscle. It creates an increase in power.
  - Circuit training: a sequence of activities that are specific to the fitness component and energy system requirements of an activity or sport. It allows the athlete to train several fitness components and energy systems at the one time, and can be done by large numbers of people in a confined space.
  - Fartlek training: slow-distance activities, such as cycling, that are interspersed with higher-intensity efforts, such as sprints, and three-quarter pace efforts. This method is designed to improve the aerobic system and, to a lesser extent, the anaerobic system. It is an excellent method for activities such as team sports where the interplay between energy systems is important.

eBook*plus*

Interactivity
Training program principles and methods quiz
Searchlight ID: int-6826

studyon

Sit VCAA exam

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 **(ACHPER Trial Exam 2015, question 12)**

Identify the correct training prescription to develop the specified fitness component.

Fitness component	Load (% of 1 repetition maximum)	Repetitions	Sets
(A) Strength	40	4	3
(B) Power	40	4	3
(C) Endurance	80	15	3
(D) Hypertrophy	40	8	3

2 **(ACHPER Trial Exam 2014, question 6)**

Georgina has been a member of the school's cross-country team, which has been training three times per week, for the past four months. During a Physical Education class, Georgina reached level 7.2 in the 20-metre shuttle run test while her friend, Paige, reached level 6.1. Paige has never been involved in running and was invited to participate in cross-country training. Three months later, they did a post-test where Georgina reached 7.5, but she was surprised that Paige reached 7.8 after only three months of training.

The training principle that best explains this situation is

(A) reversibility.
(B) detraining.
(C) law of diminishing returns.
(D) overload.

3 **(ACHPER Trial Exam 2013, question 15)**

The following table displays an example of a training day for a 1500-metre runner.

Sets	Repetitions × Distance	Work period	Rest period
1	5 × 400 metres	80 seconds	Slow jog 90 seconds
2	7 × 600 metres	130 seconds	Slow jog 120 seconds

The training method utilised is

(A) intermediate interval.
(B) long interval.
(C) fartlek.
(D) continuous.

4 **(ACHPER Trial Exam 2012, question 14)**

Which of the following is **not** a correct way of overloading an interval training session?

(A) Increasing the number of repetitions
(B) Increasing the number of sets
(C) Increasing the recovery time
(D) Increasing the intensity of the work

5 **(ACHPER Trial Exam 2011, question 12)**

An elite male soccer player is trying to develop their lactate tolerance. They perform 6 × 100 metre sprints in 14 seconds. Which of the following recovery times would be the most appropriate after each repetition?

(A) 14 seconds
(B) 42 seconds
(C) 7 seconds
(D) 70 seconds

6 Myofacial release is a technique that

(A) is used to apply pressure to tight areas of the fascia.
(B) aims to relieve tension and improve the flexibility of the targeted joint.
(C) most commonly performed with the use of a foam roller.
(D) All of the above

7 The most important training principle in terms of fitness gains is
(A) reversibility.
(B) intensity.
(C) time.
(D) type.

8 Chronic fatigue lack of motivation towards a training program could be attributed to
(A) detraining.
(B) overtraining.
(C) variety.
(D) maintenance.

9 As athletes approach their fitness potential, the rate of fitness improvement decreases. This is
(A) caused by residual fatigue from previous training sessions.
(B) known as the law of diminishing returns.
(C) the consequence of an inappropriate training program.
(D) the result of too much variety in the training program.

10 **(ACHPER Trial Exam 2010, question 13)**
The following table shows four different resistance training programs.

	% Repetition maximum	Repetition range	Sets	Repetition speed	Rest between sets
Program A	40–60	10–15	3	Slow to moderate	1 minute
Program B	80	15–25	3	Slow to moderate	2–3 minutes
Program C	40–60	15–25	3	As fast as possible	1 minute
Program D	20	10–15	3	Slow to moderate	1 minute

The program that is best suited to improving muscular endurance for a beginner is
(A) Program A.
(B) Program B.
(C) Program C.
(D) Program D.

TRIAL EXAM QUESTIONS

Question 1 **(ACHPER Trial Exam 2014, question 4)**

Melissa is a Centre player for her secondary school netball team. The following data about Melissa were collected by her coach from the first quarter of a netball match. The match consisted of 4 × 10 minute quarters.

Work to Rest Ratio

Work/Rest Periods	Time (seconds)
Shortest work period	0.61
Longest work period	11.09
Shortest rest period	1.37
Longest rest period	31.21

	Work (seconds)	Rest (seconds)
Total	186.99	444.6
	1	2.378
Ratio (approx.)	1	2

Skills and their Frequency

Skill	Frequency
Chest Pass	9
Overhead pass	15
Catch	18
Jump	13
Guard	8
Defend	13
Leap Forwards	15
Leap Sideways	7
Change of direction	55
Centre pass	5

Locomotor Patterns

Locomotion	Intensity	0–5 metres	6–10 metres	11–15 metres	16+ metres	Total (count)	Distance Metres	% Total	Average Metres
Walk	Low	12	7	3	2	24	111	26	4.6
Jog	Low–Medium	12	7	1	1	21	147	35	7.0
Sprint	High	11	9	1	0	21	127	30	4.8
Shuffle	Very High	18	4	0	0	22	36	9	1.6
Totals		53	27	5	3		421	100%	

a. Data was collected by the coach to ensure accurate application of which training principle? **1 mark**

b. Using the data provided, explain why a coach may consider including plyometrics training into a program for Melissa. **2 marks**

c. Describe or draw **one** specific plyometrics exercise that the coach could employ as part of Melissa's training program. **1 mark**

d. Using the data provided, complete the table below to provide a specific interval training session that the coach could use to improve Melissa's fitness to play as a netball Centre.

Sets	Repetitions	Time for each repetition	Recovery time between repetitions	Recovery time between sets
3	10	5 seconds		

2 marks

e. With reference to data, justify your choice of:

i. recovery time between repetitions

ii. recovery time between sets. **4 marks**

f. Discuss **one** reason why the frequency of the plyometrics sessions may differ from the frequency of the interval sessions that Melissa undertakes each week. **2 marks**

Question 2 **(adapted from ACHPER Trial Exam 2013, question 3)**

At the London 2012 Olympic Games, Sally Pearson won the 100 m hurdles in a time of 12.35 seconds, while Yuliya Zaripova won the women's 3000 m steeplechase in a time of 9 minutes and 6.72 seconds.

Both athletes would employ different training methods. Outline one training method likely to be undertaken by each athlete and justify your selection for each. **4 marks**

Question 3 **(ACHPER Trial Exam 2013, question 5)**

Georgina is a 35-year-old female who has decided to enter the Women's 5 km Fun Run in December. She attends gym regularly with a personal trainer who has advised her to begin the following continuous running training program 12 weeks before the event.

Week	Heart Rate Training zone	Session length	Sessions per week
1–3	130–135	30 minutes	3
4–6	135–145	30 minutes	3
7–9	145–150	35 minutes	3
10–12	150–155	40 minutes	4

a. Referring to the information above, outline two training principles that have been correctly applied in this training program. **2 marks**

b. Referring to the information above, identify one training principle that has been applied incorrectly and outline how this principle should be correctly applied. **2 marks**

INQUIRY QUESTION
What would be the chronic adaptations that would allow Jared Tallent to perform at his best for the 50 km walk?

CHAPTER

12 Chronic adaptations to training

Chronic adaptations are the long-term physiological changes that occur as a result of participating in a training program. The types of adaptations that lead to improved performance are dependent on the specific type of training that is undertaken.

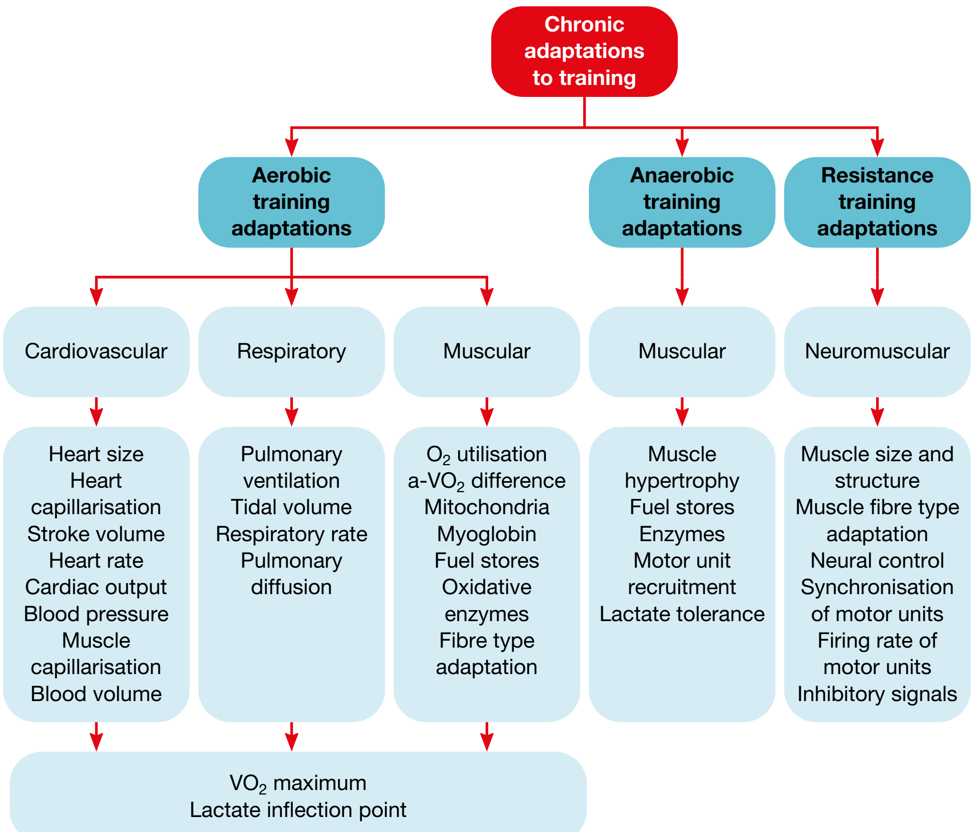
KEY KNOWLEDGE

- Chronic adaptations of the cardiovascular, respiratory and muscular systems to aerobic, anaerobic and resistance training

KEY SKILL

- Explain how the cardiovascular, respiratory and muscular systems' chronic adaptations to training lead to improved performance

CHAPTER PREVIEW



12.1 Chronic training adaptations

KEY CONCEPT Chronic adaptations of the cardiovascular, respiratory and muscular systems occur as a result of long-term participation in a training program. These responses depend on the type, frequency, duration/time and intensity of the training undertaken.

Chronic adaptations are the body's long-term responses of the cardiovascular, respiratory and muscular systems that develop over a period of time when training is repeated regularly.

Exercise or training undertaken regularly over an extended period of time (usually at least three times per week for a minimum of 6–8 weeks) leads to the development of long-term or **chronic adaptations** to training. Adaptations occur when the body responds by making specific changes that allow it to better cope with the demands placed upon it. Some of these adaptations are evident when an individual is at rest and others can be measured when the body is engaged in exercise or activity. Some adaptations are apparent when the individual is working at submaximal exercise intensities, whereas others are evident when the individual is engaged in maximal exercise. Once achieved, these adaptations are retained unless training ceases. Upon cessation, the body will gradually revert to its pre-training condition. This process is referred to as reversibility or detraining (see chapter 11).

Chronic adaptations to training vary greatly and are dependent upon:

- the *type and method* of training undertaken — whether it be aerobic, anaerobic or resistance training. Chronic training responses are very specific to the type of training performed. This is known as the SAID principle: 'Specific Adaptation to Imposed Demands'.
- the *frequency, duration/time and intensity* of the training undertaken — the greater the frequency, duration and intensity of training, the more pronounced the adaptations. However, factors such as overtraining and the principle of diminishing returns (see chapter 11) need to be considered in relation to this.
- the *individual's capacities and hereditary factors* (genetic make-up or potential), such as VO_2 max. and muscle fibre-type distribution (fast-twitch as opposed to slow-twitch fibres). According to some research, 97 per cent of fibre types are genetically determined.

Chronic training adaptations may occur at both the system level, particularly the cardiovascular and respiratory systems, and/or within the neuromuscular system.

The combined effect of all chronic adaptations is known as the training effect. Correct application of training methods and principles (see chapter 11), the use of fitness testing (see chapter 9) and monitoring training (see chapter 10) allow individuals to tailor, measure and monitor their progress to bring about the chronic adaptations described in this chapter.

Chronic adaptations to aerobic training

The minimum period for chronic adaptations to occur with aerobic (endurance) training is 6 weeks, although they are more evident after 12 weeks. Chronic cardiovascular and respiratory system adaptations to aerobic training are primarily designed to bring about the more efficient delivery of larger quantities of oxygen to working muscles. Specifically, the cardiovascular system increases blood flow and delivery of oxygen to the muscles, and the respiratory system increases the amount of oxygen available.

Aerobic training effects are developed through continuous, fartlek, long-interval and also high intensity-interval training. They may also be developed through circuit and resistance training if the exercises are designed specifically for aerobic and local muscular endurance benefits.

Chronic aerobic adaptations result in an increased ability of the athlete to produce ATP aerobically or an improved **economy**.

Economy describes the quantity of oxygen (mL/kg/min) required to generate movement at any given speed or intensity.

Oxygen delivery effectiveness is the most significant factor in aerobic exercise. O_2 delivery depends on:

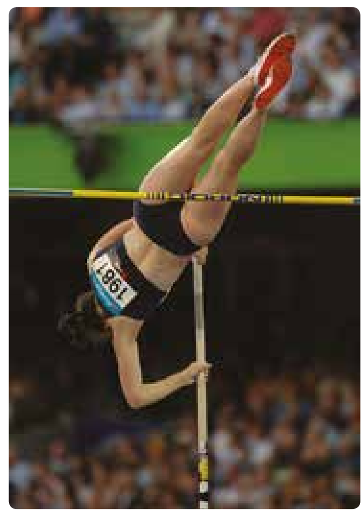
- the ability of the *lungs* to ventilate large volumes of O_2
- the ability of the *blood* to exchange O_2 at the lungs (transported by haemoglobin in red blood cells)
- the ability of the *heart* to pump large volumes of blood to the muscles ($Q = HR \times SV$)
- the ability of the *muscles* to extract O_2 from blood (role of myoglobin)
- the ability of the *muscles* to use O_2 to breakdown fuels to produce ATP (occurs in the mitochondria and requires enzymes (oxidative, glycolytic and lipolytic)).

Chronic adaptations to anaerobic training

The minimum period for chronic adaptations to occur with anaerobic training is 6 weeks. The greatest adaptations occur in the muscular system; however, changes also occur in the cardiovascular system. Adaptations to anaerobic training are designed to bring about increased muscle size (hypertrophy), enabling greater force production, power output, strength and speed. Further adaptations at the muscle tissue level improve anaerobic capacity and tolerance to metabolic by-products.

Anaerobic training effects are developed through short and intermediate interval training, plyometric training and circuit training (if designed with anaerobic-based exercises). Anaerobic adaptations will also be achieved by undertaking strength and power type resistance training.

Muscular **hypertrophy** is when there is an increase in the cross-sectional area of a muscle: an increase in the muscle size.



Chronic adaptations to resistance training

Many athletes incorporate resistance training into their overall training program. It is an equally important method of training for elite athletes wanting to achieve higher levels of performance as it is for the general population in achieving necessary health benefits. Muscle size is a significant contributor in relation to the strength of a muscle, however in the initial stages of undertaking a resistance training program, increases in strength can be attributed to the neural adaptations that occur. The neural adaptations are thought to have a substantial impact in the first 8 to 10 weeks of undertaking a resistance training program and after about 10 weeks of training, muscular **hypertrophy** becomes the predominant factor contributing to increased strength.

The specific neural adaptations that increase the strength and force production of a muscle are not fully understood, however there are some general factors that are thought to contribute and these are discussed later in this chapter.

FIGURE 12.1 Each of these athletes will develop chronic adaptations specific to their training programs.

TEST your understanding

1 Define the term *chronic adaptation*.
2 Identify and discuss the three main factors that affect chronic adaptations to training.
3 Name the training methods used that develop:
(a) chronic aerobic adaptations
(b) chronic anaerobic adaptations.
4 Outline the main factor that explains strength improvements in the first few weeks of undertaking a resistance training program.

APPLY your understanding

5 Select one of the athletes depicted in figure 12.1.
(a) Explain what type of training method would be most suitable for their sport.
(b) Suggest the physiological adaptations that would be needed for them to be able to perform at the highest level in their particular sport.

12.2 Chronic adaptations to aerobic training: cardiovascular

KEY CONCEPT There are many cardiovascular adaptations (responsible for transporting oxygenated blood) that occur as a result of aerobic training.

Increased left ventricle size and volume

Sustained aerobic training results in the enlargement of the heart muscle itself. This enlargement is referred to as **cardiac hypertrophy**. In endurance athletes, an increase in the size, and therefore volume, of the ventricular chambers, particularly the left ventricle, occurs (see figure 12.2(a) and (b)). This in turn significantly increases stroke volume and cardiac output at maximal intensities, allowing a greater volume of blood to be ejected from the heart, thus providing more oxygen for the athlete to use.

Cardiac hypertrophy is an enlargement of the heart muscle as a result of training.

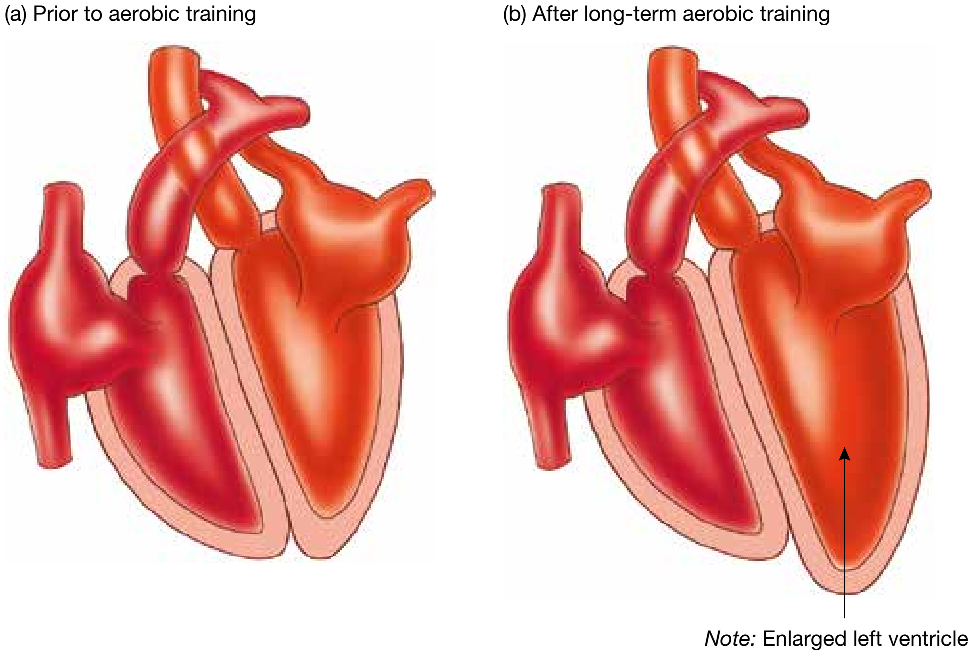


FIGURE 12.2 Effects of aerobic training on cardiac hypertrophy following intense, sustained aerobic training. The size of the ventricular cavities, particularly the left ventricle, increases.

Increased capillarisation of the heart muscle

Cardiac hypertrophy also leads to an increase in the **capillarisation** of the heart muscle itself. The increased supply of blood and oxygen allows the heart to beat more strongly and efficiently during both exercise and rest.

Capillarisation is an increase in the capillary density and blood flow to skeletal or cardiac muscle as a result of aerobic training.

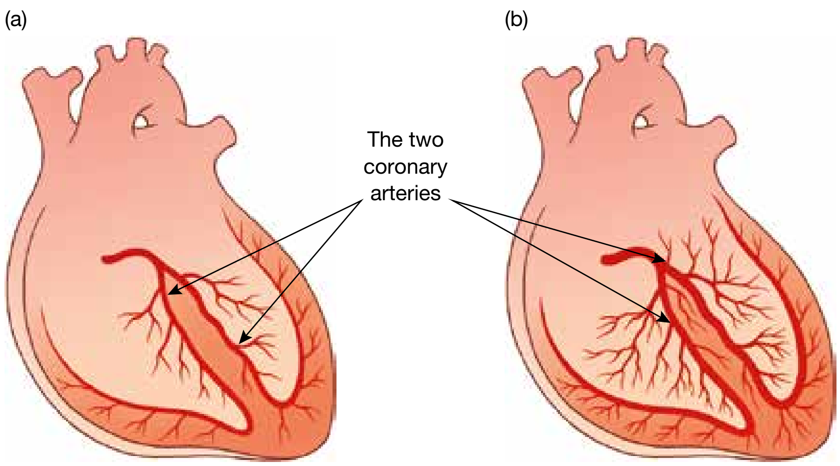


FIGURE 12.3 Capillarisation (blood supply) to the heart before (a) and after (b) a long-term aerobic training program

Increased stroke volume of the heart

Stroke volume is the amount of blood ejected from the left ventricle with each beat (contraction) of the heart.

The increased hypertrophy (capacity of the left ventricle) of the heart, reduced systemic peripheral resistance, a greater blood volume (plasma volume expansion), increased venous return and an increased ability of the ventricle to stretch are all factors that contribute to a significant increase in the heart's **stroke volume** following aerobic training. Stroke volume is greater at rest, during submaximal exercise and during maximal workloads for a trained athlete compared with an untrained person. For example, the average stroke volume at rest for an untrained male is about 70–80 millilitres per beat, whereas trained male endurance athletes may have stroke volumes at rest of 100 or more millilitres per beat. During maximal exercise, these values may increase to about 110 millilitres per beat for an untrained person, and 130 millilitres per beat for a trained athlete (see figure 12.4).

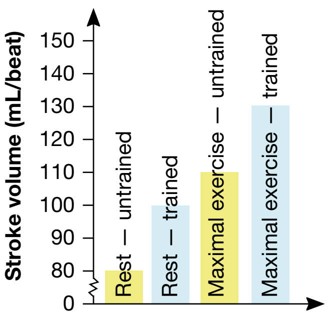


FIGURE 12.4 Stroke volume in response to aerobic training for males. Stroke volume is greater for trained endurance athletes at rest and at all exercise intensities. (*Note:* Only maximal intensities shown here.)

Elite endurance athletes may have values as high as 190 millilitres per beat. Trained and untrained females have lower stroke volumes than their male counterparts under all exercise conditions, mainly due to their smaller heart size.

As greater stroke volume allows more oxygen to be delivered to the working muscles, this improves the athlete's ability to use more oxygen and thus improves their ability to resynthesise ATP aerobically. This results in the athlete being able to work at higher intensities for longer, with fewer fatiguing factors, inevitably producing an improved overall performance.

Decreased resting and submaximal heart rate and faster recovery heart rate

An athlete's heart rate is a good indicator of their aerobic fitness. Aerobic training has a significant effect on an athlete's resting and submaximal heart rate and also how quickly their heart rate returns to pre-exercise levels during recovery. The effect that aerobic training has on an athlete's maximal heart rate is minimal, as this is largely affected by age and genetics.

Decreased resting heart rate

Cardiac output ($\dot{Q}$) is the amount of blood ejected from the left ventricle of the heart per minute. It is the product of stroke volume (SV) multiplied by heart rate (HR), $\dot{Q}$ = SV × HR.

The amount of oxygen required by an individual while at rest does not change as a result of their training status. At rest, it takes about 5 litres of blood per minute (**cardiac output**) to circulate around the body in order to supply the required amount of oxygen to the body cells (whether the individual is trained or untrained). Cardiac output ($\dot{Q}$) is equal to stroke volume (SV) multiplied by heart rate (HR):

$$\dot{Q} = SV \times HR$$

However, if an individual has developed a greater stroke volume, the heart does not have to beat as frequently to supply the required blood flow (and oxygen); the heart is more efficient. For example, before training:

$$\dot{Q} = SV \times HR$$
$$5 \text{ L/min} = 70 \text{ mL/beat} \times 71 \text{ beats/min}$$

After training:

$$\dot{Q} = SV \times HR$$
$$5 \text{ L/min} = 100 \text{ mL/beat} \times 50 \text{ beats/min}$$

Resting heart rate is the number of heart beats per minute while the body is at rest.

It is for this reason that the **resting heart rate** is a useful indicator of aerobic fitness. Generally, the lower the resting heart rate, the greater the individual's level of aerobic fitness. Resting heart rate may be as low as 35 beats per minute for elite endurance athletes, such as marathon runners, triathletes, road cyclists and distance swimmers, compared with the average resting heart rate of around 70 beats per minute for an average adult male.

Decreased heart rate during submaximal workloads

Trained aerobic athletes have lower heart rates at submaximal workloads compared with those of untrained individuals. This is mainly a result of their increased stroke volume, which means that more blood is pumped with each beat of the heart, and therefore the heart does not have to work as hard to supply the required blood flow and oxygen. Put quite simply, the heart works more efficiently.

Regular aerobic training also results in a slower increase in heart rate during exercise and a faster attainment of a steady state during similar exercise intensities as prior to training. Figure 12.5 clearly indicates the training effect on heart-rate response to submaximal workloads.

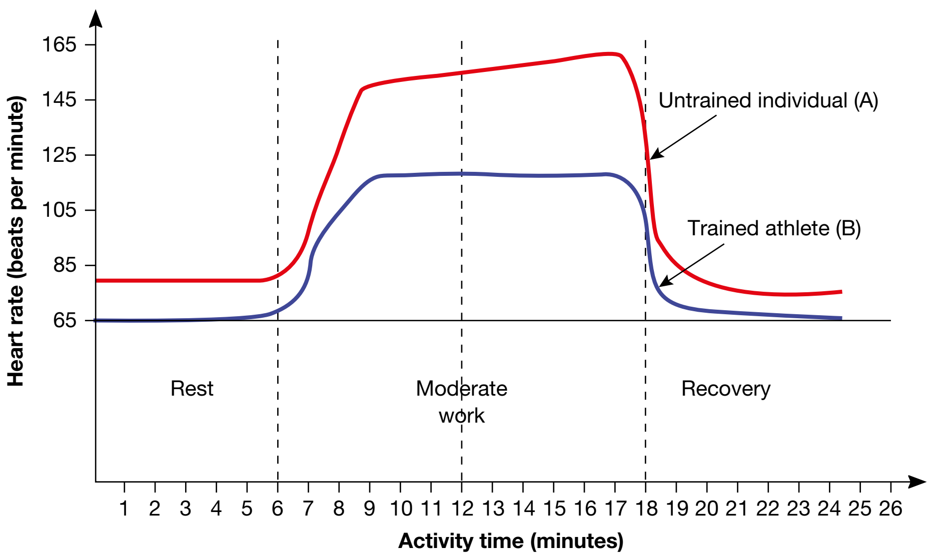


FIGURE 12.5 Heart rate response before, during and after submaximal exercise for a trained athlete and an untrained individual. Note that the heart-rate response of a trained endurance athlete (B) is lower than that of an untrained person (A) at rest and at all exercise intensities. The heart rate of a trained athlete also returns to resting values more quickly upon cessation of exercise compared with an untrained person.

Faster heart rate recovery rates

Faster heart rate recovery rates mean that the heart rate of a trained athlete will return to pre-exercise levels (resting heart rate) in a much shorter time than that of an untrained individual (see figure 12.5). A quicker heart rate recovery occurs after both maximal and submaximal exercise. This is due to the greater efficiency of the cardiovascular system to produce energy aerobically. Recovery heart rate is a very good indicator of an athlete's aerobic fitness. The quicker their heart rate recovers back to resting levels, the more aerobically fit they are.

Increased cardiac output during maximal exercise

While cardiac output remains unchanged at rest and even during submaximal exercise, regardless of training status, it does increase during maximal workloads. During maximal exercise, cardiac output may increase to values of 20–22 litres per minute for untrained males and 15–16 litres per minute for untrained females. In contrast, highly trained athletes have recorded values exceeding 30 litres per minute (see figure 12.6). The increase in cardiac output during maximal exercise is mainly due to the increase in stroke volume because maximum heart rate changes due to aerobic training are minimal.

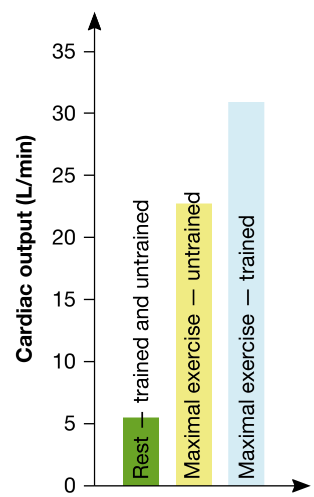


FIGURE 12.6 Cardiac output at rest and at maximal exercise for trained athletes and untrained males

Decreased blood pressure

Hypertension is high blood pressure.

An aerobic training program may lower blood pressure, especially among people who suffer from **hypertension**. Both systolic and diastolic blood pressure levels may decrease during both rest and exercise as a result of training. This helps to reduce resistance to blood flow and reduces strain on the heart, thereby decreasing the risk of heart attack and other cardiovascular conditions.

Increased capillarisation of skeletal muscle

Long-term aerobic training leads to increased capillarisation of skeletal muscle. The average number of capillaries supplying each muscle fibre is 5.9 for trained athletes compared with 4.4 for untrained individuals. Greater capillary supply means increased blood flow, which in turn allows for greater supply of oxygen and nutrients to the muscles, and increased removal of by-products. An increase in the number of capillaries surrounding each muscle fibre is one of the most significant factors that leads to an increase in an athlete's VO_2 maximum. The diffusion of oxygen from the capillaries into the mitochondria is a major factor in maximising the rate of oxygen consumption by the muscles.

Increased blood volume

Haemoglobin is a substance in blood that transports oxygen around the body.

Regular and sustained aerobic training may lead to total blood volume rising by up to 25 per cent (from 5.25 litres to 6.6 litres) for an average adult male. As a result, red blood cells may increase in number and the **haemoglobin** content and oxygen-carrying capacity of the blood may also rise. This allows for a greater amount of oxygen to be delivered to the muscles and used by the athlete.

Blood plasma volume also increases significantly. As seen in figure 12.7, the blood plasma volumes have increased from 2.8 L to 3.3 L. This results in an increased ratio of plasma in the blood cells, which reduces the viscosity of the blood, allowing it to flow smoothly through the blood vessels. The reduction of blood viscosity accompanies an improved blood flow, enhances oxygen delivery to the muscles and also increases the capacity for thermoregulation.

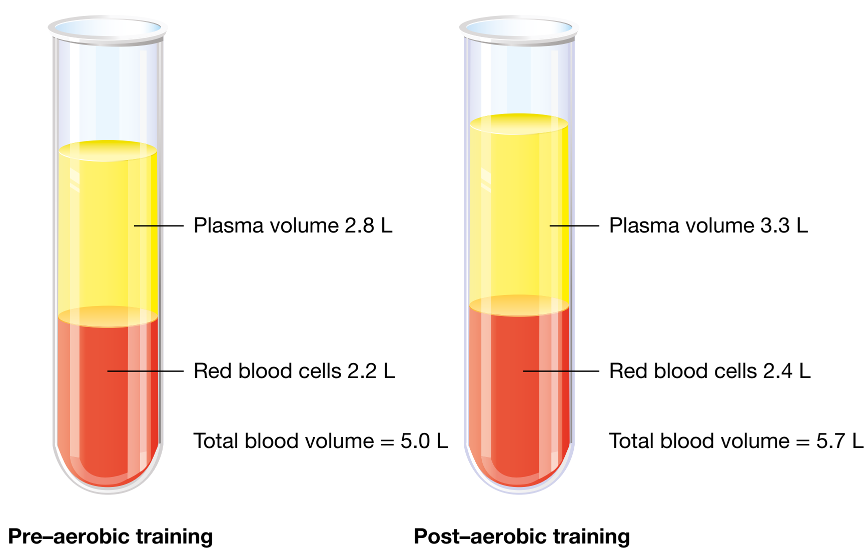


FIGURE 12.7 Aerobic training effects on blood volume

TEST your understanding

1 (a) Identify three types of athlete most likely to benefit from the cardiovascular adaptations as a result of participating in a long-term aerobic training program.
(b) Define cardiac output and outline the parameters that it consists of.

2 Complete the table below by indicating whether the physiological parameter has increased, decreased or remained unchanged as a result of participating in a long-term aerobic training program.

Physiological parameter	At rest	During submaximal exercise	During maximal exercise
Left ventricle size and volume			
Heart rate			
Stroke volume			
Cardiac output			
Blood pressure			
Arteriovenous oxygen difference			
Blood volume			

APPLY your understanding

3 (a) Outline four chronic adaptations that may occur in the cardiovascular system as a result of participating in a long-term aerobic training program.
(b) Clearly explain how these adaptations bring about improved performance.

4 Discuss the relationship between heart rate, stroke volume and cardiac output.

5 Explain why heart rate decreases at rest and during submaximal workloads but not during maximal workloads.

6 Discuss why trained athletes are able to deliver more oxygen to their working muscles as a result of blood volume changes.

7 **Practical activity: heart rate**

Work with a partner of the same gender to complete an exercise of the same intensity and for the same amount of time/duration, e.g. 10-minute ride on a stationary bike set at the same cadence and resistance.

Both wear a heart rate monitor or manually record your resting heart rate, each minute of your exercise heart rate and each minute of your recovery heart rate. Use the **Recording sheet** digital document in your eBookPLUS to record your results.

Quick and simple guidelines to manually recording your heart rate:

(1) Place two fingers on the side of your neck to find your carotid pulse.
(2) Press firmly so that you can feel the pulse but not too forcefully.
(3) Count the number of beats for 10 seconds (count the first beat as 0) and multiply × 6.
(4) This will give you the number of times your heart beats per minute (bpm).

Analyse the results — the resting heart rates, the exercise heart rates and the recovery heart rates. Discuss the differences and provide reasons for them.

EXAM practice

8 **adapted from ACHPER Trial Exam 2012, question 13**

In the 2012 Australian Open Men's Grand Final, Novak Djokovic defeated Rafael Nadal. The following table shows the score, as well as the duration, of each set:

	Set 1	Set 2	Set 3	Set 4	Set 5
Djokovic	5	6	6	6	7
Nadal	7	4	2	7	5
Minutes per set	80	66	45	88	74

In the second set, during one rally, Djokovic ran 59.0 m and Nadal ran 56.9 m. The rally included 15 shots played between the two competitors and a number of direction changes while running to return a shot.

eBook*plus*

Digital document
Recording sheet
Searchlight ID: doc-21031

studyon
Unit 4
AOS 2
Topic 4
Concept 2
Cardiovascular aerobic
Summary screen and practice questions

Djokovic was the world number one in tennis for eighteen months. Considering that he was the best player in the world for this amount of time, it is assumed that his body made a number of chronic adaptations to allow for this achievement. Using the data above, justify two chronic cardiovascular adaptations that you would expect Djokovic to develop and outline how each adaptation contributes to enhanced performance.
Cardiovascular adaptation 1:
Explanation:

Cardiovascular adaptation 2:
Explanation:

4 marks

9 **adapted from ACHPER Trial Exam 2015, question 13**

Sharon and Katherine decided that the Cooper's 12-minute run test was a suitable test to assess their aerobic capacity before undertaking their training program. They both completed the test to the best of their ability.

During the Cooper's 12-minute run test, the students' heart rate data (measured in beats per minute) were collected and are presented in the table below.

	Heart rate: Sharon	Heart rate: Katherine
Resting heart rate	72	61
Immediately before run	96	98
At the conclusion of 1st minute	160	170
At the conclusion of 2nd minute	170	171
At the conclusion of 3rd minute	171	170
At the conclusion of 4th minute	170	171
At the conclusion of 5th minute	170	172
At the conclusion of 6th minute	171	171
At the conclusion of 7th minute	172	172
At the conclusion of 8th minute	172	172
At the conclusion of 9th minute	172	172
At the conclusion of 10th minute	172	171
At the conclusion of 11th minute	185	188
At the conclusion of 12th minute	200	198
1 minute following run	185	172
2 minutes following run	171	161
3 minutes following run	165	133

(a) Using data from the table, identify the range of minutes that Sharon remained in steady state during the test. **1 mark**
(b) Identify which of the girls, Sharon or Katherine, has a better aerobic capacity. **1 mark**
(c) Provide **two** pieces of evidence from the table to support your choice in part (b). **2 marks**

12.3 Chronic adaptations to aerobic training: respiratory

KEY CONCEPT Respiratory adaptations derived from participation in an aerobic training program lead to improved performance.

Increased pulmonary ventilation during maximal exercise

Regular aerobic training results in more efficient and improved pulmonary **ventilation**, which is sometimes also referred to as minute ventilation. At rest and during submaximal exercise, ventilation may in fact be reduced due to improved oxygen extraction. However, during maximal workloads, ventilation is increased because of increased **tidal volume** (TV) and **respiratory frequency** (RF). **Pulmonary diffusion** is also enhanced as a result of training.

Ventilation is the amount of air inspired or expired per minute by the lungs. Ventilation (V) = tidal volume (TV) × respiratory frequency (RF).

Tidal volume is the amount of air inspired and expired by the lungs per breath.

Respiratory frequency is the amount of times a person breathes in and out each minute.

Pulmonary diffusion is the movement of oxygen and carbon dioxide from high concentration to low concentration between the alveoli and the surrounding capillaries.

Increased tidal volume

Aerobic training increases the amount of air inspired and expired by the lungs per breath. This is attributed to the increased strength and endurance of the respiratory muscles, allowing an athlete to exhale more air and inhale more air. This allows for a greater amount of oxygen to be diffused into the surrounding alveoli capillaries and delivered to the working muscles.

Decreased resting and submaximal respiratory frequency

The number of times an athlete breathes in and out per minute is reduced at rest and submaximal levels. This is mainly due to the improved pulmonary function and an increase in the extraction of oxygen from the alveoli to the surrounding capillaries.

Increased pulmonary diffusion

Aerobic training results in an increase in the surface area of the alveoli, which in turn increases the pulmonary diffusion. This allows for a greater amount of oxygen

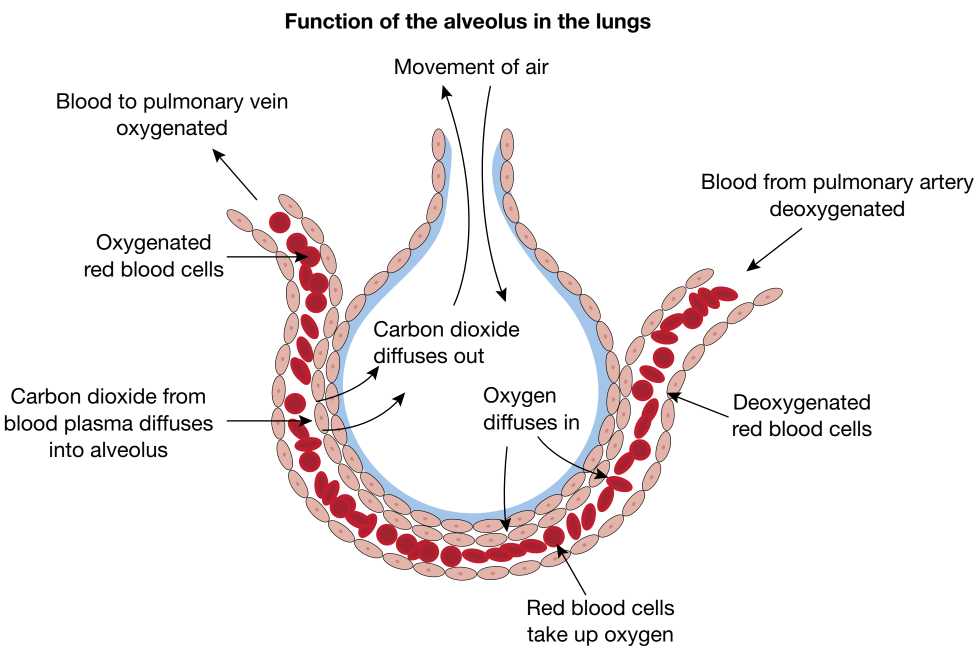


FIGURE 12.8 An increased alveolus surface area allows for a greater amount of diffusion of oxygen and CO_2.

and carbon dioxide exchange between the alveoli and the surrounding capillaries. A greater amount of oxygen is extracted from the alveoli to the surrounding capillaries and, conversely, a greater amount of carbon dioxide is diffused from the surrounding capillaries into the alveoli.

The increase in ventilation and pulmonary diffusion allows more oxygen to be inhaled, extracted and transported to the working muscles.

TEST your understanding

1 Complete the following table by indicating whether the physiological parameter has increased, decreased or remained unchanged as a result of involvement in a long-term aerobic training program.

Physiological parameter	At rest	During submaximal exercise	During maximal exercise
Ventilation			
Tidal volume			
Respiratory frequency			
Pulmonary diffusion			

2 (a) Identify three types of athletes most likely to develop chronic respiratory adaptations as a result of participating in a long-term aerobic training program.

(b) Define pulmonary ventilation and outline the parameters that it consists of.

APPLY your understanding

3 Explain how aerobic training can result in more efficient pulmonary ventilation.

4 Explain pulmonary diffusion and how it is affected by aerobic training.

5 Discuss how the aerobic adaptations of pulmonary ventilation and pulmonary diffusion lead to the improved performance of a marathon runner.

EXAM practice

6 **adapted from ACHPER Trial Exam 2015, question 9**

Amber is a 16-year-old who completes a VO_2 maximum test on a cycle ergometer just before commencing the cycling training program. She recorded a VO_2 maximum of 56 mL/kg/min. After 12 weeks of training, she completes a VO_2 maximum test on a cycle ergometer again and her VO_2 maximum has improved to 59 mL/kg/min.

Discuss one respiratory adaptation that would lead to Amber's improved VO_2 maximum. **2 marks**

studyon

Unit 4 · AOS 2 · Topic 4 · Concept 1

Respiratory aerobic Summary screen and practice questions

12.4 Chronic adaptations to aerobic training: muscular

KEY CONCEPT Muscle tissue adaptations derived from participation in an aerobic training program lead to improved performance.

Mitochondria are cell structures or organelles in which oxidative ATP resynthesis takes place.

Myoglobin is an oxygen-binding protein in skeletal muscle cells that attracts oxygen from the bloodstream and shuttles it to the mitochondria in the muscles for aerobic energy production.

Chronic aerobic training adaptations within muscle tissue are best produced through continuous, fartlek and long-interval training, high-intensity interval training or high-repetition, low-weight resistance training.

Increased oxygen utilisation

Aerobic training enhances the body's ability to attract oxygen into the muscle cells and then use it to resynthesise adenosine triphosphate (ATP) for muscular contractions. More oxygen intially surrounds the muscle by the increased capillary density and then the myoglobin and mitochondria work together to utilise the oxygen to resynthesis ATP aerobically.

This process occurs in the following ways:

- *Increased size and number of mitochondria.* The **mitochondria** are the sites of aerobic ATP resynthesis and where glycogen and triglyceride stores are oxidised. The greater the number and size of the mitochondria located within the muscle, the greater the oxidisation of fuels to produce ATP aerobically.
- *Increased myoglobin stores.* Aerobic training significantly increases the **myoglobin** content in the muscle and therefore its ability to extract oxygen and deliver it to the mitochondria for energy production. When oxygen is diffused into the muscle fibre, it binds with myoglobin, which then shuttles the oxygen to the mitochondria. Myoglobin stores can increase up to 80 per cent from undertaking an aerobic training program. Figure 12.9 illustrates the effect of aerobic training on these parameters.

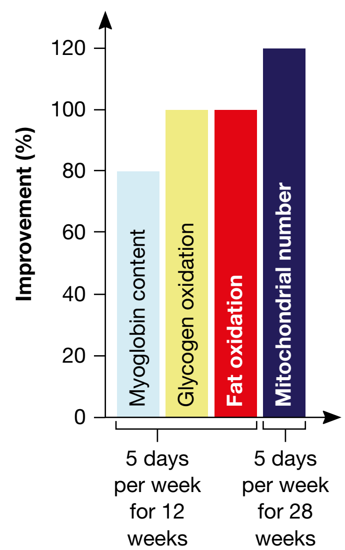


FIGURE 12.9 Effects of aerobic training on muscle tissue

Increased arteriovenous oxygen difference

Trained athletes are able to extract more oxygen from their bloodstream into their muscles during exercise performance compared with untrained individuals. This is due to increased muscle myoglobin stores and an increased number and size of mitochondria within their muscles (muscular aerobic adaptations). As a result of this, the concentration of oxygen within the venous blood is lower, and subsequently the

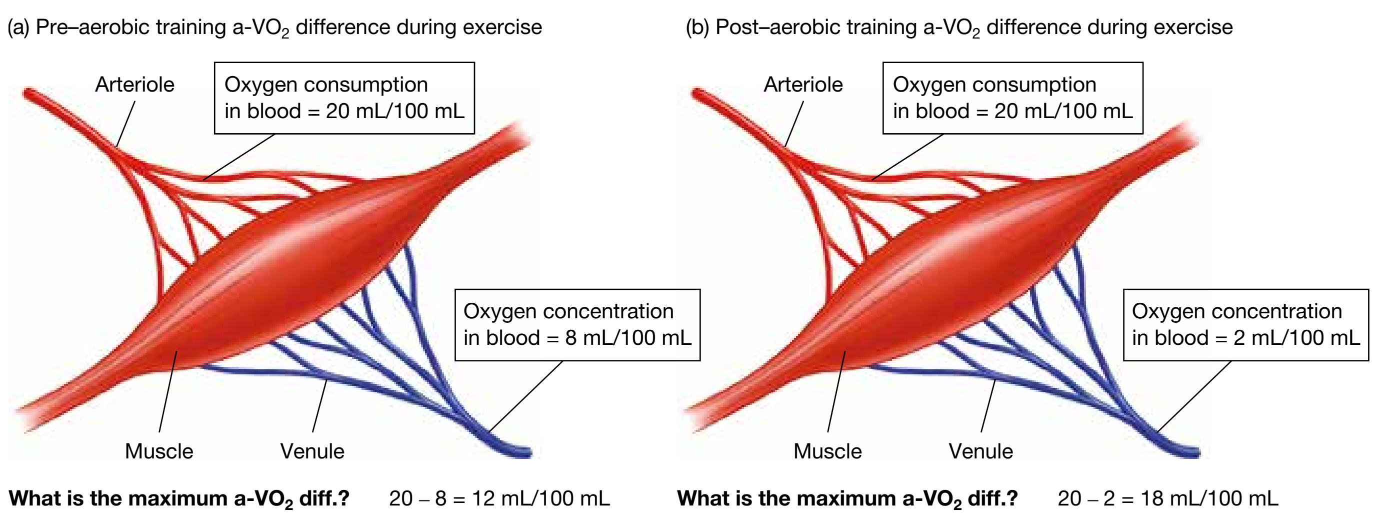


FIGURE 12.10 Aerobic training effects on a-VO_2 difference

Arteriovenous oxygen difference (a-VO_2 diff.) is a measure of the difference in the concentration of oxygen in the arterial blood and the concentration of oxygen in the venous blood. It is measured in millilitres per 100 millilitres of blood.

Oxidative enzymes are enzymes that, with the use of oxygen, speed up the breakdown of nutrients to resynthesise ATP.

Glycogen sparing is the process whereby glycogen stores are not used as early in an exercise bout due to the increased ability to use triglycerides to produce energy. This delays depletion of these stores, and thereby delays the time to exhaustion due to glycogen depletion.

Type 1 slow-twitch oxidative fibres are red, and have a high capacity to generate ATP by oxidative metabolic processes. They split ATP at a slow rate, have a slow contraction velocity and are very resistant to fatigue.

Type 2A fast-twitch oxidative fibres are red, and have a very high capacity for generating ATP by oxidative metabolic processes. They split ATP at a very rapid rate, have a fast contraction velocity and are resistant to fatigue.

Type 2B fast-twitch glycolytic fibres are white, and are geared to generate ATP by anaerobic metabolic processes. They split ATP at a very rapid rate, have a fast contraction velocity and fatigue easily.

arteriovenous oxygen difference (a-VO_2 diff.) is increased during both submaximal and maximal exercise. Therefore, an increased arteriovenous oxygen difference indicates a greater uptake of oxygen by the muscles within trained athletes and a greater capacity of the athlete to produce energy aerobically. A greater a-VO_2 difference due to aerobic training is also caused by the increased distribution of blood flow to the working muscles as a result of improved cardiovascular parameters.

Increased muscular fuel stores and oxidative enzymes

Aerobic training increases the muscular storage of glycogen and triglycerides in the slow-twitch muscle fibres and there is also an accompanying increase in the **oxidative enzymes** that are responsible for metabolising these fuel stores to produce ATP aerobically. This means that there is less reliance upon the anaerobic glycolysis system until higher intensities.

Increased oxidation of glucose and triglycerides

The muscular adaptations already discussed in this section result in an increase in the capacity of muscle fibres to oxidise both glucose and triglycerides. In other words, the capacity of the aerobic system to metabolise these fuels is increased (see figure 12.9). Furthermore, the increased oxidation of fats as a fuel source — due to the increased storage of triglycerides, plus the vastly increased levels of enzymes associated with triglyceride metabolism — means that, at any given exercise intensity, a trained athlete has to rely less on glycogen, thereby 'sparing' their glycogen stores. This process is referred to as **glycogen sparing**. In essence, this allows the athlete to sustain a higher level of intensity, maintaining a faster pace, which ultimately results in an improved aerobic performance.

Adaptation of muscle fibre type

On the basis of various structural and functional characteristics, skeletal muscle fibres are classified into three types: type 1 slow-twitch oxidative fibres, type 2A fast-twitch oxidative fibres and type 2B fast-twitch glycolytic fibres. Some evidence has shown that fast-twitch skeletal muscle type A fibres can take on the characteristics of slow-twitch type fibres as a result of endurance training. Some researchers have also demonstrated that fast-twitch type 2B fibres are recruited more in a manner that represents the more oxidative fast-twitch type 2A fibres as a result of endurance training. Slow-twitch muscle type fibres will increase in cross-sectional area as a result of endurance training; however, the extent of the increase is dependent upon the intensity and duration of training.

Type 1 slow-twitch oxidative fibres contain large amounts of myoglobin, and large numbers of mitochondria and blood capillaries. Type 1 fibres are red, split ATP at a slow rate, have a slow contraction velocity, are very resistant to fatigue, and have a high capacity to generate ATP by oxidative metabolic processes.

Type 2A fast-twitch oxidative fibres contain a large amount of myoglobin, and large numbers of mitochondria and blood capillaries. Type 2A fibres are red, have a very high capacity for generating ATP by oxidative metabolic processes, split ATP at a very rapid rate, have a fast contraction velocity, and are resistant to fatigue.

Type 2B fast-twitch glycolytic fibres contain a low myoglobin content, relatively few mitochondria and blood capillaries, and large amounts of glycogen. Type 2B fibres are white, are geared to generate ATP by anaerobic metabolic processes, fatigue easily, split ATP at a fast rate, and have a fast contraction velocity.

TABLE 12.1 Characteristics of fast- and slow-twitch muscle fibres

Characteristic	Slow-twitch	Fast-twitch oxidative	Fast-twitch glycolytic
Also known as	Type 1	Type 2A	Type 2B
Colour	Red	Red	White
Used for	Aerobic	Anaerobic (long-term)	Anaerobic (short-term)
Fibre size	Small	Medium	Large
Motor neuron size	Small	Large	Very large
Resistance to fatigue	High	Medium	Low
Force production	Low	High	Very high
Speed of contraction	Slow	Fast	Very fast
Hypertrophy potential	Low	High	High
Mitochondrial density	High	High	Low
Capillary density	High	Medium	Low
Myoglobin content	High	Medium	Low
Oxidative capacity	High	High	Low
Glycolytic capacity	Low	High	High
Major fuel	Triglycerides	Creatine phosphate/ glycogen	Creatine phosphate/ glycogen

Individual muscles are a mixture of the three types of muscle fibres, but their proportions vary depending on the action of the muscle and the genetic make-up of the individual. The Type 2B muscle fibre transformation is a very gradual process and can actually take years to manifest. The transformed fibres show a slight increase in diameter, mitochondria and capillaries but not a change in fibre type. This brings them to a level at which they are able to perform oxidative metabolism as effectively as the Type 1 slow-twitch fibres of untrained individuals.

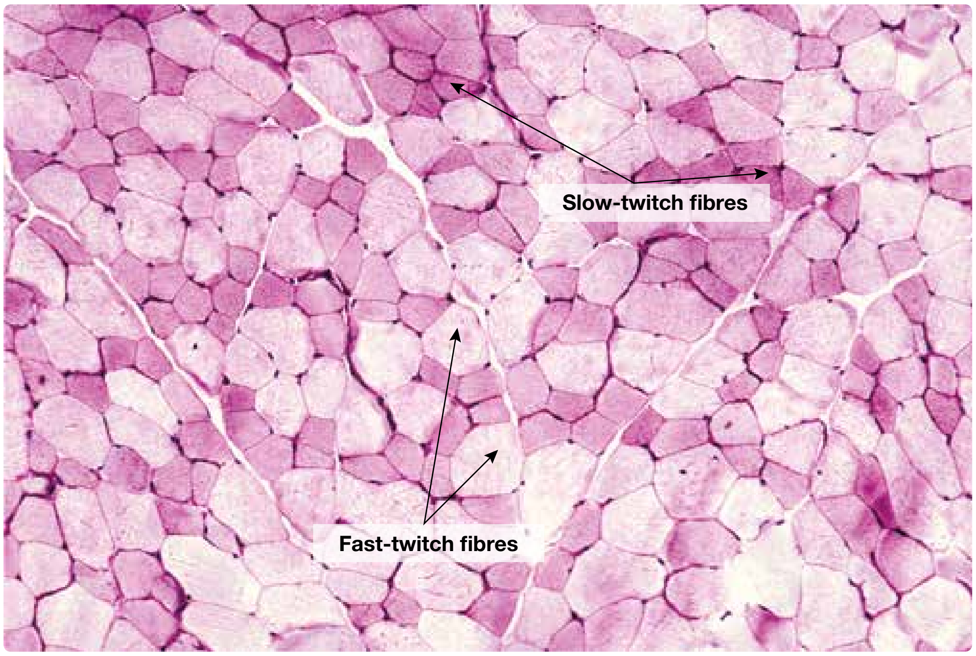


FIGURE 12.11 Cross-section of skeletal muscle fibre

studyon
Unit 4
AOS 2
Topic 4
Concept 3
Muscular aerobic
Summary screen and practice questions

TEST your understanding

1 Complete the table below by indicating whether the physiological parameters have increased, decreased or remained unchanged as a result of involvement in a long-term aerobic training program.

Physiological parameter	At rest	During submaximal exercise	During maximal exercise
Oxygen utilisation			
Size and number of mitochondria			
Myoglobin stores			
Muscular fuel stores (glycogen, triglycerides)			
Oxidisation of fats			
Muscle fibre type adaptations			

2 Outline the adaptations to muscle fibre type that have been shown to occur as a result of aerobic training.

3 (a) Identify the role of mitochondria and explain how they are affected by undertaking an aerobic training program.

(b) Identify the role of myoglobin and explain how it is affected by undertaking an aerobic training program.

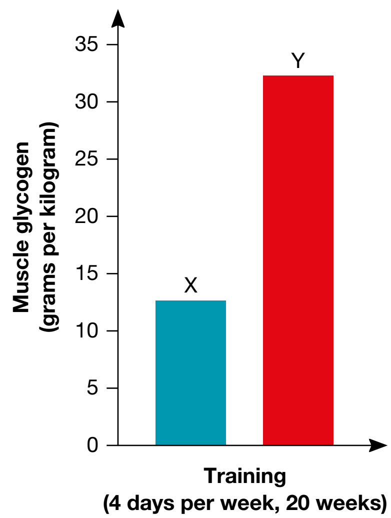
APPLY your understanding

4 Explain how increased mitochondria and myoglobin in the muscle cell improves aerobic performance.

5 Refer to the figure at right. Which column (X or Y) indicates muscle glycogen stores after completion of a 20-week aerobic training program? Explain your answer.

6 Explain which particular characteristics of fast-twitch type 2A fibres would be of benefit to an endurance athlete.

7 Explain how an increase in the number of oxidative enzymes will benefit the performance of an endurance athlete.



EXAM practice

8 **adapted from ACHPER Trial Exam 2013, question 3**

At the London 2012 Olympic Games, Yuliya Zaripova won the Women's 3000 m Steeplechase in a time of 9 minutes and 6.72 seconds. Identify two chronic muscular adaptations from Yuliya's training program and outline how these adaptations are beneficial to her performance. **4 marks**

Chronic adaptation:

Benefit to performance:

Chronic adaptation:

Benefit to performance:

12.5 Chronic adaptations to aerobic training: cardiovascular, respiratory and muscular

KEY CONCEPT Understanding chronic adaptations of the cardiovascular, respiratory and muscular systems to aerobic training: VO_2 maximum and lactate inflection point.

Increased maximum oxygen uptake: VO_2 max.

Aerobic training results in an increase in the **maximum oxygen uptake (VO_2 max.)** during maximal exercise. This improvement can be in the range of 5–30 per cent, following a regular and sustained training program. It comes about because of adaptations such as increases in cardiac output, red blood cell numbers, a-VO_2 difference and muscle capillarisation, as well as greater oxygen extraction by the muscles by the myoglobin.

VO_2 max. is the maximum amount of oxygen that can be taken in by the respiratory system, transported by the cardiovascular system and utilised by the muscular system to produce ATP. It is the point where an athlete cannot increase the amount of oxygen they take in, transport and utilise, despite an increase in their exercise intensity. An increase in VO_2 max. resulting from aerobic training is due to the aerobic chronic adaptations that occur in all three systems that have already been discussed in this chapter; for example, increased pulmonary diffusion (respiratory system), increased blood haemoglobin concentration (cardiovascular system) and an increase in mitochondria (muscular system).

Maximum oxygen uptake (VO_2 max.) is the maximum amount of oxygen per minute that can be taken in, transported and utilised by the body for energy production.

TABLE 12.2 Maximum oxygen uptake values in a variety of sportspeople

Sport	Age	Male	Female
Baseball	18–32	48–56	52–57
Basketball	18–30	40–60	43–60
Cycling	18–26	62–74	47–57
Canoeing	22–28	55–67	48–52
Football (USA)	20–36	42–60	
Gymnastics	18–22	52–58	35–50
Ice hockey	10–30	50–63	
Orienteering	20–60	47–53	46–60
Rowing	20–35	60–72	58–65
Skiing, alpine	18–30	57–68	50–55
Skiing, Nordic	20–28	65–94	60–75
Soccer	22–28	54–64	50–60
Speed skating	18–24	56–73	44–55
Swimming	10–25	50–70	40–60
Track & Field – Discus	22–30	42–55	
Track & Field – Running	18–39	60–85	50–75
Track & Field – Running	40–75	40–60	35–60
Track & Field – Shot	22–30	40–46	
Volleyball	18–22		40–56
Weightlifting	20–30	38–52	
Wrestling	20–30	52–65	

Source: https://www.brianmac.co.uk/vo2max.htm

Relative VO_2 max. takes into account body weight and is measured in mL/kg/min.

Absolute VO_2 max. is a measurement of the total amount of O_2 consumed in L/min.

Lactate inflection point (LIP) represents the highest intensity point where there is a balance between lactate production and removal from the blood.

An athlete's VO_2 max. is simply a combination of their cardiac output ($\dot{Q}$) × a-VO_2 difference. It is measured in mL of O_2 per kilogram of body weight per minute (mL/kg/min). Body weight is taken into account so that comparisons can be made **relative** to the athlete. This measurement determines how much how much oxygen per kilogram of body weight is utilised. Whereas **absolute VO_2 max.** is measured in litres per minute (L/min) and identifies the amount of oxygen that is consumed, irrespective of body weight, which does not allow for comparisons to be made between athletes.

Increased lactate inflection point (LIP)

As a result of the aerobic adaptations that improve oxygen delivery and use in the muscles (more efficient aerobic energy system usage) and economy, a higher **lactate inflection point (LIP)** is developed. LIP represents the highest intensity point where there is a balance between lactate production and removal from the blood. The advantage of having a higher LIP is that the aerobic system can produce energy at a faster rate, so there is less reliance on the anaerobic glycolysis system until higher exercise intensities are reached. Consequently, lactic acid and hydrogen ion accumulation will be delayed until these higher workload intensities are attained. Put simply, this means that the athlete can work at higher intensities for longer periods without the fatiguing hydrogen ion accumulation. Exercise intensities beyond the LIP are associated with fatigue; the greater the exercise intensity above the inflection point, the more rapid the fatigue.

As seen in figure 12.12, LIP is the point of inflection on the curve of blood lactate vs. exercise intensity (running speed) above which the rate of lactate production exceeds removal and blood lactate concentrations continue to increase disproportionally with increasing exercise intensity (running speed). There is a right shift on the graph for a trained athlete with a higher LIP.

Aerobic training at an intensity near LIP is appropriate for an untrained individual, but a higher intensity is necessary for endurance-trained athletes (as discussed in chapter 11). An athlete's LIP can be delayed until higher intensities without any variations to their VO_2 max. This is due to an increased ability to absorb, transport and metabolise hydrogen and lactate more efficiently, resulting in the exponential accumulation of lactic acid at higher exercise intensities. An increase in mitochondria size and density allows for greater aerobic ATP resynthesis and also an increased ability to remove lactate from the cell cytoplasm via the following different mechanisms:

- some lactate is re-converted to pyruvate for immediate oxidation in the mitochondria
- some lactate is transported out of the cell into the blood
- most blood lactate is oxidised by other muscles (particularly cardiac muscle and slow-twitch muscle fibres)
- some of the blood lactate is converted to glucose or glycogen in the liver.

Where maximal oxygen uptake (VO_2 max.) is equivalent between athletes, LIP is more likely to distinguish the performances of middle- and long-distance athletes. LIP is often expressed as a percentage of an athlete's VO_2 max. or maximum heart rate (MHR). An elite endurance athlete will reach their LIP at 80–90 per cent VO_2 max. or 85 per cent MHR.

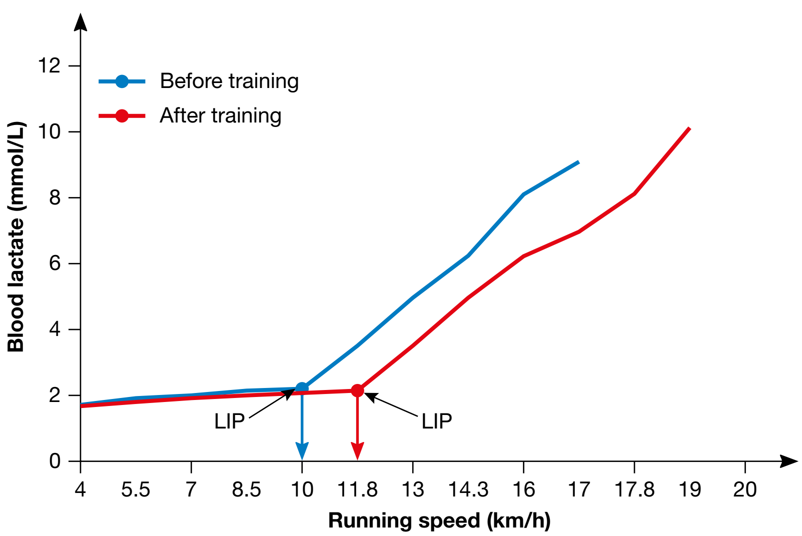


FIGURE 12.12 Training effects on blood lactate level in relation to running speeds

Source: Adapted from http://www.sport-fitness-advisor.com/lactate-threshold-training.html

TEST your understanding

1 Explain the physiological aspects that combine to determine a person's VO_2 maximum.
2 Identify the approximate maximum oxygen uptake values of three different types of Australian sportspeople.
3 Define the term *lactate inflection point* and outline the percentage of maximum heart rate at which LIP generally occurs in elite athletes.

APPLY your understanding

4 Discuss how each of the three systems (cardiovascular, respiratory and muscular) contribute to an athlete's VO_2 maximum.
5 Discuss why VO_2 maximum is measured in mL of O_2 per kg of body weight.
6 Explain how one specific aerobic adaptation for each system would lead to an improvement to an athlete's VO_2 maximum.
7 Justify how aerobic training can improve an athlete's LIP.
8 Identify the type of athlete that would benefit from having an improved LIP and explain how having a higher LIP improves that particular athlete's performance.

EXAM practice

9 **adapted from ACHPER Trial Exam 2013, question 2**

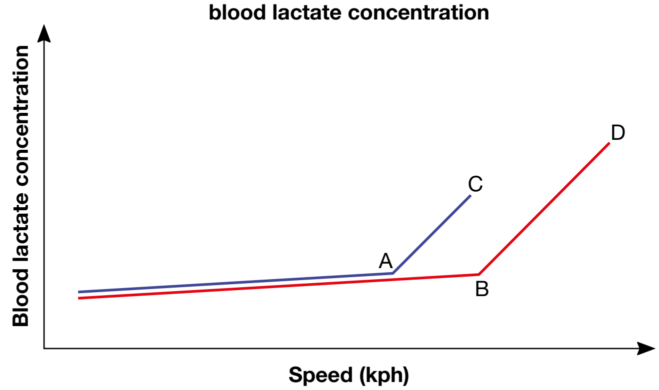
Running economy is a key factor in determining endurance performance for athletes with similar VO_2 maximums.

(a) Define VO_2 maximum and indicate an elite score for a female marathon runner. **2 marks**
(b) Explain how *running economy* will impact upon endurance performance. **2 marks**
(c) An elite male's VO_2 maximum score is generally about 10% above that of an elite female's. Outline two physiological reasons that may account for this. **2 marks**

10 **adapted from ACHPER Trial Exam 2014, question 12**

The graph below shows a recreational runner's blood lactate concentration during two different running treadmill tests until they reach exhaustion. The second test was completed after the runner completed a four-month training program.

General representation between speed and blood lactate concentration



(a) Identify what the points labelled A and B represent. **1 mark**
(b) Name the training method that would enable the shift from point A to B. **1 mark**
(c) Explain the benefit of moving from point A to point B when completing the treadmill test. **2 marks**
(d) The test is completed when the runner is unable to continue, due to fatigue. What is the most likely cause of this fatigue? **1 mark**

studyon

Unit 4 | AOS 2 | Topic 4 | Concept 4

Respiratory anaerobic and resistance
Summary screen and practice questions

12.6 Chronic adaptations to anaerobic training

KEY CONCEPT Chronic adaptations derived from participation in an anaerobic training program lead to improved performance.

As previously mentioned, anaerobic training effects are best developed through short and intermediate interval training, plyometric training, circuit training and resistance (strength and power) training. The greatest adaptations occur at the muscular system level.

Muscular hypertrophy

Anaerobic training can lead to significant enlargement of muscle fibres (mainly Type 2A and 2B fast-twitch fibres), resulting in **muscular hypertrophy** and, subsequently, greater strength. This hypertrophy occurs as a result of an increased size and number of **myofibrils** per muscle fibre and increased amounts of myosin and actin myofilaments. Muscular hypertrophy is more pronounced in males than females due to greater levels of testosterone in men.

Muscular hypertrophy is an increase in the cross-sectional size of a muscle.

Myofibrils are small fibres that run through each muscle fibre.

Increased muscular stores of ATP, ATPase, creatine kinase enzymes and CP

Muscular hypertrophy is accompanied by increased muscular stores of ATP and creatine phosphate (CP) (see figure 12.13). Increased muscular stores of ATP and creatine phosphate increases the capacity of the ATP–CP system allowing for faster resynthesis of ATP for high intensity activities. There is also an increase in the enzymes required to break down and resynthesise ATP: ATPase, which is responsible for breaking down ATP to form ADP and release energy for muscular contraction, and creatine kinase, which initiates the breakdown of CP and provides the energy to resynthesise ATP at a fast rate.

This results in an increased capacity of the ATP–CP system, namely greater energy release and faster restoration of ATP. This benefits the athlete in activities that require speed, strength and power.

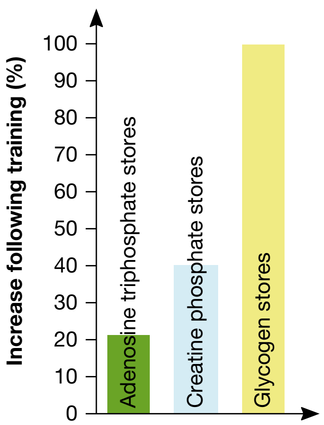


FIGURE 12.13 Effects of anaerobic training on muscular stores of ATP, CP and glycogen

Increased glycolytic capacity

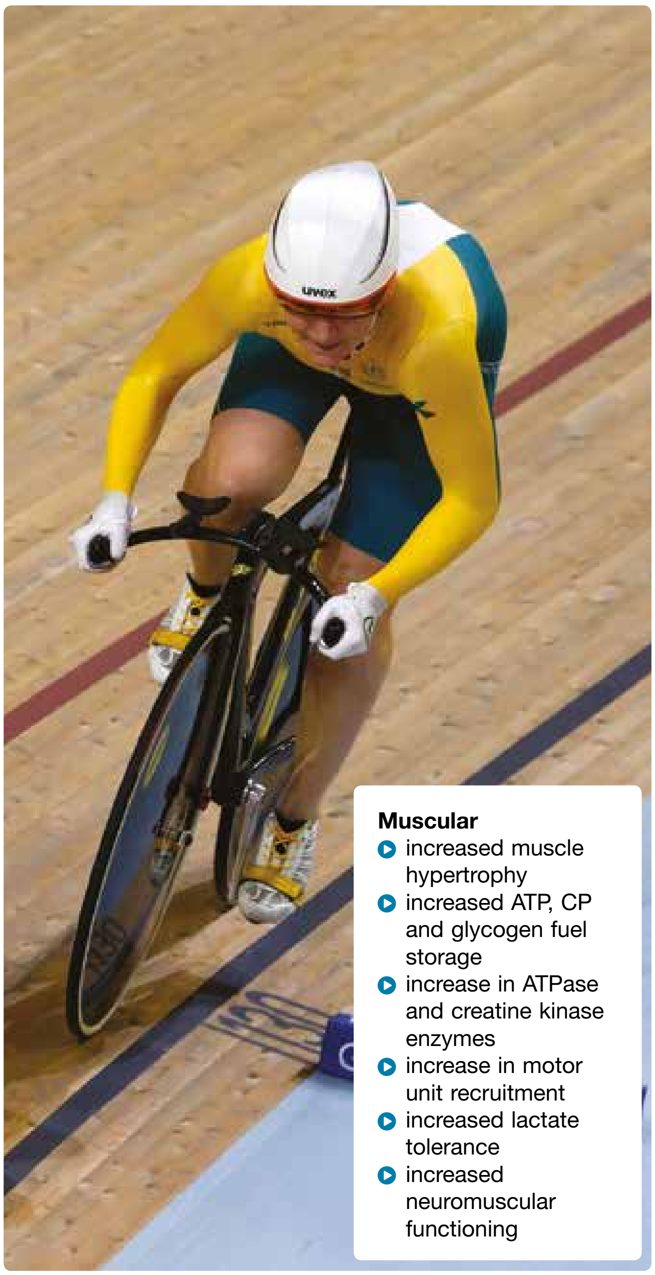
Enhanced muscular storage of glycogen and increases in the levels of glycolytic enzymes are also adaptations accompanying anaerobic training (see figure 12.13). Consequently, the capacity of the anaerobic glycolysis/non-oxidative system to produce energy is enhanced.

FIGURE 12.14 This female athlete's chronic responses to anaerobic resistance training have led to musclar hypertrophy.

Chronic adaptations to training: Athlete comparison — anaerobic and aerobic

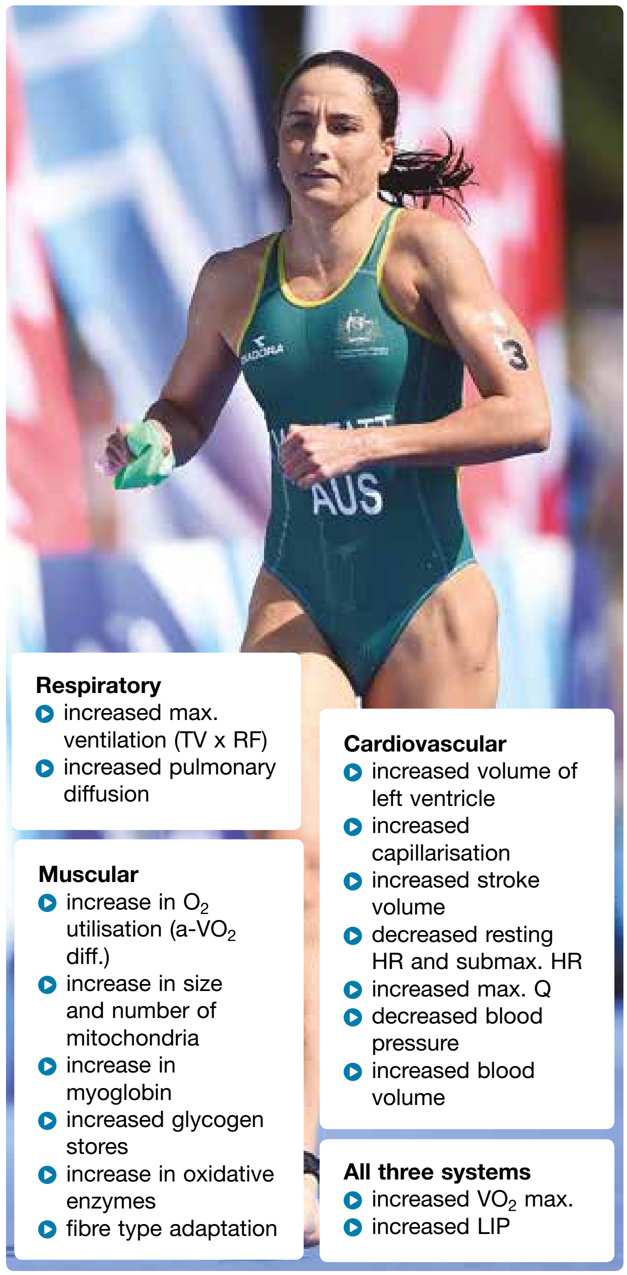
Anna Meares' world record cycling 500 m time trial: 32.836 seconds

FIGURE 12.15 Anna's chronic anaerobic adaptations allow her to generate a greater amount of pedalling force and power output. This results in her achieving faster speeds and quicker times in the 500 m time trial.



Emma Moffatt completed the 2016 World Triathlon in 2 hr 3 min 9 sec.
Swim — 00:18:39, bike — 01:06:40, run — 00:36:07

FIGURE 12.16 Emma's chronic aerobic adaptations allow her to more efficiently resynthesise ATP aerobically and improve her economy in the swim, bike and running legs. This results in her being able to compete in each leg at higher intensities for longer and ultimately produce a faster triathlon time overall.



Increase in the ability to recruit more motor units

A **motor unit** consists of one motor neuron and all of the muscle fibres that it innervates.

Buffering capacity is the ability of the muscle cell buffers to resist changes in pH (acidity).

The presence of **hydrogen ions** makes the muscle acidic and will eventually fatigue muscle function.

The ability of the nerve axons to innervate their corresponding muscle fibres increases as a result of anaerobic training. The greater the number of **motor units** that can be recruited, the greater the strength and power that can be produced by a muscle.

Increase in lactate tolerance

Working anaerobically means an athlete works above LIP, therefore producing lactate at a faster rate than it can be removed. The body learns to tolerate the increased levels of lactic acid and increase the **buffering capacity**. Anaerobic training increases the ability of the muscles to buffer (neutralise) the acid that accumulates from the production of **hydrogen ions** during an exercise bout. Buffers such as bicarbonate and muscle phosphates combine with the hydrogen ions to neutralise the increases in acidity. The increase in lactate tolerance prevents the onset of fatigue and allows an athlete to continue to generate ATP anaerobically, which is at a faster rate and allows them to work at a higher intensity, producing high lactate levels at the end of performance.

Any athlete that requires a significant contribution from the anaerobic glycolysis system, such as a 400 metre or 800 metre runner, will benefit from having an improved lactate tolerance.

Cardiac hypertrophy

Sustained anaerobic training results in the hypertrophy (enlargement) of the heart muscle itself. However, rather than increasing the size, and therefore volume, of the ventricular chambers, which occurs after prolonged aerobic training, anaerobic training produces an increase in the thickness of the ventricular walls (see figure 12.17(a) and (b)). While little or no change in stroke volume occurs, a more forceful contraction takes place and hence a more forceful ejection of blood from the heart.

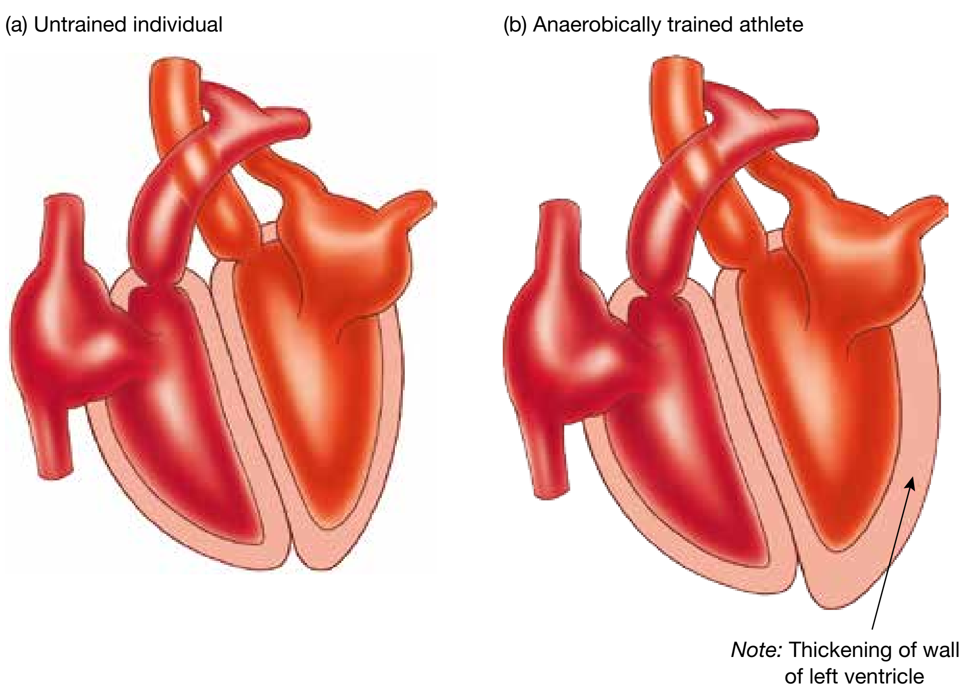


FIGURE 12.17 Effects of anaerobic training on cardiac hypertrophy. Following intense sustained anaerobic training, the thickness of the ventricular wall increases, particularly in the left ventricle, but there is no increase in the volume of the ventricular cavity.

TEST your understanding

1 Complete the following table by indicating whether the physiological parameters have increased, decreased or remained unchanged as a result of involvement in a long-term anaerobic training program.

Physiological parameter	At rest	During submaximal exercise	During maximal exercise
Muscular hypertrophy			
Muscular fuel stores (ATP and CP)			
ATPase and creatine kinase enzymes			
Glycolytic capacity			
Motor unit recruitment			
Cardiac hypertrophy			
Lactate tolerance			

2 Name the training methods that develop chronic anaerobic adaptations in muscle tissue.

3 Identify three types of athlete most likely to benefit from chronic adaptations as a result of participating in an anaerobic training program.

4 Outline the role of the enzymes ATPase and creatine kinase.

5 What is the benefit of having a larger muscular storage of ATP, CP and glycogen?

6 What is meant by the buffering capacity of a muscle?

APPLY your understanding

7 (a) Outline three chronic adaptations that may occur at the muscular level as a result of involvement in an anaerobic training program of at least 6 weeks' duration.

(b) Discuss how these adaptations can lead to improved performance.

8 An athlete participates in the following training program over a period of 6 weeks.

Session 1: 5 × 100 m runs, each taking 14 seconds
5 × 80 m runs, each taking 12 seconds
Work-to-rest ratio of 1:3

Session 2: 5 × 60 m runs, each taking 9 seconds
5 × 40 m runs, each taking 7 seconds
Work-to-rest ratio of 1:5

The athlete notices a reduction in time taken to complete each of the runs as the weeks progress. Identify and explain the chronic adaptations that have occurred to allow the athlete to run faster.

9 Involvement in a long-term anaerobic training program (i.e. intermediate interval training) may result in an increase in an athlete's lactate tolerance.

(a) Identify chronic adaptations to training that help to bring about this improvement in an athlete's lactate tolerance.

(b) Explain the advantages a higher lactate tolerance has for both athletes who perform anaerobic exercise (i.e. sprinters) and those who perform aerobic exercise (i.e. longer distance runners).

studyon

Unit 4
AOS 2
Topic 4
Concept 5

Cardiovascular anaerobic and resistance
Summary screen and practice questions

12.7 Chronic adaptations to resistance training: neuromuscular

KEY CONCEPT Explaining the specific chronic neuromuscular adaptations that occur when undertaking a resistance training program.

studyon

Unit 4	**Muscular anaerobic and resistance** Summary screen and practice questions
AOS 2	
Topic 4	
Concept 6	

As with any training, the resulting adaptations are specific to the type of training undertaken. Power and strength resistance training protocols (see chapter 11) will induce anaerobic training adaptations; likewise local muscular endurance resistance training protocols (see chapter 11) will induce some aerobic training adaptations. With any type of long-term training, adaptations occur in the neuromuscular system; however, significant specific neuromuscular adaptations occur with resistance training.

The neuromuscular system is very responsive to training. The increases in strength depend upon the type of resistance training and the muscle groups trained, and the intensity of the resistance training affects the scale of the adaptations.

Increase in muscle size and change in muscle structure

Resistance training increases the strength and size of a muscle. Increases in the cross-sectional area of a muscle are the result of an increase in the cross-sectional area of each individual fibre within the muscle. The hypertrophy of each fibre is due to an increase in the total quantity of actin and myosin protein filaments, the size and number of myofibrils and also in the amount of connective tissue that surrounds the muscle.

While most research suggests that individual fibre hypertrophy is the major reason for whole-muscle hypertrophy, some research suggests that **fibre hyperplasia**, an increase in the number of fibres, may also be a contributing factor to an increase in muscle size. It is important to note that research is unresolved as to whether or not fibre hyperplasia contributes to increases in whole-muscle hypertrophy.

Fibre hyperplasia is an increase in the number of fibres within a muscle.

Muscle fibre type adaptations

Each single motor unit contains only one type of muscle fibre (fast or slow twitch). Resistance training will cause certain types of muscle fibre adaptations based upon the specificity of the program. Research shows that Type 2 fast-twitch fibres show greater increases in size, particularly with higher loads, than do Type 1 slow-twitch fibres. This may be explained by the fact that there is a greater need to recruit more muscle fibres to produce the required force. The **size principle** suggests that all motor unit types would be recruited to lift heavy loads and therefore there is a greater involvement of the Type 2 fast-twitch fibres, which would explain why they hypertrophy to a greater relative amount.

The **size principle** is the principle by which motor units are recruited in order of their size from smallest to largest.

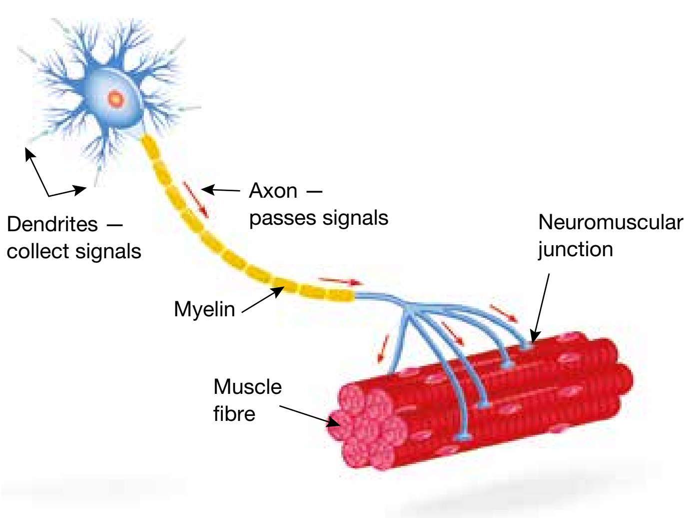


FIGURE 12.18 An example of a motor unit showing the motor neuron and the muscle fibres it innervates

Neural control

A combination of adaptations that occur at both the muscular and neural systems explains the increased strength gained from resistance training. In the absence of hypertrophy (an increase in muscular size), it is the neural adaptations that play a critical role in the increased force production of a muscle resulting from resistance training.

One important aspect of the strength gains that result from resistance training, particularly in the early stages of a program, are the neural adaptations. Increased synchronisation and recruitment of additional motor units, increase in the firing rate (rate coding) of motor units and a reduction in inhibitory signals are some of the neural factors that contribute to strength gains with resistance training.

Increased synchronisation of motor units

Motor units are not generally recruited at the same time. As discussed earlier, the 'size principle' states that motor units are recruited in order of their size from smallest to largest. Resistance training makes a number of different motor units able to fire at the same time. There is also an improved ability to recruit larger motor units that require a larger stimulus to activate and comprise the largest number of muscle fibres. The ability to recruit more motor units at the same time and to stimulate larger motor units earlier creates a more powerful muscular contraction with greater force application.

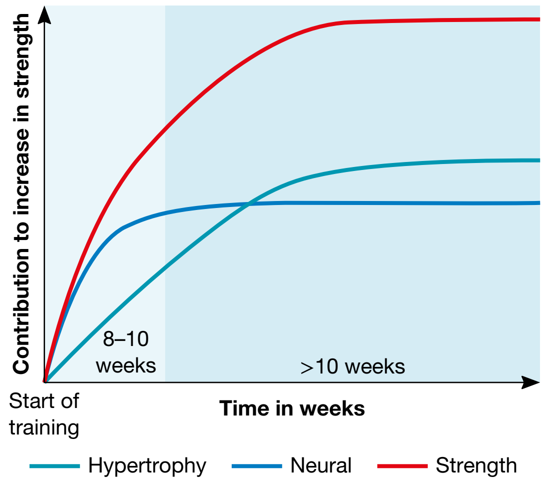


FIGURE 12.19 The contributions of neural and muscular training adaptations to increasing strength. Improvements in neuromuscular function explain the increase in strength in the early stages of training and, once the neural adaptations are maximised, further strength improvements are explained by the continued increase in the hypertrophy of a muscle.

Source: Porcari, John et al. 2015, *Exercise Physiology*, F.A. Davis.

Increase in the firing rate (rate coding) of motor units

The combination of motor unit recruitment and the firing rate or **rate coding** of motor units is known as the neural drive. Limited research suggests that the more efficient motor unit recruitment as a result of resistance training may also increase the frequency of stimulation of a given motor unit. An increase in rate coding increases the rate of force development or how quickly a muscle can contract maximally, rather than an increase in the force. This is beneficial for rapid ballistic movements where maximal force is required in a very short period of time.

Rate coding refers to the frequency of impulses sent to a muscle.

A reduction in inhibitory signals

The role of the inhibitory mechanisms that exist in the neuromuscular system (e.g. the Golgi tendon organs) is to provide an important protective reflex that limits an excessive generation of force within a muscle. This protective reflex is essential in preventing the muscles from exerting a force that is greater than they can tolerate. Resistance training can gradually override or reduce the inhibitory mechanisms and allow for a greater force production within a muscle group. The improved coordination of the **agonists, antagonists** and **synergists** is thought to allow for the reduced inhibitory effect.

The **agonist** muscle is the prime mover of the muscle action. It causes the movement to occur.

An **antagonist** muscle works in opposition to the agonist muscle.

Synergist muscles stabilise movements to and maintain control within the desired range of motion.

TEST your understanding

1 Outline how resistance training affects the size and structure of muscles.
2 Compare and contrast the difference between fast- and slow-twitch responses to resistance training.
3 Sketch a motor unit.
4 Identify how the *size principle* is changed by resistance training.
5 List the neural adaptations that account for increases in strength when hypertrophy is not present.
6 Outline the role of the Golgi tendon organs.

APPLY your understanding

7 Explain how an increase in the synchronisation of motor units can improve strength.
8 Discuss the benefit of increased rate coding of motor units. Explain for which type of actions this adaptation would be advantageous.
9 Describe how resistance training can affect the inhibitory signals within a muscle.

KEY SKILLS CHRONIC ADAPTATIONS TO TRAINING

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Contrast — explain points of difference. It is not enough to just list the differences; you need to explain *how* they are different
  Discuss — to go into detail about the characteristics of a key concept
- **Key terminology:**
  Training — chronic adaptations need to be identified and defined
  Chosen event — specific to each event (400 m and 10 000 m)
  Lead to improved performance — explanation of how the performance of each athlete is enhanced by each chronic adaptation.
- **Key concepts:**
  Chronic muscular adaptations — need to discuss the adaptations relevant to the muscular system
- **Marking scheme:** *6 marks* — always check marking scheme for depth of response required, linking to key information highlighted in the question

HOW THE MARKS ARE AWARDED

- **4 marks:** 1 mark for explaining two contrasting muscular adaptations for each event (400 m and 10 000 m)
- **2 marks:** 1 mark for discussing how the muscular adaptations lead to improved performance in each event

KEY SKILL

- Explain how the cardiovascular, respiratory and muscular systems' chronic adaptations to training lead to improved performance

UNDERSTANDING THE KEY SKILL

To address this key skill, it is important to remember the following:

- Describe how each of the adaptations to the cardiovascular system leads to the improved performance of specific activities
- Describe how each of the adaptations to the respiratory system leads to the improved performance of specific activities
- Describe how each of the adaptations to the muscular system leads to the improved performance of specific activities
- Explain the specific adaptations that occur from undertaking aerobic, anaerobic and resistance training

PRACTICE QUESTION

1 **(adapted from ACHPER Trial Exam 2015, question 2)**

Wayde van Niekerk from South Africa is the current Olympic champion in the men's 400 m track event. Van Niekerk won this event in Rio in a time of 43.03 seconds. Mo Farah from Great Britain is the current Olympic champion in the men's 10 000 m track event. He won his gold medal in a time of 27 minutes, 5 seconds.

Contrast the chronic muscular adaptations that van Niekerk and Farah would expect to bring about in training for their chosen event and **discuss** how these changes could lead to improved performance. *(6 marks)*

SAMPLE RESPONSE

May select to discuss any two of the following contrasting chronic adaptations for each athlete.

Wayde van Niekerk (400 m — 43.03 sec)

- An increase in muscle fibre size and strength of connective tissue (ligaments and tendons) allows for a greater force production in each running stride.
- An increase in the muscular stores of ATP and creatine phosphate increases the capacity of the ATP–CP system, allowing a greater percentage contribution from the ATP–CP system, which provides a faster rate of ATP resynthesis, enabling faster running speed.
- An increase in the enzyme ATPase, which speeds up the breakdown of ATP to release energy for muscular contraction, and an increase in the enzyme creatine kinase, which initiates the breakdown of PC that provides the energy to resynthesise ATP at a faster rate, therefore enabling a greater power output and faster running speed.
- Increased levels of glycolytic enzymes assists the anaerobic glycolysis system to quickly resynthesise ATP, contributing to a faster running speed.
- An increased lactate tolerance will increase the ability of van Niekerk to withstand larger amounts of hydrogen ions in his muscles, increasing the capacity of the anaerobic glycolysis system to dominate and allow him to maintain a higher running speed for longer.

All of the above chronic adaptations will help van Niekerk to complete the 400 m in as fast a time as possible.

Mo Farah (10 000 m — 27 minutes, 5 seconds)

- An increase in myoglobin, which is responsible for extracting oxygen from the red blood cells and delivering it to the mitochondria in the muscle cells, will allow for greater for aerobic energy production.
- An increase in mitochondrial density (sites of aerobic ATP resynthesis) would increase the ability to resynthesise ATP aerobically at higher intensities, delaying Farah from reaching his lactate inflection point.
- An increase in the oxidative enzymes that are responsible for metabolising glycogen and triglycerides to produce ATP aerobically means that there will be less reliance upon the anaerobic glycolysis system until higher intensities.
- An increase in Farah's lactate inflection point, which is the highest intensity running speed he can maintain where there remains a balance between lactate production and removal, will allow him to run at higher intensities with less reliance on the anaerobic glycolysis system.

All of the above chronic adaptations will increase Farah's lactate inflection point and aerobic capacity, which will improve his running economy, increase his ability to produce ATP aerobically and allow him to run at higher intensities for longer, producing a faster time for the 10 000 m event.

CHAPTER REVIEW CHRONIC ADAPTATIONS TO TRAINING

CHAPTER SUMMARY

- Long-term responses that develop over a period of time (usually a minimum of 6 weeks) when training is repeated regularly are referred to as chronic adaptations to training. The combined effect of all chronic adaptations is known as the training effect.
- Chronic adaptations to training may occur in the cardiovascular, respiratory and muscular systems. The result of these physiological adaptations is an improvement in performance.
- Chronic adaptations to training are dependent on:
  - the type and method of training
  - the frequency, duration/time and intensity of training
  - the individual athlete's capacities and genetic make-up.
- Aerobic (endurance) training adaptations lead to more efficient delivery of larger quantities of oxygen to working muscles and an improved economy. Specifically, the cardiovascular system increases blood flow and delivery of oxygen to the muscles, and the respiratory system increases the amount of oxygen available and the muscular system increases the amount of O_2 utilised for ATP resynthesis.
- Aerobic training effects are developed through continuous, fartek, long-interval and high-intensity interval (HIIT) type training.
- Anaerobic training adaptations lead to increased muscle size, enabling greater strength, power and speed, as well as changes at the cellular level that improve anaerobic energy production.
- Anaerobic training effects are best developed through short and intermediate interval training, plyometric training, circuit training and resistance (strength and power) training.
- Resistance training causes a range of neuromuscular adaptations to take place, such as increased neural control, improved synchronicity of motor units and increased firing rate of motor units.

eBook*plus*

Interactivity
Summary of chronic training adaptations
Searchlight ID: int-6828

TABLE 12.3 Summary of chronic aerobic adaptations to training

Cardiovascular

Physiological adaptation from aerobic training	Explain the adaptation from aerobic training and how it affects performance
Increased left ventricle size and volume (increased stroke volume)	Aerobic training results in *cardiac hypertrophy*. An increase in the size and volume of the left ventricle, in particular, occurs. This increases stroke volume and cardiac output, allowing a greater volume of blood to be ejected from the heart, thus providing more oxygen for the athlete to use.
Increased capillarisation of the heart muscle	Cardiac hypertrophy also leads to an increase in the *capillarisation* of the heart muscle itself. The increased supply of blood and oxygen allows the heart to beat more strongly and efficiently during both exercise and rest.
Faster heart rate recovery rates	Increased heart rate recovery rates mean that the heart rate will return to resting levels in a much shorter time than that of an untrained individual. This is due to the greater efficiency of the cardiovascular system to produce energy aerobically.
Increased blood volume and haemoglobin levels	Red blood cells may increase in number and the *haemoglobin* content and oxygen-carrying capacity of the blood may also rise. There is also an increased ratio of plasma in the blood cells, which reduces the viscosity of the blood allowing it to flow smoothly through the blood vessels. This allows a greater amount of oxygen to be delivered to the muscles and used by the athlete.
Increased capillarisation of skeletal muscle	Aerobic training leads to increased capillarisation of skeletal muscle. Greater capillary supply means increased blood flow and greater surface area for gas diffusion to take place. Increasing the oxygen and nutrients into the muscles allows for more removal of by-products
Decreased heart rate at rest and during submaximal workloads	A greater stroke volume results in the heart not having to beat as often to supply the required blood flow (and oxygen). Aerobic training also results in a slower increase in heart rate during exercise and also a lower steady state that is reached sooner.

Respiratory

Physiological adaptation from aerobic training	Explain the adaptation from aerobic training and how it affects performance
Increased alveolar surface area (increased pulmonary diffusion)	Aerobic training increases the surface area of the alveoli, which in turn increases the pulmonary diffusion, allowing more oxygen to be extracted and transported to the working muscles for use.
Increased tidal volume	Aerobic training increases the amount of air inspired and expired by the lungs per breath. This allows for a greater amount of oxygen to be diffused into the surrounding alveoli capillaries and delivered to the working muscles.
Increased ventilation during maximal exercise	Aerobic training results in more efficient lung *ventilation*. Ventilation may be reduced slightly at rest and during submaximal exercise due to improved oxygen utilisation. At maximal workloads, ventilation is increased due to an increase in tidal volume and respiratory frequency. This allows for greater oxygen delivery to working muscles at maximum exercise intensities.

Muscular

Physiological adaptation from aerobic training	Explain the adaptation from aerobic training and how it affects performance
Increased size and number of mitochondria	Mitochondria are the sites of aerobic ATP resynthesis and where glycogen and triglyceride stores are oxidised. The greater the number and size of the mitochondria located within the muscle, the greater the ability to resynthesise ATP aerobically.
Increased myoglobin stores	Myoglobin is responsible for extracting oxygen from the red blood cells and delivering it to the mitochondria in the muscle cell. An increase in the number of myoglobin stores increases the amount of oxygen delivered to the mitochondria for energy production.
Increased fuel storage and oxidative enzymes	Aerobic training increases the muscular storage of glycogen and triglycerides in the slow-twitch muscle fibres and there is also an increase in the oxidative enzymes that are responsible for metabolising these fuel stores to produce ATP aerobically. This means that there is less reliance upon the anaerobic glycolysis system until higher intensities. In addition to this, due to increased levels of the enzymes associated with fat metabolism, an aerobically trained athlete is able to 'glycogen spare' more effectively and therefore work at higher intensities for longer.
Increased muscle oxygen utilisation (a-VO_2 difference)	All of the above listed factors contribute to the body's ability to attract oxygen into the muscle cells and then use it to produce adenosine triphosphate (ATP) for muscle contraction. A measure of this is the difference in the amount of oxygen in the arterioles in comparison to the venules.
Increased muscle fibre adaptation	Some research has indicated that skeletal muscle fast-twitch type 2A can take on some of the characteristics of slow-twitch as an adaptation of aerobic training. This would allow for a greater ability to generate ATP aerobically with fewer fatiguing factors.

All three systems: cardiovascular, respiratory and muscular

Physiological adaptation from aerobic training	Explain the adaptation from aerobic training and how it affects performance
Increased VO_2 max.	An increase in the *maximum oxygen uptake (VO_2 max.)* allows for a greater amount of oxygen that can be taken in by the respiratory system, transported by the cardiovascular system and utilised by the muscular system to produce ATP, improving the economy of the athlete.
Increased lactate inflection point	LIP represents the highest intensity point where there is a balance between lactate production and removal from the blood. The advantage of having a higher LIP is that the anaerobic glycolysis system isn't contributing as much until higher exercise intensities are reached. This means that the athlete can work at higher intensities for longer periods without the fatiguing hydrogen ion accumulation.

TABLE 12.4 Summary of chronic anaerobic adaptations to training

Muscular

Physiological adaptation from anaerobic training	Explain the adaptation from anaerobic training and how it affects performance
Muscular hypertrophy	An increase in muscle fibre size due to an increase in the size and number of myofibrils and the protein filaments actin and myosin. This increase in muscle size allows for a greater production of strength and power.
Increased muscular stores of ATP and CP	Increased muscular stores of ATP and creatine phosphate increases the capacity of the ATP–CP system, allowing for faster resynthesis of ATP for high intensity activities.
Increase in ATPase and creatine kinase enzymes	ATPase is responsible for breaking down ATP to form ADP and release energy for muscular contraction. Creatine kinase initiates the breakdown of CP, which provides the energy to resynthesise ATP at a fast rate.
Increased glycolytic capacity	Increased muscular storage of glycogen and consequently the increased levels of glycolytic enzymes, enhances the capacity of the anaerobic glycolysis system to produce energy.
Increase in the number of motor units recruited	An increase in the number of nerve axons and their corresponding muscle fibres increases the power and strength of muscular contractions.
Increased lactate tolerance	An increase in the ability of the muscles to buffer (neutralise) the acid that accumulates from the production of hydrogen ions during an exercise bout. The increase in lactate tolerance prevents the onset of fatigue and allows an athlete to continue to generate ATP anaerobically, which is at a faster rate, and allows them to work at a higher intensity, producing high lactate levels at the end of performance.

TABLE 12.5 Summary of chronic adaptations to resistance training

Neuromuscular

Physiological adaptation from resistance training	Explain the adaptation from resistance training and how it affects performance
Increase in the cross-sectional area of a muscle (muscle hypertrophy)	An increase in the total quantity of actin and myosin protein filaments, the size and number of myofibrils and also in the amount of connective tissue that surrounds the muscle. This allows the muscle to create a greater amount of strength and power with each contraction.
Increased synchronisation of motor units	An increase in the ability for a number of different motor units to fire at the same time and an improved ability to recruit larger motor units that require a larger stimulus to activate. The ability to recruit more motor units at the same time and to stimulate larger motor units creates a more powerful muscular contraction.
Increase in the firing rate (rate coding) of motor units	An increase in the frequency of stimulation of a given motor unit (rate coding) increases the rate of force development or how quickly a muscle can contract maximally. This is beneficial for rapid ballistic movements where maximal force is required in a very short period of time.
A reduction in inhibitory signals	The improved coordination of the *agonists, antagonists* and *synergists* is thought to allow for the reduced inhibitory effect. The reduction in the inhibitory mechanisms allow for a greater force production within a muscle group.

eBook*plus*

Interactivity
Chronic adaptations to training quiz
Searchlight ID: int-6827

studyon

Sit VCAA exam

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 **(ACHPER Trial Exam 2015, question 3)**
A chronic adaptation of aerobic training is an increase in plasma volume.
This increase aids performance by
(A) improving the ability of the blood to carry oxygen.
(B) enabling an increase in haemoglobin.
(C) facilitating an increase in red blood cells.
(D) improving the effectiveness of by-product removal.

2 **(ACHPER Trial Exam 2015, question 14)**
The world record for the men's 100 m Butterfly event is 49.82 seconds, set by American swimmer, Michael Phelps in 2009. Successful performance by a swimmer such as Phelps is enabled because he would have a
(A) larger finite capacity of the ATP–CP energy system.
(B) larger finite capacity of the anaerobic glycolysis energy system.
(C) larger finite capacity of the aerobic energy system.
(D) higher lactate inflection point.

3 **(ACHPER Trial Exam 2015, question 11)**
VO_2 maximum is calculated by which of the following formulae?
(A) (220 – age) × 85% of maximum heart rate
(B) (heart rate × stroke volume) × arteriovenous oxygen (a-VO_2) difference
(C) maximum heart rate × 85%
(D) lactate inflection point × maximum ventilation

4 **(ACHPER Trial Exam 2014, question 12)**
A previously untrained Year-12 student completed a 6-week training program to improve aerobic capacity.
Which of the following would be a chronic vascular adaptation to a long-interval training program for this student?
(A) Increased size of the left ventricle
(B) Increased contractility of the heart
(C) Increased myoglobin levels
(D) Increased haemoglobin levels

5 Which of the following is not a chronic adaptation to training?
(A) Increased red blood cell count
(B) Increased capillarisation of the heart muscle
(C) Increased muscular storage of glycogen
(D) Increased resting heart rate

6 Which of the following chronic adaptations to training would indicate an improved level of aerobic fitness?
(A) Decreased stroke volume at rest
(B) Increased cardiac output during maximal exercise
(C) Increased blood pressure at rest
(A) Decreased arteriovenous oxygen difference during submaximal exercise

7 **(adapted from ACHPER Trial Exam 2016, question 12)**
Following a two-month training program, aiming to increase muscular strength, adaptations that are likely to occur include an increase in
(A) mitochondrial mass and myoglobin.
(B) stroke volume and cardiac output.
(C) ATP and oxidative enzymes.
(D) contractile proteins and number and size of myofibrils.

8 **(adapted from ACHPER Trial Exam 2013, question 9)**
Lactate inflection point can occur when an athlete
(A) exercises at submaximal intensity.
(B) fails to improve their lactate tolerance.
(C) depletes their muscle and liver glycogen stores.
(D) exceeds their VO_2 maximum.

9 **(adapted from ACHPER Trial Exam 2011, question 10)**

When a comparison is made between an untrained person and an elite athlete runner of the same age in the same 5 km fun-run event, which of the following is true of the elite runner?

(A) Submaximal heart rate is lower, stroke volume is lower
(B) Submaximal heart rate is higher, stroke volume is lower
(C) Submaximal heart rate is lower, stroke volume is higher
(D) Submaximal heart rate is higher, stroke volume is higher

10 **(adapted from ACHPER Trial Exam 2011, question 11)**

To increase a person's lactate inflection point (LIP), which of the following training programs is recommended?

(A) Both elite and non-elite performers should engage in continuous training at, or slightly below, their LIP
(B) Both elite and non-elite performers should engage in continuous training at, or slightly above, their LIP
(C) Elite performers should engage in continuous training at, or slightly below, their LIP, while non-elite performers should perform continuous training at, or slightly above, their LIP
(D) Elite performers should engage in continuous training at, or slightly above, their LIP while non-elite performers should perform continuous training at, or slightly below, their LIP

TRIAL EXAM QUESTIONS

Question 1 **(adapted from ACHPER Trial Exam 2008, question 6)**

a. List two chronic/long-term adaptations that could be expected to occur within each of the listed body systems as a result of participation in a long-term aerobic (endurance) training program.

Body system	Chronic adaptations due to aerobic training
Cardiovascular	i. ii.
Respiratory	i. ii.

4 marks

b. Outline how these chronic adaptations contribute to improved performance. **4 marks**

Question 2 **(adapted from ACHPER Trial Exam 2014, question 11)**

Caitlin Sargent from Queensland ran the fastest 400 m by an Australian female athlete in 2013.

She completed the race in a time of 52.16 seconds. Caitlin would include interval training as part of her training routine. As a result of her training, she would expect to develop an increase in glycolytic enzymes, an increase in contractile proteins and an increased tolerance to hydrogen ions.

a. Which of the following interval sessions would be most likely to bring about these adaptations?

Please circle the most appropriate session — either A, B or C. **1 mark**

	Sets	Repetition number	Distance (metres)	Time (seconds)	Recovery (seconds)
A	3	8	30	4	30
B	3	5	150	20	60
C	3	5	600	120	120

b. Complete the table below to describe how an increase in each factor can lead to improved performance in the 400 m by Caitlin. **6 marks**

	Role in improving performance in the 400 m event
Glycolytic enzymes	
Contractile proteins	
Tolerance to hydrogen ions	

Question 3 **(adapted from ACHPER Trial Exam 2013, question 8)**

The lactate inflection point (LIP) and lactate tolerance are terms related to exercise science. With specific reference to these parameters, complete the following table. **8 marks**

	Lactate inflection point	Lactate tolerance
Definition		
Appropriate training method to achieve improvement		
Event likely to benefit from this parameter		
Outline how improvement in this parameter will benefit performance		

INQUIRY QUESTION

What are some performance enhancement and recovery strategies that Kimberley Brennan may have used in her preparation for winning gold in the single sculls at the Rio Olympics?

CHAPTER

13 Performance enhancement and recovery strategies: psychological, nutritional and hydration

Manipulation of an athlete's nutritional and hydration needs, as well as addressing psychological strategies, can enhance performance, and aid in recovery from both training and competition.

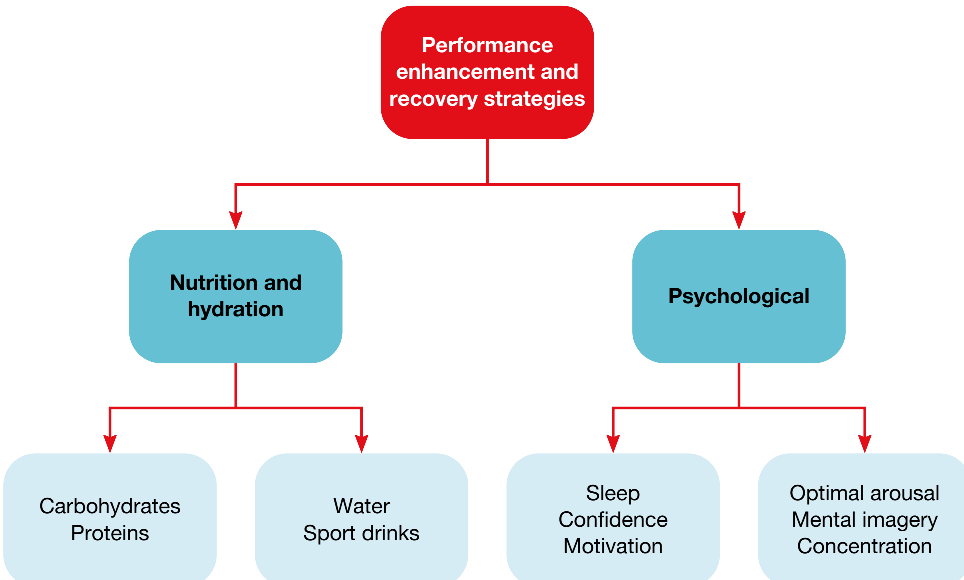
KEY KNOWLEDGE

- Psychological strategies used to enhance performance and aid recovery, including sleep, confidence and motivation, optimal arousal, mental imagery and concentration
- Nutritional and rehydration recovery strategies including water, carbohydrate and protein replenishment

KEY SKILLS

- Evaluate a range of psychological strategies which affect performance and recovery
- Explain and apply relevant nutrition and rehydration strategies to enhance recovery

CHAPTER PREVIEW



13.1 Nutritional needs of athletes: a balanced diet

KEY CONCEPT Nutritional strategies are a vital component of an athlete's diet and should be utilised in order to enhance their performance and improve their recovery.

It does not matter whether you are an international athlete, a regular club participant or a weekend fun-runner, it is essential that all athletes consume a good balance of nutrients to supply their body with the energy needed for physical activity and to aid in recovery after exercise. Nutrition and hydration play a key role in optimising the benefits for sports performance. Appropriate nutrition is vital for all of us, not only in the choice of foods we ingest, but also with timing and quantity of foods consumed. The essential nutrients that are required by all athletes include:

- carbohydrates
- fats
- proteins
- vitamins
- minerals
- water
- fibre.

Each sport and athlete has different nutritional requirements. No set dietary regime will cater for all athletes' individual needs. However, there are some common nutritional principles. The Australian Government's Guide to Healthy Eating (figure 13.1) provides a useful model that demonstrates a **balanced diet**.

A **balanced diet** is the appropriate balance of nutrients needed to supply the body with energy for physical activity and to aid in recovery after exercise.

Athletes must develop their own individual eating plans to achieve maximum results from their training programs. Not only does the athlete need to take into consideration the specific nutritional requirements of the sport that they participate in, they also need to consider their individual energy expenditure, metabolism and state of health when determining an appropriate nutritional intake. Good nutrition and hydration strategies should be practised for both training and competition. Some athletes place an emphasis on the nutrition and hydration during competition, however the intake during training is just as important.

Athletes will need to consider appropriate nutrition and hydration plans for before (pre), during and after (post) training/competition and each plan has a particular purpose.

- Pre-training/competition — aim is to keep the athlete from feeling hungry before and during exercise, and maintain optimal levels of energy stores for the activity that follows.
- During training/competition — acts as an alternative fuel source and maintains fluid lost throughout the exercise bout. *Note:* Some evidence suggests that top-up fuelling is beneficial for events lasting longer than 30 minutes, as the body preferentially uses glucose from the blood due to it being a faster fuel source.
- Post-training/competition — ingested in a timely manner, aims to optimise recovery following the exercise session.

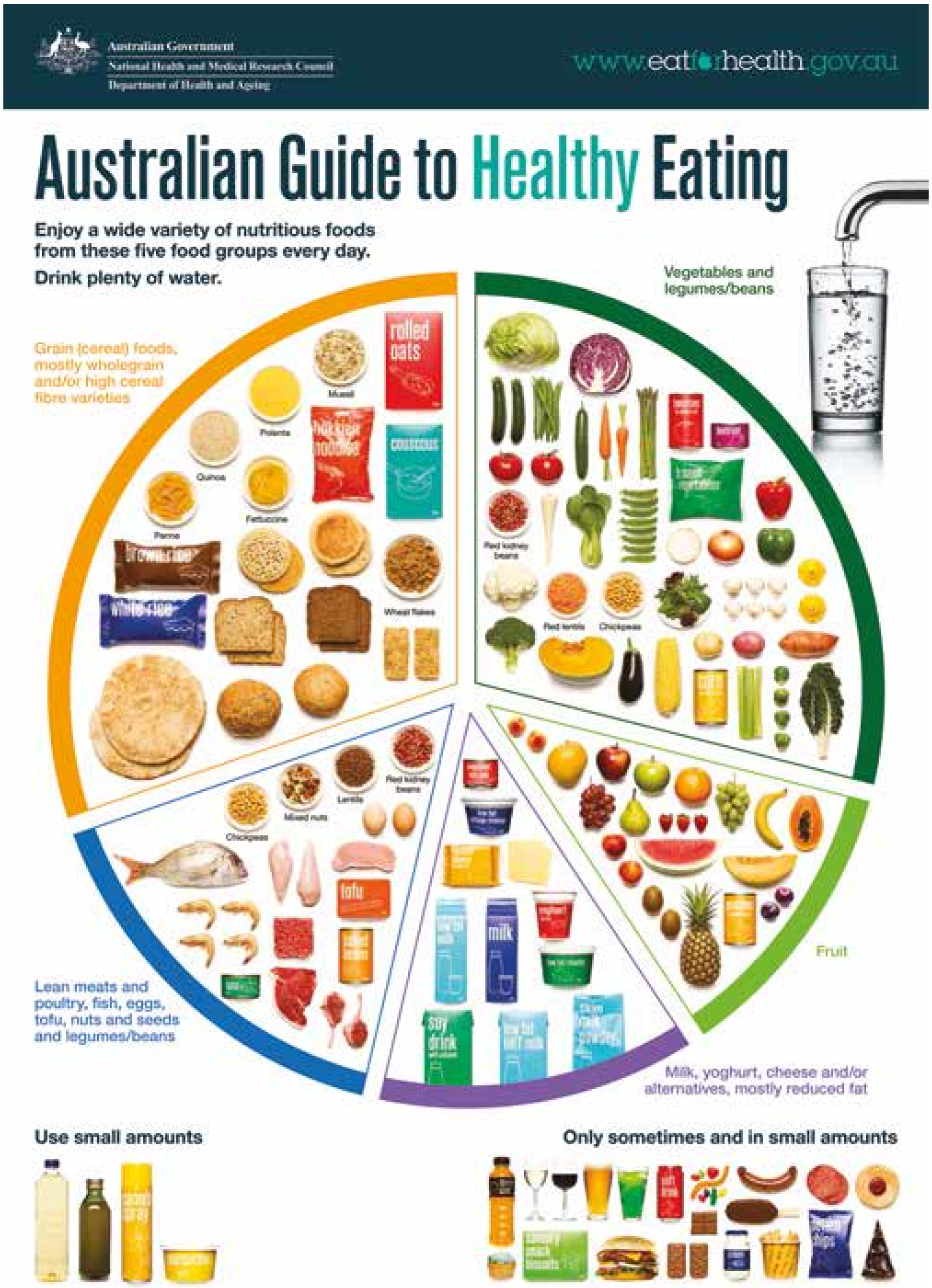


FIGURE 13.1 The Government's Guide to Healthy Eating

Source : https://www.eatforhealth.gov.au/guidelines/australian-guide-healthy-eating

TEST your understanding

1. List the essential nutrients required by all athletes for a balanced diet.
2. Outline what an athlete should consider when developing their own individual eating plan.
3. Outline the general purpose of nutritional and hydration strategies before, during and after training/competition.

13.2 Nutritional needs of athletes: carbohydrates

KEY CONCEPT Effective carbohydrate recovery strategies are essential and play a vital role in exercise performance as carbohydrates are the most preferred and readily available source of energy to fuel working muscles.

studyon

Unit 4	**Carbohydrates in recovery**
AOS 2	Summary screen and practice questions
Topic 5	
Concept 6	

Carbohydrates

Carbohydrates serve many functions:
- they are the major energy fuel source for high-intensity activities
- they regulate the metabolism of fat and protein
- the nervous system relies on them for energy in order to function
- they are broken down into glycogen to be stored in the liver and muscles
- they are transported via the bloodstream in the form of glucose.

How much carbohydrate?

Any excess carbohydrate, beyond what the muscles and liver can store, is converted to fat and therefore the amount of carbohydrate that an athlete consumes has a direct impact on the amount of muscle glycogen available for training and competition. Figure 13.2 shows that athletes who consumed a high carbohydrate diet (70 per cent of their daily intake) were able to recover their muscle glycogen storage to nearly optimum levels prior to their next two-hour training bout; whereas when the same athletes consumed a low carbohydrate diet (40 per cent of their daily intake) they experienced accumulative decreases in muscle glycogen storage with each training bout.

The most important factor in relation to carbohydrate (CHO) consumption is the number of grams ingested.

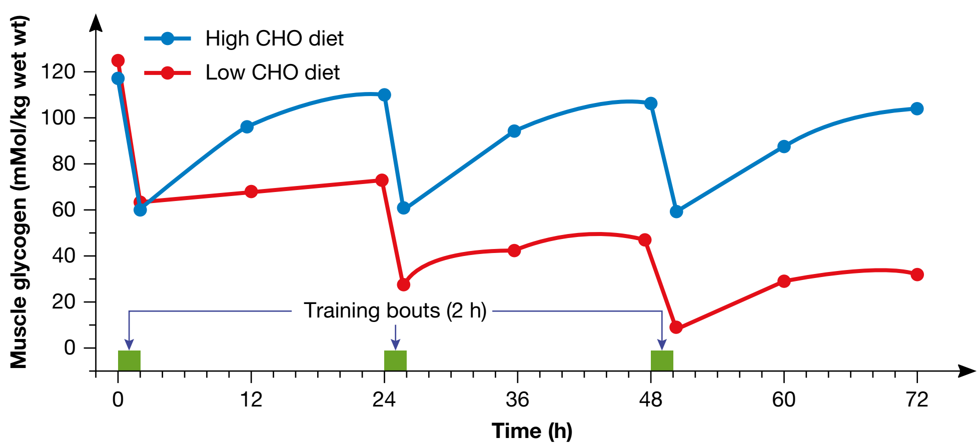


FIGURE 13.2 The influence of different carbohydrate diets on muscle glycogen stores during repeated days of training. (Adapted from Coston and Miller 1980.)

A general guideline of 7–10 grams of carbohydrate per kilogram body mass (BM) is appropriate for an athlete. This can be achieved by planning meals to ensure this target level is met. Table 13.1 is a guide to carbohydrate intake for the athlete.

The carbohydrate needs of an athlete are dependent on the training and competition that they undertake. The frequency, duration and intensity of the activity session all contribute to determining an athlete's fuel needs. These needs may change daily. On days where the athlete undertakes high activity levels, more carbohydrates should be consumed and conversely for low activity level days. Because of the importance of carbohydrate as a fuel for providing energy, athletes need to continually top up glycogen stores by consuming carbohydrates to ensure there is enough in the muscles before the start of training and competition. Add to this the body's limited capacity to store carbohydrates as glycogen, and you can see the importance of an athlete consuming carbohydrate before, during and after their performance in order to achieve optimal performance.

TABLE 13.1 Carbohydrate intake goals

Situation	Recommended carbohydrate intake
Daily refuelling needs for training programs less than 60–90 minutes per day or low-intensity exercise	Daily intake of 5–7 grams per kilogram BM
Daily refuelling for training programs greater than 90–120 minutes per day	Daily intake of 7–10 grams per kilogram BM
Daily refuelling for athletes undertaking an extreme exercise program: 6–8 hours per day (cycling tour)	Daily intake of 10–12 + grams per kilogram BM
Carbohydrate loading for endurance and ultra-endurance events	Daily intake of 7–10 grams per kilogram BM
Pre-event meal (meal eaten 1–4 hours pre-competition)	1–4 grams per kilogram BM
Carbohydrate intake during training sessions and competition events longer than 1 hour	1 gram per minute or 30–60 grams per hour
Rapid recovery after training session or multi-day competition, especially when there is less than 8 hours until next session	Intake of 1–1.5 grams per kilogram BM for every hour in the early stages of recovery after exercise, contributing to a total intake of 6–10 grams per kilogram BM over 24 hours

Application of the glycaemic index

The glycaemic index refers to a scale that ranks carbohydrates by how much they raise blood-glucose levels over a two-hour period compared with pure glucose. Foods are ranked from 0 to 100. Foods that have a high glycaemic index (70 and above) are digested quickly, resulting in a rapid and high increase in blood-glucose levels. On the other hand, foods with a low glycaemic index (55 and less) are digested more slowly, resulting in a more gradual and less rapid rise in blood-glucose levels (see figure 13.3).

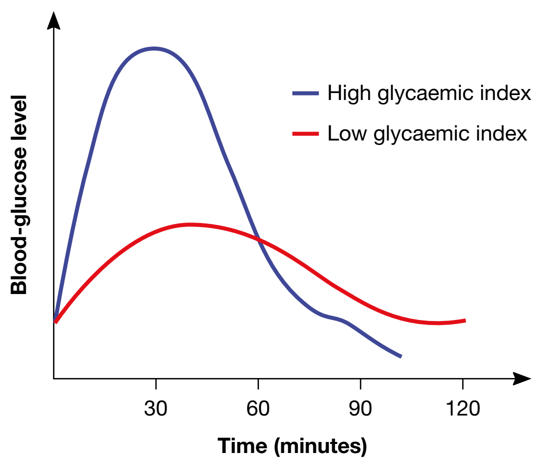


FIGURE 13.3 Rate of release of glucose for foods with a high and low glycaemic index

Knowledge of the glycaemic index allows athletes, coaches and sports dietitians to determine what carbohydrate foods to eat and when to eat them. Manipulated correctly, this can enable the athlete to optimise their carbohydrate availability and thereby optimally enhance their performance and recovery. Put more simply, there would appear to be times when foods with a low glycaemic index provide an advantage, and times when foods with a high glycaemic index are better. For best performance, athletes need to understand which foods have high and low glycaemic index ratings and when it is best to eat them. The athlete should use their individual experience and preference to guide their choice of pre-event meal.

It is important to understand that any food consumed is only useful once it has been digested and absorbed. The athlete should always consider their specific dietary requirements and look at the whole nutritional makeup of the food rather than just the carbohydrate component.

TABLE 13.2 The nutritional classification of carbohydrates — Australian Institute of Sport

Category	Description	Examples	Use for athletes
Nutrient-dense carbohydrate	Foods and fluids that are rich sources of other nutrients including protein, vitamins, minerals, fibre and antioxidants in addition to carbohydrate	Breads and cereals, grains (e.g. pasta, rice), fruit, starchy vegetables (e.g. potato, corn), legumes and sweetened low-fat dairy products	Everyday food that should form the base of an athlete's diet. Helps to meet other nutrient targets
Nutrient-poor carbohydrate	Foods and fluids that contain carbohydrate but minimal or no other nutrients	Soft drink, energy drinks, lollies, carbohydrate gels, sports drink and cordial	Shouldn't be a major part of the everyday diet but may provide a compact carbohydrate source around training
High-fat carbohydrate	Foods that contain carbohydrate but are high in fat	Pastries, cakes, chips (hot and crisps) and chocolate	'Sometimes' foods best not consumed around training sessions

Source: www.ausport.gov.au

Rebound hypoglycaemia is low blood glucose followed by a rapid rise of blood glucose.

Some research indicates that there is a potential disadvantage in consuming carbohydrates before exercise. **Rebound hypoglycaemia** is when a rise in blood insulin levels suppresses the use of fat as an energy supply and makes the muscles rely more on carbohydrate for fuel. If this happens, the result is that there will also be a drop in blood-glucose levels in the initial stages of exercise. Based on this theory, there is some evidence to suggest that the pre-event meal should consist of low glycaemic index ranked foods as these types of carbohydrates will prolong the use of glycogen stores and reduce the likelihood of rebound hypoglycaemia occurring.

- **Pre-exercise** meals may provide an opportunity for athletes competing in longer duration events (> 90 minutes) to increase their fuel storage.
- **During exercise** carbohydrates should be consumed regularly throughout the activity as this is an effective way to enhance endurance and performance. High glycaemic index ranked foods are recommended to be consumed during exercise as these types of foods are rapidly digested and absorbed, and therefore are more readily available as an immediate energy source.
- **Post-exercise** meals should consist of high glycaemic index carbohydrates to promote muscle glycogen resynthesis.

In more general dietary terms, athletes should aim to shift their daily nutritional choices towards consuming more foods with a low glycaemic index. There are many benefits of a low glycaemic index diet, including:

- lowered lipid (fat) levels in the blood
- assistance with weight control
- decreased risk of heart disease
- decreased risk of diabetes.

Table 13.3 gives some examples of the glycaemic index of particular foods.

TABLE 13.3 Average glycaemic index of some common carbohydrate-rich foods

	Food	Glycaemic index (glucose = 100)
High glycaemic index	Rice crackers	87
	Cornflakes	81
	Porridge, instant oats	79
	Potato, boiled	78
	Watermelon	76
	White bread	75
	White rice, boiled	73

Moderate glycaemic index	Popcorn	65
	Sweet potato, boiled	63
	Honey	61
	Soft drink	59
	Pineapple	59
	Muesli	57
	Porridge, rolled oats	55
Low glycaemic index	Sweetcorn	52
	Pasta, white	49
	Orange	43
	Chocolate	40
	Milk, full fat	39
	Apple	36
	Lentils	32

Source: Copyright ©2008 American Diabetes Association. From: *Diabetes Care*, December 2008, 31: 2281–2282. Reprinted with permission from The American Diabetes Association.

The **Glycaemic index** weblink in your eBookPLUS also allows you to search the particular blood-glucose rankings of certain foods.

Other personal factors (e.g. taste and palatability, convenience and portability, cost, ease of preparation) may also have an impact in making nutritional choices. These will be specific to the individual and their exercise situation.

In summary, knowledge and application of the glycaemic index can help to optimise performance and recovery. It is therefore advisable that athletes and coaches understand the different types of carbohydrates and how the body metabolises them.

eBook*plus*

Weblink
Glycaemic index

Carbohydrate gels

The following information about carbohydrate gels is provided by the Australian Institute of Sport through its website.

Carbohydrate gels

Supplement overview

- Highly concentrated source of carbohydrate (65–70 per cent) in easily consumed and quickly digested gel form
- Substantially more concentrated in carbohydrate than sports drinks to provide a large fuel boost in a single serve
- High cost alternative to other suitable foods and fluids, and should therefore be used only in specific situations for which they are most suited, rather than as a general snack

Supplement profile

- Gels deliver a substantial carbohydrate serve in a compact and easily consumed form. They may provide a practical way to carry or consume carbohydrate in a number of sports or environments.
- Some brands of gels also contain other compounds such as medium chain triglycerides (MCTs) and caffeine. Athletes should note that intake of large amounts of MCTs (e.g. > 25 grams) may lead to gastrointestinal problems.

Situations for use in sport

- Compact fuel source for endurance athletes during exercise lasting longer than 90 minutes, especially where it is impractical to carry large amounts of sports drinks (i.e. cyclists, triathletes)
- Compact fuel source for team sports athletes during breaks in play during extended training or competition sessions
- Compact and portable source of carbohydrate for post-exercise recovery when regular foods are not tolerated by the athlete
- Low-fibre and compact pre-event snack for athletes unable to tolerate regular foods and fluids

FIGURE 13.4 Carbohydrate gels *(continued)*

(continued)

Concerns associated with supplement use

- Gastrointestinal intolerance may occur due to concentrated carbohydrate load.
- Sports gels should always be consumed with adequate fluid to meet hydration needs.
- Athletes should practise use of gels and assess tolerance during training sessions if they are intended for use during competition.
- Gels may lead to over-consumption and over-reliance on low-nutrient carbohydrate sources.
- Gels are an expensive alternative to regular food and fluid choices. This supplement should only be used for specific conditions for which it is suited, rather than as a general snack.
- Some gels contain other compounds such as medium chain triglycerides (MCTs) and caffeine. Athletes should be aware that intake of large amounts of MCTs (e.g. > 25 grams) may lead to gastrointestinal problems.

Source: Australian Institute of Sport website.

Carbohydrate gels are concentrated carbohydrates and, to be effective, they must be consumed with water. Gels provide similar benefits as sports drinks (when taken with water) and should be consumed in the same circumstances: during exercise, sports and events lasting more than an hour. Gels and sports bars taken together should be avoided when high sweat rates occur because of the large increase in carbohydrate concentration and resultant slowing of hydration rates. The use of carbohydrate gels during exercise is to supplement the carbohydrate supply for muscular activity. It is used as an immediate fuel source directly from the bloodstream to resynthesise ATP.

FIGURE 13.5 A convenient way for athletes to maintain adequate carbohydrate supplementation during performance is with carbohydrate gels and bars that have a moderate to high glycaemic index.

TEST your understanding

1 Carbohydrates are broken down into simpler forms to be transported and stored in the body. Name these forms and where they are found.
2 (a) State the percentage of carbohydrate intake recommended daily for most athletes.
   (b) How much carbohydrate should an athlete consume per kilogram body mass?
3 Define the term *glycaemic index*.
4 Discuss how knowledge of the glycaemic index of foods can help an athlete.
5 Explain why some research suggests that foods with a low glycaemic index are more appropriate for pre-event meals.
6 (a) Identify the general ingredients of carbohydrate gels.
   (b) Identify some sporting situations where carbohydrate gels may be used.

APPLY your understanding

7 Using the **Eat like an athlete** weblink in your eBookPLUS, listen to Michael William's ABC radio interview with Professor Louise Burke (Head of Sports Nutrition — AIS).
   (a) Explain what Professor Burke means when she says that it is a team approach to the athlete's success.
   (b) Explain what is meant by the theory of fat adaptation. What are the consequences for athletes in adopting this type of diet?
   (c) Outline two important aspects about carbohydrates that Professor Burke discusses.
   (d) Describe what she means by carbohydrates being 'more economical'.
   (e) Explain why Professor Burke states that carbohydrates are important for high intensity exercise.
   (f) Outline why 'one size fits all' is a very simplistic approach to nutrition.
   (g) Explain why it is important to take into account the training goals of an athlete and provide some specific examples as to different approaches to particular athlete diets.
   (h) Outline how Professor Burke nutritionally prepares race walkers for their competition.
   (i) Discuss Professor Burke's underlying principles for good nutrition.
8 Consider the nutritional requirements for your particular sport and explain how carbohydrates should be appropriately incorporated into your dietary plan.
9 **Practical activity: dietary intake record**
   (a) Record your dietary intake for one day.
   (b) Use the **Glycaemic index** weblink in your eBookPLUS to identify the glycaemic index ranking of each food and liquid item consumed.
   (c) Classify each carbohydrate food item or liquid as nutrient-dense carbohydrate, nutrient-poor carbohydrate or high fat carbohydrate.

EXAM practice

10 **ACHPER Trial Exam 2014, question 9**
Marathon runners are often encouraged to consume both high glycaemic index (GI) foods and low GI foods. Outline the most appropriate time a marathon runner should utilise each type of GI food. **2 marks**

eBook*plus*

Weblinks
Eat like an athlete
Glycaemic index

13.3 Nutritional needs of athletes: protein

KEY CONCEPT Protein is required in the athlete's diet to assist in recovery and in optimising performance in a variety of ways.

studyon
Unit 4
AOS 2
Topic 5
Concept 7
Protein in recovery
Summary screen and practice questions

Protein

Protein has several important functions in the body. These include:
- muscle construction and repair
- promoting glycogen resynthesis
- playing an important role in the immune system
- facilitating the transmission of nerve impulses throughout the nervous system
- preventing sports anaemia (low iron) by promoting an increased synthesis of haemoglobin, myoglobin and oxidative enzymes.

Protein is broken down through digestion into amino acids, of which there are two types:
1. *essential amino acids* — cannot be made by the body, so must be consumed
2. *non-essential amino acids* — can be made from other amino acids in the body.

Animal foods such as meat, poultry, fish, eggs and dairy food are rich in protein and contain all the essential amino acids. Plant foods such as breads, breakfast cereals, grains, lentils, beans and peas are good protein sources, but they miss at least one essential amino acid so they should be eaten with other plant or animal sources.

Proteins can also be classified as:
- structural proteins, which are needed to build connective tissue, cell membranes and muscle cells
- regulatory proteins, which act as enzymes or transport vehicles.

Both endurance and muscle strengthening exercises stimulate muscle protein synthesis and therefore the role of protein in both type of activities is important.

How much protein?

Protein is an important part of an athlete's diet as it plays a key role in post-exercise recovery and repair. Nutritionists recommend that protein contributes up to 15 per cent of total daily food intake; however, strength and endurance athletes may require additional volume of protein for growth of muscle tissue as a consequence of their training. Most athletes would meet their daily protein requirement just through consuming a balanced diet. It has been found that additional amounts of protein are naturally ingested when the athlete increases their food intake in response to an increased training load. This is because many high-carbohydrate foods are also rich in protein; for example, bread, rice, pasta and baked beans. A guideline of 1–2 grams of protein per kilogram of body mass (BM) is recommended depending on the type of activity the athlete is participating in. Table 13.4 provides a specific guide for protein requirements for different athletes.

Research conducted at the Australian Institute of Sport (AIS) suggests it is not necessarily the increased amount of protein that can lead to gains in lean-muscle tissue, but rather the timing of the protein intake for the athlete. There is a constant balance between protein breakdown and protein rebuilding in the muscles. It is important that athletes consume foods that contain protein (amino acids) as part of their post-training or post-competition recovery process. Following intense exercise, muscle protein is actually being broken down as a result of catabolic micro-trauma due to the demands of the exercise. Consumption of protein immediately after exercise is essential in order to reverse this negative protein balance. By consuming protein post exercise, muscle uptake and retention of amino acids is enhanced and appears to continue to be enhanced for up to 24 hours. Therefore, athletes should continue to consume protein throughout the day as well as immediately after exercise.

TABLE 13.4 Maximum protein needs for different groups of athletes

Group	Protein intake (g/kg/day)
Sedentary men and women	0.8–1.0
Elite male endurance athletes	1.6
Moderate-intensity endurance athletes*	1.2
Recreational endurance athletes**	0.8–1.0
Football players, power sports athletes	1.4–1.7
Resistance athletes (early training)	1.5–1.7
Resistance athletes (steady state)	1.0–1.2
Female athletes	Approximately 15 per cent lower than male athletes

*Exercising approximately four to five times per week for 45–60 minutes
**Exercising four to five times per week for 30 minutes at < 55 per cent VO_2 max.

Protein and carbohydrates

When protein and carbohydrates are consumed together, they stimulate a greater release of insulin, which enhances amino acid uptake and promotes glucose delivery to depleted muscle cells. Research suggests that a 1:4 ratio of protein to carbohydrates is the most effective combination to support glycogen replenishment immediately post-exercise.

Insulin also plays a key role in the dynamics of protein synthesis. Insulin stimulates protein synthesis and helps to reduce protein breakdown and enhance skeletal muscle protein remodelling. Given the complementarity of these nutrients, in order for athletes to maximise their post-exercise recovery, they should ingest both carbohydrate and protein, both of which are important to rapidly restore muscle function and performance.

The consumption of protein is therefore essential on two fronts — to help boost insulin release and therefore restore muscle glycogen levels, and to provide the basic building blocks for muscle repair. Examples of good snacks that include both protein and carbohydrates include:

- yoghurt
- milk drinks
- fruit smoothies
- lean meat or cheese sandwiches.

High-protein, low-carbohydrate diets have been quite popular, but research suggests that protein consumption well above recommended intakes (> 2 grams per kilogram BM) does not stimulate further muscle building or recovery and is not recommended by sports dietitians. In fact, extra consumption simply increases

FIGURE 13.6 Foods that provide both protein and carbohydrates are excellent for post-exercise nutrition.

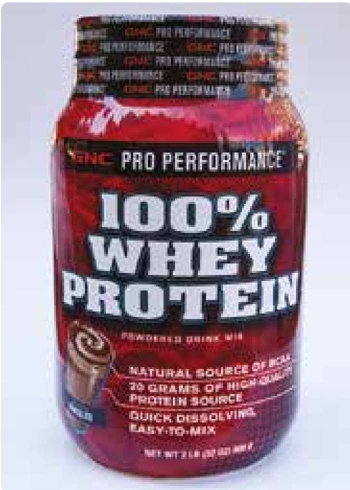


FIGURE 13.7 Whey protein is one of the popular nutritional supplements used by many athletes.

eBook*plus*

Weblinks
Protein intake for optimal muscle maintenance
Protein supplementation

the use of protein as a fuel and may displace other important nutrients, such as carbohydrates, from the athlete's diet. Some health risks might also be associated with excessive protein intake because of the extra demand placed on the kidneys to excrete any unused amino acids. Furthermore, excessive protein intake can compromise bone density and may also lead to weight gain if food choices are also high in fat.

Protein supplementation

Protein and amino acids are popular nutritional supplements used by many athletes. As previously discussed, ingestion of protein with carbohydrates immediately post exercise enhances the synthesis of glycogen and stimulates muscle protein synthesis, which is important in terms of post-exercise recovery from catabolic micro-trauma, and aids in muscle growth as part of the adaptive process. The most common forms of supplementation are protein powders made into shakes and protein bars.

It is interesting to note that current nutritional guidelines do not foresee the need for protein supplements for athletes, and research suggests supplements offer no advantage over consuming protein-rich foods as part of a balanced diet. However, athletes may require a supplement when consumption of food is difficult post exercise and products such as liquid meal supplements offer convenience and a practical solution to consuming adequate protein.

While supplements containing amino acids are popular among strength and endurance athletes, claims of their benefits remain unproven. It is important to note that excess proteins cannot be stored and are broken down and excreted — large quantities may place a significant strain on the kidneys.

The ACSM outlines specific protein recommendations in relation to resistance training (see the **Protein intake for optimal muscle maintenance** weblink in your eBookPLUS).

Sports Dietitians Australia provides some information about protein supplementation (see the **Protein supplementation** weblink in your eBookPLUS).

TEST your understanding

1. List the functions of protein in the body.
2. Protein is broken down into a simpler form to be transported and stored in the body. Name this form and where it can be found.
3. (a) State the percentage of protein intake recommended daily for athletes.
   (b) How much protein should an athlete consume per kilogram body mass?
4. Identify the best time for an athlete to consume protein. Explain why.
5. Explain the benefit of consuming protein with carbohydrates post exercise.

APPLY your understanding

6. Create a table summarising the nutritional needs of athletes (sections 13.2 and 13.3). Include the following information:
   - transported as nutrient
   - stored as
   - common food source
   - percentage total daily intake
   - recommended consumption per kilogram body mass
   - predominant energy supply (exercise type).
7. For each of the following, provide examples of food that would assist the athlete's nutritional and energy needs.
   (a) 100-metre sprinter
   (b) Marathon runner
   (c) Team sportsperson (60–90 minutes' duration)
8. (a) Access the **Protein supplementation** weblink in your eBookPLUS to compare and contrast two different protein supplements using a Venn diagram.

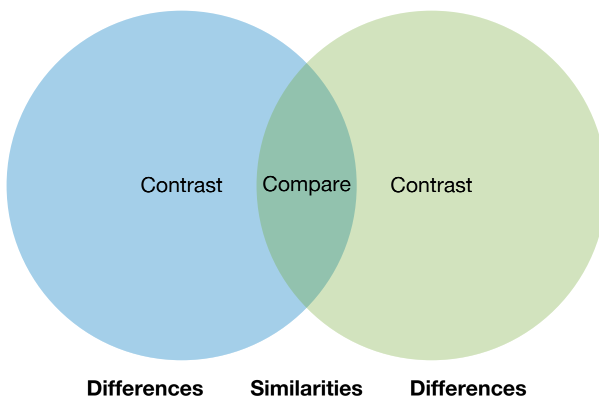


FIGURE 13.8 Sample Venn diagram

   (b) From your analysis, justify whether you think protein supplementation should be recommended for any particular type of athlete.

9 Use the **Protein intake for optimal muscle maintenance** weblink in your eBookPLUS to read the ACSM fact sheet.
(a) Explain the process of protein turnover and how is it affected by resistance training.
(b) Outline the recommendations in relation to protein intake for a person who lifts weights regularly or is training for a running or cycling event.
(c) Explain how exercising on an empty stomach affects the level of protein storage.
(d) List the suggested benefits of pre-exercise protein supplementation.
(e) Describe the role of protein ingestion following an acute bout of resistance training.
(f) Explain the roles of different types of proteins in relation to performance.

10 **Practical activity: food and drink journal**
Complete your own food and drink journal over a typical 24-hour period, using the example below as a guide. (Remember, some foods will fit into more than one group.) Analyse your diet and answer the following questions.
(a) Review your journal example in comparison to the Australian Guide to Healthy Eating (see figure 13.1).
(b) Did you neglect a particular food group? If yes, how could you incorporate it in your diet?
(c) If you were going to compete in a 10-kilometre run tomorrow, how would you change your daily eating plan?

EXAM practice

11 **ACHPER Trial Exam 2012, question 12**
Protein is a vital component in an athlete's diet.
(a) Name two foods that are a high source of protein. **2 marks**
(b) Outline two roles that protein plays in exercise recovery. **2 marks**
(c) Describe one situation in which protein may be used during exercise as an energy source. **1 mark**
(d) Research indicates that using protein as an energy source during exercise may be detrimental to performance. Outline the reason for this. **2 marks**

My food and drink journal **Date: ....**

	Number of serves										
		Nutritious carbohydrate									
	Fluid	Breads, cereals and grains	Vegetables	Fruit	Milk and milk products	Meat and meat alternatives	Fat and oil	Sugar	High-fat carbohydrate	Fibre	Other
Breakfast											
Morning tea											
Lunch											
Afternoon tea											
Dinner											
Other snacks											
TOTAL											

13.4 Nutritional recovery in relation to the type of sport or activity

KEY CONCEPT Type and timing of food and drink consumed is extremely important and athletes must consider their post-event meals in relation to the requirements of their sport.

As athletes often train for many hours, and generally more than once a day, each meal must be considered carefully to ensure that all nutritional requirements are met and the athlete is ready to train or compete again. Athletes must avoid chronic carbohydrate depletion, as it will impair both training adaptation and competition performance. Recovery is essential for successful athletic outcomes. Athletes need to learn specific nutritional strategies to enable them to reach optimal performance levels, in both training and competition.

Athletes must strive to maintain optimal work output and avoid fatigue caused by inadequate or inappropriate nutrition. The following factors can cause nutrition-related fatigue in an athlete:

- depletion of glycogen stores
- hypoglycaemia (low blood-glucose levels)
- dehydration
- low blood-sodium levels
- gastrointestinal upset.

Athletes should undertake a nutritional strategy specific to their training or competition needs. They should also consume foods and fluids that are well tolerated, tried and tested. Their strategy must include recovery meals as well as re-hydration procedures.

Nutritional preparation and type of sport

If athletes are adequately fuelled and hydrated prior to and during their event then the recovery process is achieved more easily. The ability of an athlete to recover in order to perform at their optimum during their next training session or competition relies on them undertaking effective nutritional and hydration recovery practices.

FIGURE 13.9 Usain Bolt, Jamaican 100-metre sprinter. Athletes competing in short-duration, high-intensity sports do not require increased carbohydrate consumption, as their main fuel source comes from creatine.

Nutritional preparation for shorter-duration sports

As fatigue is not usually caused by glycogen depletion during high-intensity sports that last for less than 60 minutes, there is little need to fuel during the event; however, there is evidence to suggest fuelling during events 30 minute plus can be beneficial as it provides the brain with food, or a feed-forward mechanism to increase rate of neural firing and thus aid in maintaining intensity and preventing fatigue. The athlete should ensure that glycogen stores are replenished afterwards so that full storage of carbohydrate is available for the next training bout or performance. Fluid replacement is the main concern and should match fluid loss. Water is adequate for short-duration activities; however, recent studies have suggested that sports drinks containing carbohydrates are useful and may be more palatable.

Nutritional preparation for moderate-intensity or intermittent sports

Intermittent or team sports lasting 60–90 minutes can be fuelled by 'normal' glycogen stores in most well-trained athletes.

Nutritional preparation for prolonged submaximal events

To maximise glycogen stores, endurance athletes competing in events lasting longer than 90 minutes — for example, marathons, triathlons and cross-country skiing — need to consume additional carbohydrate before the event. This process is known as **carbohydrate loading**.

Well-trained endurance athletes are already at an advantage because aerobic endurance training trains the muscles to store greater amounts of glycogen and to use it sparingly during aerobic exercise by increasing fat mobilisation (glycogen sparing). Carbohydrate loading can increase stores of muscle glycogen by 50–100 per cent above normal resting levels.

During the event, consumption of 30–60 grams of carbohydrate per hour, as well as fluid replacement, is encouraged.

Carbohydrate loading involves the manipulation of training and nutrition prior to endurance events to maximise muscle glycogen (carbohydrate) stores.

FIGURE 13.10 Simon Gerrans followed closely by Richie Porte trying to catch Cadel Evans on Corkscrew Road at Stage 3 of the Santos Tour Down Under. Amounts of carbohydrate should be consumed immediately after participating in such prolonged submaximal sporting events.

It is important to note that food consumed before exercise is only useful once it has been digested and absorbed. This means athletes need to time their carbohydrate intake so they allow time for it to be stored as glycogen and available as a muscle fuel during the exercise bout.

Fuelling during exercise

Carbohydrate and fat are the most common fuels used by athletes. Sports lasting less than 90 minutes can be adequately fuelled from stored carbohydrate and fat without the need to replenish these fuels during the actual event. However, some level of fatigue may occur and refuelling via drinks containing carbohydrate, such as sports drinks, is recommended.

Sports that last longer than 90 minutes may benefit from the consumption of carbohydrate during the activity and high GI carbohydrates are the best to be ingested at this time. Consumption of carbohydrate can keep blood-glucose levels within 'normal' range, therefore providing extra immediate fuel sources and delaying fatigue. Sports Dietitians Australia recommends that athletes start refuelling early in the event and consume 30–60 grams of carbohydrates that have a moderate to high glycaemic index per hour to adequately refuel. Some examples of suitable foods that provide 60 grams of carbohydrates include:

- two large bananas
- one and a half sports bars
- 95 grams of jelly beans
- one jam sandwich.

The combined refuelling of carbohydrate with fluid replacement is also sound practice for athletes to follow. **Carbohydration**, as the practice is known, meets the refuelling requirements outlined above, and at the same time replaces any fluids lost through sweat. Commercially available sports drinks such as Gatorade and Powerade promote both rehydration and the replenishing of fuels. Athletes should strive to replace approximately 500–1000 millilitres of fluid per hour, although individual variations must also be catered for.

Carbohydration is the combination of hydration with the replenishing of carbohydrate lost during activity, in order to avoid dehydration.

TABLE 13.5 Suggested fuelling during exercise

Type of exercise	Refuelling suggestion
Intermittent team sports lasting 60–90 minutes	• Recent studies have found that intermittent team sports may benefit from consumption of carbohydrate during the game as it is said to delay fatigue, prevent low blood-glucose levels and promote glycogen sparing.
Endurance events > 90 minutes	• As there is no indefinite supply of glycogen within the muscles or liver, carbohydrate refuelling is advised at a rate of approximately 30–60 grams per hour, or 500–1000 mL of a sports drink, or 10–20 jelly beans. (This is dependent on the individual athlete and will be determined following specific experimentation and consideration of environmental factors such as heat.) • Sports drinks, bananas, sports bars or sugar confectionery such as jelly beans are highly recommended, although ultimately it is the choice of the athlete as to which foods are most comfortable to ingest while competing.
Ultra-endurance events > 4 hours	• Typically these athletes compete at a lower intensity than most team sports or short-distance events. This allows digestion to take place while competing, so the athlete can consume small amounts of solid foods. • High-carbohydrate foods, in conjunction with small amounts of protein and fat, are advised for the ultra-endurance athlete. Muesli bars, sports or breakfast bars and jam sandwiches are a good choice for ingestion during performance. • Hydration must also be addressed throughout the event. Carbohydration is beneficial in these events as well.

FIGURE 13.11 Athletes commonly consume bananas in order to 'top up' blood-glucose levels during endurance events.

Nutrition and recovery from exercise

The importance of carbohydrate and protein consumption post-exercise has already been discussed earlier in this chapter, however athletes must restore muscle and liver glycogen stores as quickly as possible, as well as rehydrate. Immediately post-exercise is when the rate of glycogen synthesis is at its greatest. The key to a speedy recovery of muscle glycogen is to eat immediately after exercise. The post-exercise period is considered to be the most critical part of nutrient timing. Consuming the proper ratio of nutrients during this time enhances the rebuilding of catabolic muscle microtrauma and restores energy reserves.

Studies have shown that an athlete should consume carbohydrate-rich foods and drinks that provide at least 1 to 1.5 grams of carbohydrate for each kilogram of body mass within 30 minutes after exercise. It does not matter if this is in the form of a full meal or just a snack. It seems that in the initial couple of hours following exercise, the muscle is more receptive to restoring greater amounts of carbohydrate. Athletes must take advantage of this time period. In addition, researchers have found that foods with a high glycaemic index may be a better choice for fast glycogen replenishment.

The main points for consideration for post-exercise nutrition include the following:

- Consuming high glycaemic ranked carbohydrates will allow for a faster absorption and resynthesis of glycogen in the muscle and liver.
- The consumption of carbohydrates should occur within the first 30–60 minutes post-exercise when the muscles are most receptive to converting glucose to glycogen.
- A high carbohydrate diet should be maintained in the 4–6 hours following exercise so as to further enhance glycogen resynthesis.
- The consumption of both carbohydrate and protein post-exercise will enhance the nutritional recovery process due to the increased presence of insulin, which stimulates muscle growth and also the uptake of glycogen into the muscle cells.
- The appropriate post-exercise nutrition will also support the immune system.

Combining carbohydrates and protein (1:4) for enhanced recovery

Carbohydrates provide a source of glucose in the blood for the recovery of fuel stores, whereas protein provides a source of amino acids for the recovery of catabolic microtrauma within the muscle cells. These two macronutrients work in synergy to enhance the recovery process. The glucose and amino acids together stimulate the production of insulin, which in turn acts as a very powerful anabolic hormone to increase the uptake of amino acids and enhance muscle recovery and growth. The combination of quick-absorbing carbohydrate (high GI) and fast-digesting protein (whey protein) sources is the best recovery combination. A protein–carbohydrate snack after exercise allows for the muscle repair and anabolic adaptation to training to occur and also the restoration of muscle glycogen levels.

High performance chocolate milk: why most sports supplements are more spin than substance

BY BRIANNA NEWLAND

Unfortunately, in their efforts to surpass the competition, product marketers have created so much clutter and mixed messaging that endurance athletes struggle to understand what product is best (or even necessary). For example, marketers have convinced athletes that leading and expensive post-exercise recovery drinks are superior to and enhance performance better than a more cost-effective chocolate milk option found at your local grocer. Rather, the truth is chocolate milk is an effective supplement for endurance athletes.

Recent exercise science research has shown that endurance athletes receive optimal recovery from nutrition with a balance of the macronutrients protein, carbohydrate and fat.

In addition to replenishing glycogen stores, endurance athletes must also consider electrolyte replacement. Until recently, Gatorade — arguably the leader in this realm — for example, has only provided the athlete with a sugary electrolyte replacement with no protein option. Gatorade's 'G Series' now includes protein recovery products.

Unbeknown to most athletes, the low-fat chocolate milk option not only provides a rich source of protein, but also the valued electrolytes necessary for rehydration. But it's not just about what athletes should be using, but also the timing for when it is consumed. The timing of consumption in order to support performance is heavily researched and debated. While this has had incredible impact in the sport science world, it can certainly add to confusion among consumers who don't understand the science (or the debate) within the sport science community.

Source: www.theconversation.com, 11 May 2013.

Recovery nutrition to support the immune system

Intensive training causes the suppression of the immune system and this continues in the hours following the training or exercise bout. During this time, athletes have a greater susceptibility to illness. Consuming adequate levels of the micronutrients vitamin C and E, glutamine, zinc and probiotics has been thought to reduce the risk of illness; however, ensuring the consumption of adequate carbohydrates before, during and after prolonged or high-intensity exercise has been found to reduce the immune system susceptibility. Carbohydrates reduce the stress hormone response and also supply fuel to the immune system white cells.

TEST your understanding

1 List the factors that can cause nutrition-related fatigue in an athlete.
2 Compare the differences in fuelling for events of differing durations.
3 With reference to the glycaemic index, identify the types of foods that should be consumed pre-event, during the event and post-event.
4 Define carbohydration.
5 Outline the role of carbohydrates in supporting the immune system during recovery.

APPLY your understanding

6 The modern pentathlon is an Olympic sport that consists of five different events: fencing, 200 metres freestyle swimming, show jumping, pistol shooting and a 3200 metre cross-country run. All events are completed in one day. Consider the specific recovery nutritional strategies Chloe Esposito may have used to perform at her optimum and win gold at the Rio 2016 Olympic Games.

FIGURE 13.12 Chloe Esposito won gold for Australia in the modern pentathlon at the Rio Olympic Games 2016.

7 **Practical activity: nutritional needs**
(a) Select two different sports from the range of fact sheets listed on the **Sports diet** weblink in your eBookPLUS, providing information on nutritional recommendations.
(b) Research the nutritional needs of both of the sports selected by referring to the following:
– characteristics of the sport
– common nutrition issues
– training diet
– fluid needs
– pre-event requirements
– requirements during the event
– recovery
– other nutrition tips.
(c) Present your findings to the class in the form of two case studies.

eBook*plus*
Weblink
Sports diet

8 **Practical activity: diet of an athlete**
Interview an athlete in a sport of your choice, preferably someone performing at an elite or subelite level, with the aim of determining whether or not they have a dietary plan designed to enhance their level of performance and recovery. Determine whether the athlete has a specific dietary plan for training, competition and/or recovery.
After completing your interview, answer the following.
(a) Assess their current dietary plan. Determine whether this dietary plan is satisfactory for optimum performance in their sport, and for their recovery from training and competition.
(b) What modifications or suggestions would you make to improve their dietary plan?

EXAM practice

9 Lucy is training as a part of the women's eight rowing crew. Her training day typically consists of the following:

- Morning, water session — 90 mins/17–20 km long steady-state rowing
- Afternoon, dry land — rowing ergometer 4 × 25 min or 3 × 7 km, medium to high intensity
- Once a week she performs a test ergometer — 30 min max or 5 km max
- 3 × week she also undertakes resistance training.

Lucy's meal plan is listed in the table.

(a) Identify one food source rich in carbohydrate. **1 mark**

(b) Identify one food source rich in protein. **1 mark**

(c) Outline the role of protein in recovery. **2 marks**

(d) Research suggests that combining carbohydrate and protein post-exercise will enhance the recovery process. Identify the recommended ratio and discuss how combining the two macronutrients assists in the recovery process. **3 marks**

(e) An athlete undertaking an intense training program may be more susceptible to illness. Explain why this may be the case and outline how carbohydrates may help to reduce the risk. **4 marks**

Meal	Sample menu
Pre-workout (5:30 am)	1 apple + 2 tbsp peanut butter
Post-workout (9 am)	1 cup muesli + 1 banana + 1 tbsp honey + 1 plain greek yogurt + 1 small cup peanut butter + 1 tbsp sliced almonds
Pre-workout (1:00 pm)	2 whole eggs + 57 g smoked salmon + 1 whole wheat english muffin + 1 orange
Lunch (3:00 pm)	1 smoothie + ¾ cup cooked rice + 2 cups cooked broccoli + 1 small avocado + 4 oz chicken
Dinner (7:00 pm)	1 large green salad w/ 2 tbsp balsamic vinegar + 2 tbsp olive oil + 5 oz salmon + 1 cup acorn squash + 2 dark chocolate squares + 1 small plain greek yogurt + ½ cup raspberries

13.5 Hydration needs of athletes

KEY CONCEPT Adequate hydration allows an athlete to perform at an optimal level. Depending on the type and duration of activity, water and sports drinks can assist an athlete to remain hydrated.

More than half your body weight and over 70 per cent of your body mass is water. Each day the body needs to replace about 2 litres of fluid to balance what is lost (and this is not even accounting for fluid loss through sweating!).

Fluid serves many important functions:

- to transport energy, waste, hormones and antibodies
- to dilute waste products
- to lubricate surfaces and membranes
- to help regulate body temperature
- to be involved in all chemical reactions in the body.

Dehydration is the result of thermoregulatory fatigue. It is vital for athletes to ensure their fluid intake compensates for sweat lost during exercise. Performance has been shown to decrease as athletes become dehydrated, and extreme levels of dehydration can lead to life-threatening problems. It is important to develop good fluid intake practices before, during and after training and competition.

Dehydration is the deficiency in the body's fluid stores caused by the lack of fluid replacement demanded by physical activity.

How much fluid?

Sports dietitians suggest as a general guide that athletes should consume approximately 200–600 millilitres of fluid prior to their event, and that they should strive to replace approximately 500–1000 millilitres of fluid per hour during the actual event, although individual variations must also be catered for. Athletes should begin drinking early in exercise and consume small volumes (200–300 millilitres) every 15–20 minutes if possible.

Replacing body fluids lost during training or competition is an integral part of the recovery process. The amount of fluid needed to restore fluid levels may vary from 0.5 litres up to 3–4 litres, depending on how much fluid was lost during the exercise bout. In endurance exercise, as much as 6 litres, or the equivalent of 3–4 kilograms of body weight, can be lost through sweat and other mechanisms.

It is a good idea for an athlete to gain an understanding of their sweat rates during exercise so that the most appropriate hydration strategies can be followed to achieve optimum performance. It is not necessary for athletes to drink enough to prevent loss of body weight, but the amount of their dehydration should be limited to less than 2 per cent of body weight so as not to result in a decrease in performance.

Estimating sweat rate and loss during exercise

- Measure body weight (kg) both before and after at least one hour of exercise. The post-exercise reading should be taken as soon as is practical after the session, and after towelling dry.
- Note the volume of fluid consumed during exercise (litres).
- Calculations: Sweat loss (litres) = body weight before exercise (kg) − body weight after exercise (kg) + fluid consumed during exercise (litres)
- To convert to a sweat rate per hour, divide by the exercise time in minutes and multiply by 60.
- Post-exercise, athletes should aim to drink about 1.2–1.5 litres of fluid for each kg of weight lost during their training or competition.

As well as water, the body also loses some electrolytes (salts and minerals such as sodium and potassium) through sweating during exercise. These electrolytes also need to be restored.

While water itself is a suitable fluid replacement and is a good choice for sports lasting less than 60 minutes, it is not always the most efficient, especially if fluid losses have been high. In this case, specially formulated **sports drinks** can be a better option. Provided the concentration of these dissolved electrolytes and carbohydrate is appropriate, sports drinks can actually speed up the process of absorption (gastric emptying) and the retention of water in the body. As a rule, athletes should consume these drinks as soon as possible after exercise. However, the body may take from 4 to 24 hours to completely rehydrate, depending on the exercise undertaken. It is important to note that studies have shown fluid intake increases when drinks are cool, flavoured and contain sodium.

Sports drinks are specially formulated drinks in which carbohydrates and/or electrolytes are dissolved.

eBook*plus*

Weblink
Fuelling recovery: fluids in sport

Over-hydration: risky business!

Over-hydration is a serious condition with life-threatening complications and it can result from an athlete simply trying too hard to prevent dehydration. Hyponatremia (low blood sodium levels) is one of the most common complications associated with over hydration. Hyponatremia can develop from drinking too much fluid before, during, and even after the race. Inexperienced endurance athletes are generally the type of athlete most at risk of developing hyponatremia. When running at a slower pace they tend to have more opportunities to hydrate and are often naïve about the recommended fluid balance.

Signs and symptoms of hyponatremia

The signs and symptoms of hyponatremia are similar to those of dehydration; however, thirst will precede other symptoms of dehydration and therefore should be used as the distinction between the two.

Symptoms associated with hyponatremia include:

- disorientation
- confusion
- headache
- muscle weakness
- nausea and vomiting.

In severe cases, hyponatremia can progress to seizure, brain swelling, pulmonary oedema, coma, cardiorespiratory arrest or death. A 28-year-old woman died of hyponatremia after completing the 2002 Boston Marathon. Although hyponatremia is often associated with endurance athletes, any type of athlete is susceptible to the condition. A 17-year-old American high school footballer had complained of cramping during training. He had consumed 7.5 litres of water and a further 7.5 litres of Gatorade during and after training. He later collapsed at home and was taken to hospital where doctors say that he suffered massive swelling around the brain from over-hydration.

studyon

Unit 4 | AOS 2 | Topic 5 | Concept 5

Water in recovery
Summary screen and practice questions

Water versus sports drinks

In recent years, sports drinks have become increasingly popular as a means of replenishing fluid losses after exercise. Some well-known sports drinks include:

- Gatorade
- Isosport
- Lucozade Sport
- Powerade
- Staminade
- Endura.

FIGURE 13.13 Female athlete consuming a sports drink

- Sports drinks rehydrate, replace electrolytes and refuel carbohydrates.
- Electrolytes are used by muscle, nerve and cardiac cells to maintain voltages across their membranes and allow electrical messages to flow across them.
- The higher the carbohydrate levels in drinks, the slower the rate of stomach emptying.
- Electrolytes reduce urine output, enable fluid to empty quickly from the stomach, promote absorption from the intestine and encourage fluid retention.

When considering the advantages of sports drinks, it is important to recognise that there are three different types of sports drinks available on the market, all of which contain various levels of fluid, carbohydrate and electrolytes.

Types of sports drinks

Table 13.6 provides a summary of the three main types of sports drinks available on the market today.

TABLE 13.6 Types of sports drinks

Type	Content
Isotonic	Fluid, 6–8 per cent carbohydrate, 4–8 g of CHO per 100 mL
Hypotonic	Fluid, low level of carbohydrate (< 6 per cent), < 4 g of CHO per 100 mL (e.g. water)
Hypertonic	Fluid, high level of carbohydrate (> 8 per cent); > 8 g of CHO per 100 mL

Isotonic sports drinks

Isotonic sports drinks are the most widely used, and are the fluid replacement drink of choice for most athletes. These types of sports drinks offer a number of advantages over plain water.

First, the carbohydrate and electrolytes (particularly sodium) in these drinks provide flavouring and taste that can increase palatability and help to stimulate consumption. Second, the sodium also aids in the retention of consumed fluids within the intracellular spaces without inhibiting the thirst mechanism. Third, the carbohydrate aids in energy replenishment — another key aspect of the recovery process.

Isotonic sports drinks have relatively the same osmolality (a measure of the concentration of all chemical particles of a solution) as the body's own blood, containing between 4–8 g of CHO per 100 mL. An isotonic drink which has 4–8 per cent carbohydrate concentration provides a rapid delivery of fluid and fuel, and maximises the gastric tolerance and palatability for the athlete.

Hypotonic sports drinks

Hypotonic sports drinks act to quickly replace fluids and electrolytes lost through sweating. They have a low osmolality, containing the lowest concentration of carbohydrate and electrolyte particles. Hypotonic sports drinks are more diluted and therefore absorbed at a faster rate than ordinary water. Hypotonic drinks generally contain less than 4 g of CHO per 100 mL. They are most suitable for athletes who need fluid without the added boost of carbohydrate or electrolytes. These drinks are suitable for athletes such as jockeys who require fluid replenishment without the carbohydrate, or athletes competing in hot and humid environments where sweat losses are increased and re-hydration is the main priority.

Hypertonic sports drinks

Hypertonic drinks are usually consumed to help meet an athlete's energy requirements during and after prolonged endurance and ultra-distance events. They have a higher osmolality than the body's own blood, which means their absorption is slower than water. They generally contain > 8 g of CHO per 100 mL. They are ingested after exercise to resynthesise muscle glycogen stores, and during exercise to top up blood-glucose levels in order meet energy requirements. When consumed during exercise, hypertonic drinks should be ingested in conjunction with isotonic drinks or water to replace fluids effectively.

Sports Dietitians Australia outlines the following practical applications for consuming sports drinks.

1. **Before exercise**
   Sports drinks may be useful before an event to fine tune fluid and fuel (carbohydrate) intake. The carbohydrate in sports drinks can increase carbohydrate availability, while the added sodium may reduce urine losses before exercise begins.
2. **During exercise**
   Sports drinks are primarily designed for use during exercise lasting more than 90 minutes, by providing optimal fluid and fuel delivery. Sports drinks may allow athletes to perform for longer and more effectively in training and competition by providing energy to working muscles and the brain.
3. **Recovery**
   Sports drinks can help meet nutrition recovery goals by replacing fluids and electrolytes lost in sweat and helping to replenish glycogen stores. If there is limited time between training sessions or competition, drinks with higher sodium content may promote more effective rehydration. To meet all recovery goals, the ingestion of sports drinks should be complimented with foods and fluids that provide adequate carbohydrate, protein, and other nutrients essential for recovery.

Are sports drinks better than water when exercising?

Sometimes, it depends on the individual situation.

Should you take a bottle of sports drink down to the gym when you do that hour's aerobics class? Will you feel ill effects without it? And what about that Saturday soccer game?

Well, whether you would benefit from consuming a sports drink depends on the events you are taking part in and your goals, says Professor Louise Burke of the Australian Institute of Sport.

Sports drinks typically contain water and electrolytes (usually sodium and potassium) for rehydration, and carbohydrates (as sugars) for energy.

They were invented in the 1960s to replenish fluid and provide extra fuel for intense sporting activity of a long duration (more than 90 minutes).

'If you're in the gym pedalling to lose weight while you read a magazine, then you don't need a sports drink, just drink water,' says Burke, who runs the nutrition program for the elite athletes at the institute.

Professor Clare Collins, a spokesperson for the Dietitians Association of Australia, agrees, saying sports drinks are for serious athletes only.

'For ordinary people who play soccer on a Saturday, there's no need for them because their fluid requirements can be met by water and generally you're not sweating enough to lose excessive amounts of electrolytes.'

Do you need the carbs?

But what if you do consider yourself a committed athlete and you're taking part in a marathon or triathlon event?

Well, Burke says the carbs in sports drinks can be helpful if you are aiming for a personal best, or taking part in a competition you really must win.

'From the physiological point of view, there's a benefit in having carbs for sustained intense exercise of over 90 minutes,' says Burke — who declares the AIS receives a sponsorship from a sports drink manufacturer.

This is because when we start exercising, our muscles initially use their stores of carbohydrate for fuel, but these stores become depleted after about 90 minutes.

Our muscles then start to become more reliant on fat burning for fuel. This isn't as efficient as burning carbohydrates, so our pace is slowed.

'The intake of worthwhile amounts of carbohydrate from a source during exercise, such as a sports drink, will provide an alternative or additional source of fuel to allow carbohydrate to continue to be 'burned' at the higher levels needed to sustain the athlete's optimal pace,' Burke explains.

The carbs can also have a motivational effect even in shorter workouts, says Burke.

'Experiments have shown that just swilling a sports drink around your mouth and then spitting it out, can make athletes perform better.' The brain seems to become more motivated with just the promise of carbs.

Don't forget the sugar

But if a sports drink can help a serious athlete, why shouldn't we all use them?

Well, the problem is the carbohydrates (usually sugars) in the drink: one litre containing 60 grams of carbs equates to 960 kilojoules.

'We want people to be aware of the kilojoules they contain,' says Collins.

'If you are exercising to lose weight, then drinking a sports drink could mean you need to spend another 30 minutes or more in the gym.'

The American Academy of Pediatrics recently expressed concern about the carbohydrates in sports drinks, saying: 'Frequent or excessive intake of caloric sports drinks can substantially increase the risk for overweight or obesity in children and adolescents.'

We should also be mindful of their effects on our teeth. Both Burke and Collins warn that, like all sugary acidic beverages, sports drinks contribute to dental erosion, so it's important to consider this in your overall dental care regime.

Lastly, don't confuse sports drinks with energy drinks. These often contain more carbohydrates than sports drinks as well as stimulants like caffeine.

So, when you're deciding whether to choose water or a sports drink, here are some guidelines.

Use water:

- when exercising to lose weight
- when exercising for an hour or less.

Consider using a sports drink:

- for fuel when doing intense sustained exercise for 90 minutes or more. You need at least 30 g carbs/hour.
- when the outcome of a competition is important to you and you need to perform at your best. Using small amounts every 10–15 minutes can make you feel like working harder.

Professor Louise Burke of the Australian Institute of Sport and Professor Clare Collins of the Dietitians Association of Australia spoke to Clare Pain.

Source: www.abc.net.au

The use of intravenous drips in rehydration

For many years, **intravenous (IV) hydration** has been used in sport to medically assist athletes suffering from severe dehydration. In 2003, Belgian tennis player Justine Henin-Hardenne (figure 13.14) won the US Women's Open after spending part of the previous night on an IV drip. This was considered necessary to reverse the dehydration she suffered during her three-hour, three-set victory over Jennifer Capriati in the semi-final the night before.

During the 2001 AFL season, the Brisbane Lions made headlines with their use of IV drips at halftime to rehydrate players during matches. The AFL banned the use of IV drips some 18 months after the Lions first started using the procedure.

Intravenous (IV) hydration is the provision of fluids, usually saline, into a vein to correct fluid and electrolyte deficits in people unable to do this normally by eating and drinking.

In 2005, the World Anti-Doping Agency (WADA) included IV infusions on their list of prohibited substances and methods. They can only be legally administered if medically required and authorised.

FIGURE 13.14 Belgian tennis player Justine Henin-Hardenne won the 2003 US Open after spending several hours undergoing intravenous fluid replenishment the night before the final.

Standard IV fluids provide saline (water and sodium) in various concentrations and, sometimes, a low level of glucose. In medical practice they are used to correct fluid, electrolyte and carbohydrate deficits in people who are unable to do this normally by eating and drinking (e.g. if unconscious or suffering severe vomiting or diarrhoea). Some athletes who have used IV drips after exercise bouts claim that it makes them feel better and helps them to recover more quickly. However, many medical experts dispute that this is anything more than a placebo effect. They counter that the main benefits associated with IV drips are the novelty and attention, and being forced to lie still for one to two hours after an event. Apart from the possible psychological benefit from using an IV drip during recovery, there may in fact be some practical advantages as well.

Athletes often experience difficulties in juggling the need for adequate recovery, refuelling and rehydration during busy competition schedules. With an IV drip the athlete can be given a known amount of fluids and carbohydrate, and be 'consuming' these while resting, or even sleeping. Furthermore, some athletes find it difficult to orally ingest the amounts of fluids and foods that are recommended as part of the recovery process immediately post exercise. IV drips overcome these problems by delivering a specified volume of fluids and a concentration of nutrients directly to the bloodstream.

However, it is also possible that IV fluid replenishment is not as effective as the more conventional method of simply drinking liquids. Research has demonstrated no discernable advantage for IV compared with oral rehydration. The data also suggested that oral fluid replacement might provide a performance advantage, reduce the subjective perception of thirst and make exercise feel easier. Additional research is needed to further characterise these differences.

TEST your understanding

1 (a) As a general guideline, state how much fluid sports dietitians recommend an athlete should consume before, during and after an exercise session.
(b) Why is this different for each individual athlete?
2 Define the term *sports drink*.
3 (a) What is meant by the term hyponatremia?
(b) List the symptoms associated with hyponatremia.
4 Explain the underlying rationale behind the use of IV drips as a means of rehydrating athletes after competition or training.

APPLY your understanding

5 Explain why sports drinks are sometimes the preferred source of rehydration in comparison to water.
6 Compare each type of sports drink and include the following information:
- type
- carbohydrate concentration
- type of athlete suited to
- other considerations.

7 For each of the following people, suggest what type of hydration would be best.
(a) Mum who walks for 30 minutes with pram around local creek to maintain weight and fitness.
(b) Local footballer who goes to the gym four times a week to work on his strength and power via a weights program.
(c) Elite netballer who trains five times a week, completing individual cardio sessions (i.e. running) or specified team training sessions. She also plays competitively once a week.
(d) Weight-lifter who trains every day but needs to monitor weight prior to competition.
(e) A road cyclist competing in a multi-day event consisting of approximately 100 km each day.
8 Read the article 'Are sports drinks better than water when exercising?' and answer the following questions.
(a) Explain why sports drinks were originally invented.
(b) Describe the types of activities where water is the recommended hydration method.
(c) Describe the types of activities where sports drinks are the recommended hydration method.
(d) Discuss how sports drinks can have a motivational effect on an athlete's performance.
(e) Explain why sports drinks are not recommended for the average person.
9 **Practical activity: fluid intake**
Monitor your fluid intake over three days.
(a) Weigh yourself and calculate your recommended daily fluid intake (40 millilitres per kilogram of body weight = millilitres of fluid to be consumed daily).
(b) Include in your report any exercise or exertion that requires extra rehydration.
(c) Explain your adherence to, or departure from, the correct hydration habits, and suggest how you could improve this aspect of your lifestyle.
10 **Practical activity: sports drinks and energy drinks**
Visit a supermarket and look at the range of sports drinks and energy drinks available.
(a) Record the available sports and energy drinks according to the following categories: isotonic, hypotonic, hypertonic and energy drinks.
(b) Analyse these products in terms of their main ingredients (including percentage concentrations) and any claimed benefits of each drink.
(c) Present your findings as a written report.

EXAM practice

11 **ACHPER Trial Exam 2014, question 9**
This year, in October, thousands of runners will compete in the annual Melbourne Marathon.
Hyponatremia is a very real, yet often ignored, hydration problem. Many factors can lead to hyponatremia, one of which is consuming too much water.
(a) How does hyponatremia affect performance in a marathon? **2 marks**
(b) Identify and briefly explain **one** strategy that could help to prevent hyponatremia. **2 marks**
12 **ACHPER Trial Exam 2011, question 7**
A class of Year 12 students undertook a Cycle-Spin class at the local gymnasium. This class consisted of 45 minutes of continuous cycling mixed with random bursts of speed. During the class, the instructor varied the intensity of the movements and instructed the students to increase or decrease the resistance on their stationary bikes. The session included a five-minute warm-up and a five-minute cool-down that included stretching.
The 45-minute Cycle-Spin class was held indoors. Despite the use of fans, the temperature inside the room was 30 degrees Celsius. Following the class students drank fluids.
(a) Which type of fluid would maximise the students' recovery immediately after the class?
A. Water B. Hypotonic drink
C. Isotonic drink D. Hypertonic drink **1 mark**
(b) Justify your choice. **2 marks**

13.6 Psychological strategies to enhance performance and aid recovery: sleep, confidence and motivation

KEY CONCEPT Sleep, confidence and motivation are very important for an athlete to perform successfully. Setting goals and understanding the reasons for participating in activity will assist an athlete to achieve optimal performance.

Sports psychology is the sports science that seeks to understand psychological and mental factors that affect performance in sports, physical activity and exercise, and apply these to enhance individual and team performance.

Sports psychology is so important to performance at the top level of sport that most elite sporting clubs and individuals now employ sports psychologists to work with them.

The work of sports psychologists tends to focus on techniques that athletes can use in competitive and training situations to maintain control. Psychological skills training (PST) helps athletes make adjustments to their actions, thoughts, feelings and physical sensations. It should be an integral part of an athlete's overall training program and preparation.

The following factors are vital in allowing an athlete to be at their psychological peak:

- quality and quantity of sleep
- self-confidence
- motivation
- optimal level of arousal
- focus (mental imagery)
- concentration.

For an Olympic athlete like Cate Campbell, who has dedicated years of training to her swimming, the difference between success and failure comes down to just a few seconds. There is intense pressure for Olympic athletes and any other elite athlete to perform at their best at the right time. In Cate's case, the right time was a 52-second time period in the 100 m freestyle final at the Rio Olympics. Despite already winning one gold (4 × 100 m freestyle) and one silver (4 × 100 m medley), the expectation was that she would win gold in the individual 100 m freestyle event; however, she placed fifth.

'The world got to witness possibly the greatest choke in Olympic history a couple of nights ago,' — Cate Campbell after her 100 m freestyle loss at the Rio Olympics.

The role of sports psychology is to help athletes like Cate develop strategies that enable them to manage the pressures and enhance their performance.

Use the **Sports psychology and improving performance** weblink in your eBookPLUS to hear Professor Martin Hagger from Curtin University explain the importance of sports psychology in enhancing sports performance. He discusses some specific examples of athletes and how they use psychological strategies for their particular sport.

eBook*plus*

Weblink
Sports psychology and improving performance

Sleep

Sleep and rest are essential for gaining the anabolic effects of training. Sleep plays an important role in:

- tissue growth and repair
- immune function
- allowing the brain to rest and recharge.

Sleep is essential for an athlete's recovery and performance. Lack of sleep can have psychological effects on the body. It can lead to the athlete functioning at a less than optimal level via reduced:

- visual processing ability
- concentration.

studyon

Unit 4	**Sleep** Summary screen and practice questions
AOS 2	
Topic 5	
Concept 1	

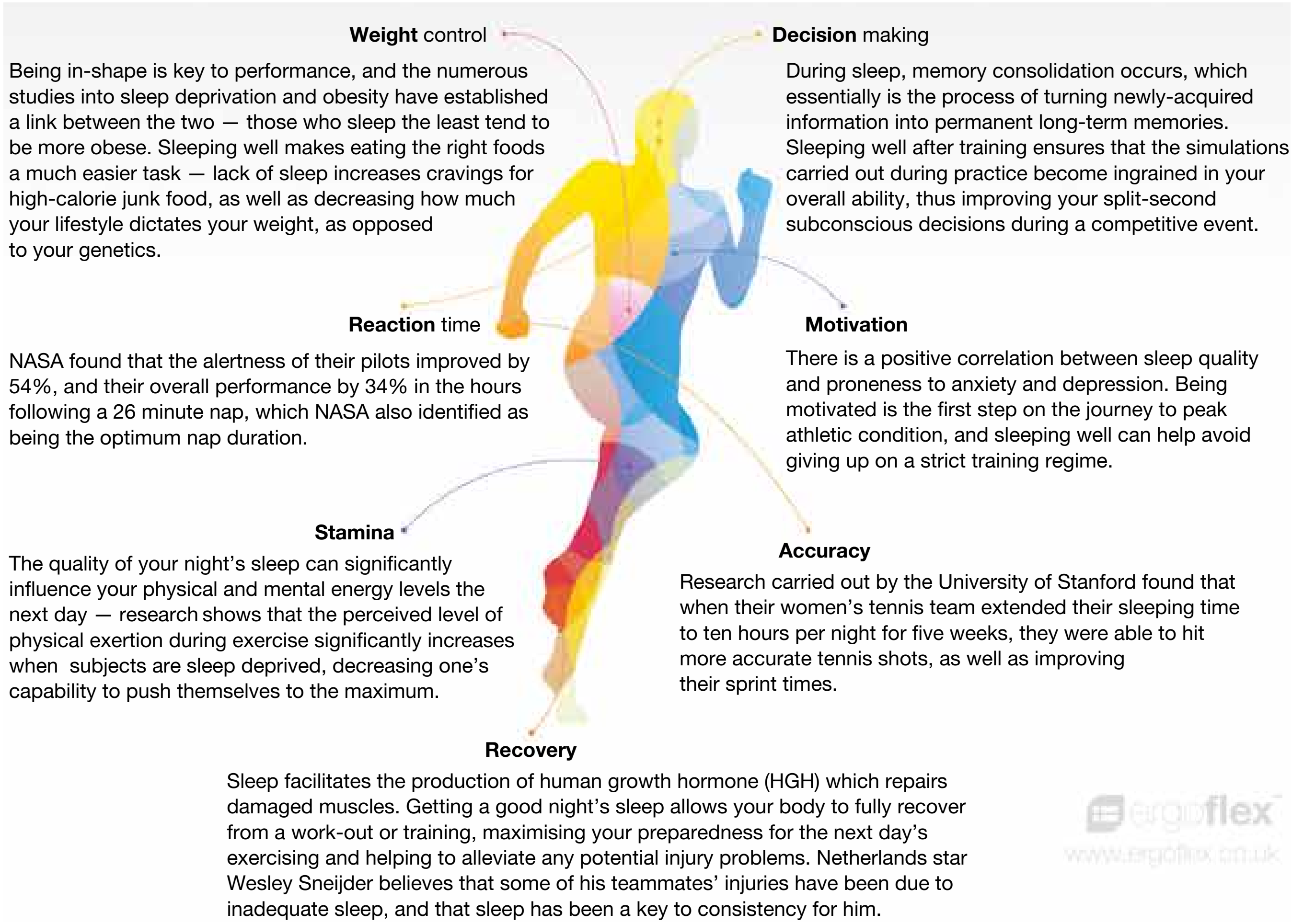


FIGURE 13.15 How a good night's sleep can improve your athletic attributes

Both quantity and quality of sleep are very important. Athletes are encouraged to view their sleeping habits in the same way they would their training habits. Establishing a pre-sleep routine is very important. Sports psychologists agree that **sleep hygiene** is essential for athletes to benefit from a good night's sleep. The following are all imperative to quality sleep:

- a conducive sleeping environment (comfortable bed, well-ventilated room)
- switching off from the day's activities
- slowing down the functioning of the brain
- going to bed when you are tired
- avoiding screen time close to bed time
- avoiding stimulants (caffeine or alcohol)
- not consuming a large meal directly before bed and allowing four hours after a meal before sleep.

Relaxation techniques such as progressive muscle relaxation, centred breathing and meditation are all ways to assist with winding down before bed.

Furthermore, it is interesting to note that studies have shown that sleep is thought to contribute to memory and that a certain amount of sleep is required to consolidate learning of motor skills and therefore improvements.

Sleep hygiene is the routine that an individual goes through before falling asleep.

eBook*plus*
Audio
Sleep podcast
Searchlight ID: aud-0348

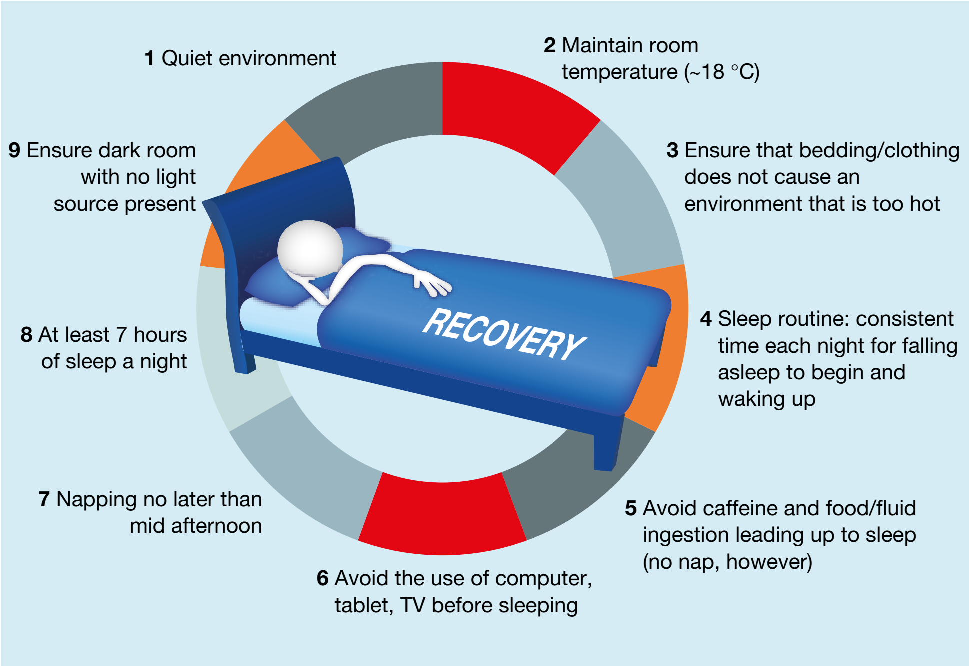


FIGURE 13.16 Checklist for athletes to consider to enhance sleep

Source: Marshall & Turner, *Strength and Conditioning Journal*, 2016.

Confidence

Self-confidence is what an individual has when they believe that they can successfully perform a task and achieve their goal.

Confidence is a belief an athlete has about their ability to execute a specific task or goal successfully. The athlete will have **self-confidence** if they believe they can achieve their goal. When an athlete has self-confidence they will:

- persevere even when things are not going to plan
- show enthusiasm and motivation
- be positive in their approach and take their share of the responsibility in success and failure.

Self-confident athletes:

- believe in themselves and their skills
- exhibit positive emotions
- remain calm under pressure
- think more positively
- have a greater ability to follow, understand and execute game plans.

An athlete's level of confidence is considered one of the key influencing factors that will differentiate between a successful and an unsuccessful performance.

Choking is when an athlete fails to perform effectively under pressure conditions.

Confidence can be lost when athletes start focusing on things that are outside their control, such as other competitors' performances, or become overly critical of their own individual performance. In sporting terms, this is often referred to as **choking**. As well as attentional changes such as loss of confidence or focus, choking can also include physical changes including increased heart rate, breathing rate and muscle tension. The athlete may have performed the skill many times before, but their anxiety about performing the skill correctly and under pressure can result in impaired performance. This often occurs at crucial times in an event and can result in:

- an increase in negative self-talk
- poor judgement and decision making, leading to poor skill selection
- a decrease in selective attention and an inability to attend to relevant cues
- rushing and not taking the normal preparation time for skill execution
- a decrease in coordination and timing due to increase in muscular tension.

The Australian Sports Commission says that an athlete will have confidence in an activity by:

- knowing what to do
- knowing how to do it
- knowing when to do it
- having the resources and ability to do it
- wanting to do it

and that athletes can build confidence by:

- working hard at training
- practising good self-management
- rewarding themselves when successful
- recording/logging their successes.

'I stopped listening to music pre-game because I felt it got me too wound up and I tried some different things . . . I don't think I have an ego, but I'm certainly confident in my ability and I feel like I can be a good player and I want to achieve what I feel like I am capable of achieving.' — Jack Viney

FIGURE 13.17 Jack Viney (Melbourne Football Club) attributed his some of his improvement in his performance to working with a sports psychologist.

studyon
Unit 4 | AOS 2 | Topic 5 | Concept 2
Confidence and motivation Summary screen and practice questions

Motivation

Successful sports performance depends on the athlete being fully committed and motivated towards achieving their goals. **Motivation** may be defined as 'the causes of the initiation, maintenance and intensity of behaviour'. In other words, motivation is a reason for participating in an activity, learning the skills involved, training and practising, and dedicating effort to improvement. It is also linked to the satisfaction gained from participation and from achieving ambitions. Motivation can also be described as the driving force behind an athlete's desire and determination to achieve their goals.

Motivation is a reason for participating in an activity.

Athletes with high levels of motivation often exhibit the following characteristics:

- a desire for success
- a willingness to take risks
- an acknowledgement of their own ability as crucial to their success
- an ability to increase their effort and concentration as the task difficulty increases.

Goal setting involves setting plans to work towards achieving specific and beneficial objectives and results.

Athletes who do not have this level of motivation are less likely to perform successfully and less likely to achieve elite levels. Therefore, coaches have been greatly concerned with what optimally motivates athletes. One of the most widely used methods of achieving this is through the use of **goal setting**.

Goal setting

Goal setting is an extremely effective motivational technique. However, to be a successful tool, goals must meet the following criteria based on the acronym SMARTER:

- Specific — athletes and coaches should make their goals as specific and detailed as possible.
- Measurable — goals should be measurable and assessed against a standard or previous performance, otherwise there is no way of determining whether or not they were achieved.
- Accepted — all of the parties involved in the setting of the goals (e.g. the athlete, coach, manager, family members) should accept them.
- Realistic — goals need to be challenging, but also achievable. Goals should be framed in a positive manner and focused most importantly on improvement, rather than just on winning.
- Timeframed — short-term and long-term goals should be set and there should be a specific date for when they will be achieved.
- Exciting — the goals set should challenge, excite and inspire the athlete.
- Recorded — the agreed goals should be recorded by the coach and the athlete so as to provide a constant reminder and to act as a source of motivation.

Goals can also be categorised as:

- *Outcome goals* — which are related to the overall results of a competition; for example, a golfer winning a tournament or their ranking compared to other golfers.
- *Performance goals* — which are related to the athlete's own personal level of performance irrespective of others. For example, a golfer may analyse their game and aim to improve from hitting 50 per cent of the greens in regulation to hitting 60 per cent of the greens in regulation.
- *Process goals* — are related to performance goals, but the athlete focuses on the physical movement or game strategy aspects. For example, in addition to setting a performance goal of increasing the number of greens hit in regulation by 10 per cent, a golfer may also develop a set routine to perform before every shot.

FIGURE 13.18 Setting achievable yet challenging goals helps motivate an athlete to achieve their ultimate aim.

Intrinsic and extrinsic motivation

Motivation may be either *intrinsic* or *extrinsic*.

- Intrinsic motivation comes from within and occurs when factors such as enjoyment, satisfaction, improvement and enhanced feelings of self-worth are the primary motivation for performance.
- Extrinsic motivation has an external focus and usually involves some form of material benefit such as financial reward (prize money), awards and trophies, glory and recognition. Most researchers agree that intrinsic motivation to perform is more desirable than extrinsic motivation, as it will serve as a more powerful and sustainable source of motivation.

TEST your understanding

1 Outline the importance of sleep for an athlete.
2 Explain what is meant by the term *sleep hygiene*.
3 Define the term *confidence*.
4 Describe choking and identify reasons athletes might choke during critical moments in performance.
5 Describe ways an athlete can improve their confidence.
6 Explain the acronym SMARTER and what it relates to.
7 Outline the difference between intrinsic and extrinsic motivation. Provide examples.

APPLY your understanding

8 Select a sport of your choice and apply the SMARTER principle for goal setting.
9 Develop a specific 'good sleep guide' for an athlete of your choice. Consider the training requirements of the sport that they participate in, e.g. swimmers may train at 5 a.m.

EXAM practice

10 **adapted from ACHPER Trial Exam 2013, question 4**

At the 2013 Australian Tennis Open, Belarusian Victoria Azarenka played American teenager Sloane Stephens in her semi-final match. Azarenka won the first set, 6 games to 1. In the second set at 5 games to 3, Azarenka served for the match five times but was unsuccessful. Eventually, after two medical time-outs that took Azarenka off the court for seven minutes, she came back to win the match 6–4 in the second set. Azarenka told an on-court interviewer immediately after the match: 'Well, I almost did the choke of the year … at 5–3, having so many chances I couldn't close it out.'

(a) Azarenka believed she almost choked. Define choking. **1 mark**
(b) List two physical changes that are likely to occur when a player 'chokes'. **2 marks**
(c) Explain how one of the physical changes you have listed in (b) will affect performance. **2 marks**
(d) Explain one psychological strategy that Azarenka's coach could introduce into her training routine to prevent 'choking' from occurring again. **2 marks**

13.7 Psychological strategies to enhance performance and aid recovery: optimal arousal, mental imagery and concentration

KEY CONCEPT An athlete's arousal level and concentration while participating in physical activity can affect their ability to succeed. Strategies that focus on maintaining these can optimise performance.

Maintaining control

An athlete's ability to maintain control of their emotions in the face of pressure or adversity and remain positive is essential to successful performance. Performance (or competitive) anxiety and arousal levels are two emotional control factors that can impact on performance.

Performance anxiety

Anxiety is an emotional state associated with heightened arousal.

Anxiety can be defined as a maladaptive emotional state that is typically associated with heightened arousal and the interpretation of a situation as threatening and/or dangerous. Performance or competitive anxiety can cause athletes to react both physically and mentally in a manner that can negatively affect their performance. Performance anxiety can manifest itself in two ways:

1. physical (or somatic) anxiety — butterflies, sweating, nausea, needing to go to the toilet
2. mental (or cognitive) anxiety — worrying, negative thoughts, confusion, lack of concentration.

A range of psychometric tests or sport anxiety questionnaires (SAQ) have been used by sports psychologists to understand and measure competitive anxiety. The Sport Competition Anxiety Test (SCAT) is one such test (see figure 13.19). To help the athlete control competitive anxiety a range of somatic techniques, such as progressive muscle relaxation, and cognitive techniques, such as mental imagery, can be used (these will be discussed in some detail later in this chapter).

Factors that can affect an athlete's level of anxiety include:

- the importance of the event or competition — the more important the event is, for example, a grand final, the more likely the athlete will experience anxiety.
- level of spectator support — studies have shown that the 'home ground advantage' does occur and teams are more likely to win when playing at their home venue. This occurs not only for team sports but also for major events such as the Olympic games as seen with the record-breaking number of medals won by Australia in Sydney 2000.
- individual sports versus team sports — competitors of individual sports generally suffer more anxiety than competitors in team sports due to the sense of isolation and increased exposure.
- expectation of success — individuals and teams can be affected by the expectation that they will win; such an expectation can increase an athlete's level of anxiety. An example of this was the Australian Women's 4 × 100 m freestyle swim team who were hot favourites to win gold at the Rio Olympics.

Sport Competition Anxiety Test (SCAT)

Assessing your anxiety
Read each statement below and decide if you 'Rarely', 'Sometimes' or 'Often' feel this way when competing in your sport. Tick the appropriate box to indicate your response.

	Rarely	Sometimes	Often
1. Competing against others is socially enjoyable.			
2. Before I compete I feel uneasy.			
3. Before I compete I worry about not performing well.			
4. I am a good sportsman when I compete.			
5. When I compete, I worry about making mistakes.			
6. Before I compete I am calm.			
7. Setting a goal is important when competing.			
8. Before I compete I get a queasy feeling in my stomach.			
9. Just before competing, I notice my heart beats faster than usual.			
10. I like to compete in games that demand a lot of physical energy.			
11. Before I compete I feel relaxed.			
12. Before I compete I am nervous.			
13. Team sports are more exciting than individual sports.			
14. I get nervous wanting to start the game.			
15. Before I compete I usually get uptight.			

Athlete's Name ______________________________

SCAT Score [ ]

Less than 17	You have a low level of anxiety.
17 to 24	You have an average level of anxiety.
More than 24	You have a high level of anxiety.

Analysis
The score for the response to each question is detailed below. Enter the score for each question in the 'Athlete's score' column and then total the column to provide a SCAT score.

Note that questions 1, 4, 7, 10 and 13 score zero regardless of the response.

Question No.	Rarely	Sometimes	Often	Athlete's Score
1	0	0	0	
2	1	2	3	
3	1	2	3	
4	0	0	0	
5	1	2	3	
6	3	2	1	
7	0	0	0	
8	1	2	3	
9	1	2	3	
10	0	0	0	
11	3	2	1	
12	1	2	3	
13	0	0	0	
14	1	2	3	
15	1	2	3	
			Total	

SCAT Score	Analysis
Less than 17	You have a low level of anxiety.
17 to 24	You have an average level of anxiety.
More than 24	You have a high level of anxiety.

FIGURE 13.19 Sport Competition Anxiety Test (SCAT)

Arousal is the readiness an individual experiences when faced with a sporting situation or task.

Arousal and performance

Arousal in sport can be defined as the degree of activation (both physiological and psychological) that an individual experiences when faced with a sporting situation or task. It can be viewed as a continuum ranging from drowsiness/sleep to a psyched-up, hyperactive state.

In the field of sports psychology, many models have been created to explore arousal levels as they relate to athletic performance. These models include the following.

Drive theory

According to drive theory, if an athlete is appropriately skilled then it will help them to perform well if their drive to compete is aroused (i.e. they are 'psyched up').

Inverted-U hypothesis

The inverted-U hypothesis predicts that the relationship between arousal and performance approximates an inverted-U shape (see figure 13.20). The theory is that as arousal increases performance improves, but only up to a certain point (top of the inverted U). If the athlete's arousal is increased beyond this point then performance diminishes. A moderate degree of arousal is seen as being optimal to performance.

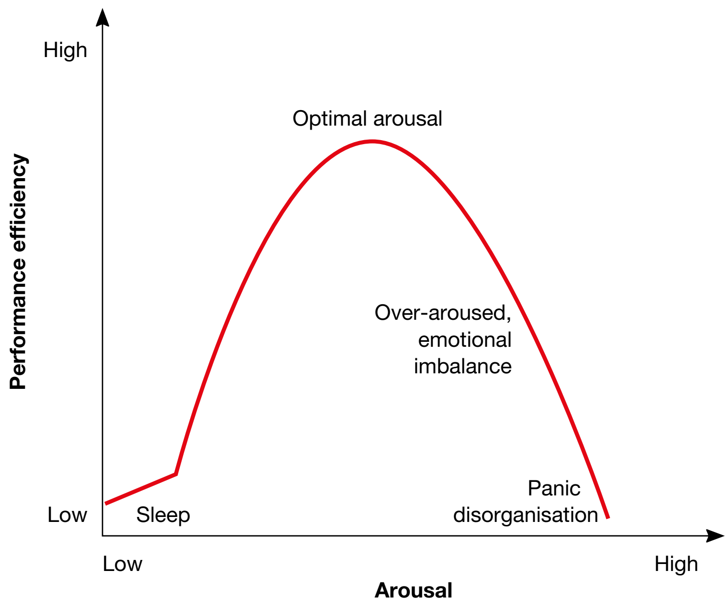


FIGURE 13.20 The inverted-U hypothesis proposes that increases in arousal have a positive effect on performance up to a certain point, after which continued increases in arousal detrimentally affect performance.

Optimum arousal theory

According to the optimum arousal theory, there is substantial individual variability in arousal–performance relationships. Each athlete will perform at their best if their level of arousal or competitive anxiety falls within their optimum functioning zone. Some athletes perform best under conditions of high arousal, some when arousal is moderate and some when it is low. To maximise performance, an athlete needs to find their optimal level of arousal.

Techniques to decrease arousal levels

Arousal reduction techniques include the following.

Progressive muscle relaxation (PMR)

Athletes undergo a series of exercises that lead to progressive muscle relaxation and eventually total body relaxation. This technique is based on the simple premise of tensing (tightening) one muscle group at a time, followed by a release of the tension. Through repetitive practice athletes quickly learn to recognise and distinguish between the associated feelings of a tensed muscle and a completely relaxed muscle. With this simple knowledge, they can then induce physical muscular relaxation at the first signs of the tension that accompanies over-arousal and associated anxiety. This physical relaxation can then help to induce a state of mental relaxation and calmness in many situations.

eBook*plus*

Weblink
Progressive muscle relaxation

Controlled breathing

The technique of controlling and slowing down breathing to release tension and anxiety can be used before or during performance. This technique helps the athlete to focus while they are preparing for the next action.

When an athlete experiences over-arousal, one of the first things that is disrupted is their breathing. It becomes short and sharp and they are therefore unable to deliver a sufficient amount of oxygen to their muscles in order to perform at their best. Controlled breathing ensures that enough oxygen can be taken up, which ultimately relaxes the athlete and provides them with a greater sense of control. It will also give the athlete a greater level of confidence and enable them to more easily combat negative thoughts.

Controlled breathing involves taking smooth, slow and regular breaths. Sitting upright or standing allows the athlete to increase the capacity of their lungs.

An example of a process for controlled breathing is as follows:

1. Take a slow, deep breath in through the nose, breathing into the lower abdomen — approximately 4–5 seconds.
2. Hold breath for 1 or 2 seconds.
3. Exhale slowly through the mouth — approximately 4–5 seconds.
4. Wait 2 seconds and start again.

Repeat the process until arousal levels have reduced to optimal levels.

Controlled breathing is particularly beneficial for activities and sports that require significant concentration and focus, such as taking a free throw in basketball or a penalty goal in soccer. Controlled breathing will help athletes to maintain their composure in high pressure situations. They are better able to read their environment if they are calm and relaxed. They will be more able to focus on relevant cues and ignore irrelevant and distracting ones, which is essential in performing well and achieving success.

Meditation

Meditation involves focusing the mind on a particular thing for a certain period of time. It can involve using a mantra (repeating a calming word or sound), or using blank meditation. Meditation is used to help reduce stress before an event. The aims of this technique are to calm the mind and relax the body.

Four reasons why every athlete should meditate

BY DR. KRISTIN KEIM (CLINICAL SPORT/PERFORMANCE PSYCHOLOGIST) FOR THE HEADSPACE APP.

> 'Bike racing is always physically hard, but the mental part can be even harder.'

Just the other day an athlete posted this on social media, and they're right. A mind that is not under control is a mind that makes mistakes — mistakes that could prevent you from winning. High levels of stress decrease your ability to maintain focus and concentration. Of course, stress can be a helpful tool when used correctly; but when it's not, it can not only impact your performance, but your life. As a clinical sport psychologist I have worked with a vast array of elite, professional and amateur athletes. Despite their differences in level and/or sport, they all face similar challenges: anxiety, depression, stress, inability to maintain focus, sleep difficulties, life balance, confidence, the list goes on. But so does the game. So when my athletes need to step up but are having trouble finding the mental wherewithal, one of the key techniques I rely on to change their thoughts and behaviours is meditation.

Why should you consider practicing meditation for athletic performance?

1. Stress reduction

Stress reduction is vital for optimal performance. Racing and competing when under stress has been proven to negatively impact athletic performance. A study published in the *Journal of Health Psychology* showed that the results of meditation are associated with reduced stress levels in addition to decreased levels of the stress hormone cortisol. Being relaxed and centred increases the ability to remain calm under pressure and also improves focus and concentration. By consistently practising meditation, your body will learn how to relax in stressful situations, building self-confidence and ultimately achieving a more positive mindset.

2. Improved sleep patterns and speeding recovery time

Sleep is imperative to all human beings, especially athletes. A study published in the *Journal of Sleep* showed that athletes who are not able to get enough sleep will experience a number of negative effects including: weight gain, mood disturbance, increased anxiety/depression, inability to maintain focus/concentration and decreased motor control. Athletes who consistently practise meditation can help their body to recover quicker from training, racing and even injury. While physical training is good, it also places high levels of stress on the body, including muscle fibre tears. Recovery time from many common sports injuries can actually be reduced. In addition, meditation boosts the immune system, preventing illness that can hinder your training and/or performance. Researchers from the University of Wisconsin School of Medicine and Health found that those who practise meditation experience fewer acute respiratory infections, as well as a shortened duration and severity of symptoms from the common cold. Therefore, meditation aids in improving the quality/length of sleep and the immune system.

3. Enhanced endurance

This might be one of the most popular reasons to include meditation into your training routine. By practising meditation that utilises visualisations, athletic endurance can be enhanced. Athletes who visualise accomplishing specific objectives/goals, combined with the regular practice of breathing exercises, can train the body to work harder and for a longer period of time in training and competition.

4. Improved sense of identity, self and the body

Meditation in sport can help athletes conquer those common 'blind spots' that tend to make performance challenges seem worse than they actually are. These blind spots negatively impact performance, and meditation helps you recognise your blind spots. By recognising these blind spots, you can work on improving your physical/mental training, skills and coping mechanisms. This serves to build your athletic identity and self-confidence, and improve performance. Furthermore, the meditator learns to enhance awareness of each muscle, which can help pinpoint an injury and prevent further damage. Finally, meditation in sport can greatly improve the mind-body connection, allowing you to discover your optimal zone of performance.

Meditation in sport is not only helpful for performance, but can also aid athletes who experience anxiety, depression and other mental health illnesses. The practice can help athletes through injury, as well as to overcome challenges such as the transition back into sport or out of sport (e.g. retirement).

The practice of meditation is a journey similar to that of any athletic pursuit, and it could offer that small percentage needed to make you a better athlete and a happier human being.

Source: www.headspace.com

Biofeedback

Athletes can learn to recognise cues that inform them of their readiness for competition. These may be physical indicators such as heart rate and breathing rate, or mental cues such as attention and concentration levels.

Biofeedback is a process for monitoring information about physiological functions that are controlled by the autonomic nervous system. The data generally analysed are heart rate, blood pressure and respiration responses. Biofeedback is essentially a training and coaching tool that provides information to the athlete about their physiological responses, which enables them to acquire some skills that enhance the relationship between their physical and mental performance.

For example, for a long jumper who repeatedly commits a foot fault, the coach will use biofeedback such as heart rate responses to identify the precise moment of heightened anxiety and tension that the athlete feels during the jump sequence. The coach will then use this information to help the athlete in developing an appropriate psychological strategy to maintain a consistent level of arousal throughout the jump.

FIGURE 13.21 Australian long jumper Brooke Stratton may use biofeedback to enhance her psychological readiness for performance.

Stress inoculation training (SIT)

Stress inoculation training involves an athlete being exposed to increasing levels of stress, building up to levels similar to those imposed during competition or games. This process allows the athlete to gradually develop their ability to cope with the heightened pressure of competition and enhance their overall performance. This technique helps the athlete to learn to prepare for any stressors, control their responses to the stressors and maintain their focus. It is a way of developing an athlete's immunity to stress.

There are three stages of SIT:

1. the conceptualisation stage: an awareness of positive and negative thoughts
2. the rehearsal stage: learning to use coping strategies such as positive self-talk and imagery
3. the application stage: practising the coping strategies initially in low-stress conditions and gradually progressing to high-stress situations.

Techniques to increase arousal levels

Arousal promotion techniques include the following.

Elevated breathing rate

Taking short sharp breaths can trigger the central nervous system into an increased state of awareness.

Act energetic

Increasing an athlete's physical intensity and 'pumping themselves up' when they are feeling particularly low helps to increase their arousal levels; for example, Lleyton Hewitt's famous 'C'mon!'.

FIGURE 13.22 Leyton Hewitt was known to act energetically in order to increase his arousal levels — 'C'mon'

studyon

Unit 4 | AOS 2 | Topic 5 | Concept 3

Optimal arousal and concentration
Summary screen and practice questions

Positive self-talk

Athletes can increase their arousal levels by repeating positive self-statements/affirmations (for example, 'I am feeling fit and strong', 'I am ready to go', 'I can do this'). They can also use cue words to remind them of what they need to concentrate on in order to remain focused.

Energising imagery

Athletes may visualise something that is uplifting to help them increase their arousal levels; for example, crossing the finish line in a 100 m sprint or kicking the ball through the goal posts in Australian Rules football.

Use of music

Music is a common strategy used by athletes in many sports to control their arousal levels. Music has a profound physical and emotional impact with the ability to make an athlete feel inspired and motivated.

Pre-competition workout

Athletes raise their arousal levels to desired performance levels before competition through the use of warm-up exercises such as shadow boxing, motivational addresses, music and video footage.

FIGURE 13.23 Skeleton athlete preparing for her race with the use of music

Mental imagery (visualisation)

Mental imagery involves an athlete visualising that they are performing a skill flawlessly without making any physical movements.

Simulation is the practice of training in an environment that is specifically designed to emulate actual conditions during competition.

Mental imagery or visualisation is one of the simplest and most tried-and-true methods for psychologically preparing athletes to perform. Mental imagery involves athletes visualising themselves performing a skill or competition event flawlessly, such as sinking a putt in golf or successfully throwing a free throw goal in basketball.

There are a variety of techniques that involve the use of mental imagery:

- mental practice — used for a specific movement or skill, such as a penalty kick in soccer
- mental rehearsal — used for a complete athletic performance. The athlete must create as detailed an image as possible, and visualise themselves performing flawlessly in a game environment.
- mental review — used to recount a past performance. It is important for the athlete to learn from any negative aspects, yet move past them to focus on positive results.
- self-affirmation — used to improve self-confidence by imagining successful performances.

Simulation and mental imagery should be used together for maximum effect. Simulation is achieved by making the physical training environment as similar as possible to game demands (a dress rehearsal). It is similar to the principle of specificity but with a psychological focus. Simulation training works on the theory that athletes will learn to concentrate effectively in actual situations if they have trained in situations that are similar. This may involve an athlete training in the same venue as the competition venue or incorporating match play with opponents into their training regime.

Visuo-motor behaviour rehearsal (VMBR) utilises a combination of a number of psychological strategies.

It is comprised of three main phases:

1. Optimal arousal phase
2. Visualisation/mental imagery phase
3. Performing/simulation phase.

Concentration

Concentration (or attention) is the mental ability to focus on the task at hand while ignoring distractions. The capacity to 'concentrate' is widely regarded by athletes, coaches and sports psychologists as one of the keys to successful performance in sport. Coaches have long been concerned with how concentration or attention levels among athletes can be improved and maintained, and how distractions can be avoided. Common distractions appear to be anxiety, skill errors and mistakes, fatigue, weather, public announcements, opposition players, 'sledging' and negative thoughts.

Concentration is the ability to focus on the task at hand and ignore distractions.

Research on concentration and attention suggests that coaches can assist athletes to improve their level of attention by:

- assessing the attentional strengths and weaknesses of their athletes. Coaches should encourage athletes to think about when and where they displayed good concentration and under what conditions or situations their concentration tends to wander.
- assessing the attentional demands of a given sport. Each sport is different in terms of its attentional demands. The demand for attention varies from sport to sport and even from skill to skill (for example, sustained attention is required for distance running and tennis, short bursts of attention are required for cricket and athletic field events, intense attention is required for sprinting events and skiing).

Strategies for improving concentration and attention

A variety of techniques have been formulated to help improve concentration and attention. These techniques should be implemented after considering the athlete's attentional strengths and weaknesses in addition to the sport-specific attentional demands. These techniques or strategies include:

- centred or controlled breathing
- mental imagery and rehearsal (visualisation)
- positive self-talk and cue words (practise using words such as 'relaxed hands', 'knees together')
- utilising a clear pre-performance routine. This is seen when golfers follow a set routine before driving off the tee, in basketball players as they step up to the free-throw line, in tennis players before they serve and in footballers when they kick for goal.

studyon
Unit 4
AOS 2
Topic 5
Concept 4
Mental imagery
Summary screen and practice questions

TEST your understanding

1 Identify and provide examples of the ways performance anxiety can manifest itself.
2 (a) Explain the inverted-U hypothesis. Include a diagram.
(b) List three strategies that an athlete may use to increase their arousal level.
(c) List three strategies that an athlete may use to reduce their arousal level.
3 Outline the process of mental imagery/visualisation.
4 List common distractions that can affect an athlete's ability to concentrate.
5 Suggest ways coaches can assist athletes to improve their level of concentration.

APPLY your understanding

6 Describe, in detail, two of the techniques that can be used to control performance anxiety and arousal.
7 Identify the techniques that involve the use of mental imagery and provide detailed examples for each technique.
8 Pre-performance routines have been identified as a strategy to assist an athlete's concentration. Choose three sports and describe a pre-performance routine that may be used in each of those sports.
9 **Practical activity: Sport Competition Anxiety Test (SCAT)**
Use the **Sport Competition Anxiety Test (SCAT)** digital document in your eBookPLUS to complete the test, then answer the following.
(a) What was your level of anxiety?
(b) Suggest reasons why you scored as you did.
10 **Practical activity: arousal levels**
Participate in a team sport such as basketball or netball. Prior to the beginning of the game, use one of the following techniques to increase or decrease your arousal levels:
- progressive muscle relaxation
- meditation
- warm-up exercises
- pre-competition 'psyche up'.

At halftime, undertake a different technique before resuming the game.
(a) What techniques did you practise?
(b) What effect did each of the techniques have on your performance?
(c) Were these techniques appropriate for the sport you participated in? Explain.

EXAM practice

11 **ACHPER Trial Exam 2016, question 2**
In 2011 there were nearly 600 000 members of golf courses in Australia. Many of these courses hold a weekly competition for their members to play in. The competition normally costs a small amount of money ($5) to enter and the winners receive prizes from the golf club such as trophies and golf equipment. The games are played under professional competition rules and all the golfers' scores are logged and recorded for data use in the future.
(a) Discuss, and include two signs of, how 'stress' and 'tension' can negatively affect the performance of an amateur golfer. **3 marks**
(b) Professional golfers would undergo practices to help alleviate psychological detractors to performance. Explain one of these and how they help improve performance. **2 marks**

eBook*plus*

Digital document
Sport Competition Anxiety Test (SCAT)
Searchlight ID: doc-2913

KEY SKILLS PERFORMANCE ENHANCEMENT AND RECOVERY STRATEGIES: PSYCHOLOGICAL, NUTRITIONAL AND HYDRATION

KEY SKILLS

- Evaluate a range of psychological strategies which affect performance and recovery
- Explain and apply relevant nutritional and rehydration strategies to enhance recovery

- **yellow** identify the action word
- **pink** key terminology
- **blue** key concepts
- **light grey** marks/marking scheme

UNDERSTANDING THE KEY SKILLS

To address these key skills, it is important to remember the following:

- Be able to provide a detailed account and determine the importance of a range of psychological strategies that will impact on the performance and recovery of a variety of different athletes and situations
- Be able to provide a detailed account and determine the importance of a range of nutritional and rehydration strategies that impact on recovery specific to different types of athletes and circumstances

PRACTICE QUESTION

1. **(adapted from ACHPER Trial Exam 2015, question 3)**

Maria Sharapova has not defeated Serena Williams in a grand slam tennis tournament in 10 years. In 2015, Serena again defeated Maria in the final of the Australian Open.

a. **Provide** one psychological strategy that Maria could incorporate into her preparation prior to the next grand slam match in order to improve her performance. **Describe** the strategy selected. *3 marks*

b. **Explain** how the strategy selected in part a could improve Maria's performance in a grand slam final against Serena Williams. *2 marks*

STRATEGIES TO DECODE THE QUESTION

- **Identify the action words:**
  Provide — give or state
  Describe — provide a detailed account of
  Explain — to make the meaning of something clear and understandable
- **Key terminology:**
  Incorporate into her preparation prior — discuss how the strategy chosen is best used in preparation for her next match
  Improve her performance — must make links to how the selected strategy assists with improving performance
- **Key concepts:**
  One psychological strategy — need to discuss one psychological strategy that is relevant to the performance improvement
- **Marking scheme:** *3 + 2 marks* — always check marking scheme for the depth of response required, linking to key information highlighted in the question

SAMPLE RESPONSE

a. May select and describe any one of (but not limited to) the following psychological strategies:

- Stress inoculation training (SIT) is where an athlete exposes the body to certain situations, so that they develop immunity to high pressure situations.
- Biofeedback is when an athlete uses electrical sensors to help them receive information about their body functions. It helps them to focus on relaxing certain muscles.
- Breathing control is when an athlete slows down their breathing and breathes deeply in order to decrease muscle tension.
- Progressive muscle relaxation (PMR) is where athletes undergo a series of progressive muscle tightening and relaxing exercises in order to release tension in the body.

b. Explanation of how the strategy chosen could improve Maria's performance:

Stress inoculation training (SIT) — Maria might have a scoreboard that she uses during training that has a score line where she is behind and has to work through coping strategies to overcome that information and employ positive self-talk and imagery to help her maintain a high level of performance that is free of errors. This would increase her ability to cope with such close and tense situations in the match in order to allow her to perform at her optimum.

Biofeedback— In monitoring the electrical activity that causes her muscle contractions, Maria will develop the power to use her thoughts to control her body, make subtle changes such as relaxing certain muscles and therefore improve her overall performance.

Breathing control — Maria's coach may help her develop this technique of encouraging slow and deep breathing, so that she is able to maintain control over her anxiety and ignore irrelevant cues. She may use breathing control when she is in between games or as she is walking back to the service line, allowing her to focus specifically on her next action and increasing the likelihood of a successful performance.

Progressive muscle relaxation (PMR) — through repetitive practice of tensing and releasing one muscle group at a time, Maria will learn to recognise the different feelings associated with tense and relaxed muscles. With this knowledge, she will be able to induce muscle relaxation strategies at the early signs of tension. If Maria is over-aroused prior to the game, she may undertake PMR in order to instigate a state of muscular and mental relaxation to allow her to be at her optimum level of performance.

HOW THE MARKS ARE AWARDED

- **3 marks: 1 mark** for the identification of an appropriate psychological strategy and **2 marks** for describing the strategy and its effect on performance.
- **2 marks: 1 mark** for discussing examples of how the psychological strategy could be incorporated and **1 mark** for explaining how it could lead to the improved performance of the tennis match.

CHAPTER SUMMARY

Nutritional needs

- It is essential that all athletes consume the correct balance of nutrients to supply their body with the energy needed for physical activity and to aid in the recovery process.
- The main nutrients required to supply the body with energy include carbohydrate, protein and fat. Carbohydrate-rich food should constitute approximately 55–65 per cent of our total daily intake, protein should contribute 15 per cent and fats 20–30 per cent; however, the percentages will vary according to each individual athlete's specific needs.
- Not only must athletes adhere to these dietary guidelines, they must also develop their own eating plan to help achieve the best from their training. This plan will be specific to their sporting event, ensure an optimal intake of nutrients and meet the need for increased fluid and energy.
- Carbohydrate is broken down into glucose and transported in the bloodstream as a source of energy to fuel working muscles. Glucose is stored as glycogen in the liver and muscles if the body does not require energy immediately.
- Carbohydrate provides the body with its major fuel source for exercise during both extended high-intensity work and prolonged submaximal work. As the ability to store carbohydrate is limited, it is important to consume the appropriate amount before, during and after exercise. Training will dictate the amount of carbohydrate needed by the individual athlete.
- The glycaemic index (GI) is a ranking system that compares individual carbohydrate foods according to how they affect blood-glucose levels.
  - Foods with a high glycaemic index are appropriate for the rapid recovery of muscle glycogen stores.
  - Foods with a low glycaemic index are appropriate for sustained energy during an event.
- Protein is required to assist in the recovery or repair of damaged body tissue. It is also needed for the growth of additional muscle tissue when using resistance training to achieve gains in body strength. Additional amounts of protein are usually achieved by the increase in carbohydrate intake as a part of the training diet. Protein supplements are rarely needed in addition to this. Timing of protein consumption is a more important consideration for the athlete.
- The consumption of both carbohydrate and protein (1 (CHO): 4 (protein)) post-exercise will enhance the nutritional recovery process due to the increased presence of insulin, which stimulates muscle growth and also the uptake of glycogen into the muscle cells.
- Athletes must plan pre-event, event and recovery diet programs to ensure they have appropriate nutrition to optimise performance. During post-event recovery, athletes must restore muscle and liver glycogen stores as quickly as possible when the rate of glycogen synthesis is at its greatest.
- It is important that an athlete considers effective immune system functioning as a part of their recovery nutrition. They may do this by consuming micronutrients such as vitamins C and E, glutamine, zinc and probiotics. Carbohydrates also reduce the stress hormone response and supply fuel to the immune system white cells.
- Carbohydration is a convenient and effective way of consuming carbohydrates to replace used stores, while also addressing the need to keep the body hydrated. Commercially prepared sports drinks are the most common form of carbohydration used by athletes today.

Hydration

- Fluid loss can lead to a decline in performance. It is important to consume fluid before, during (if applicable) and after exercise. Water is suitable for short-duration events lasting less than 60 minutes; longer events are better served by a sports drink that contains carbohydrate and electrolytes.
- Most athletes should consume approximately 200–600 millilitres of fluid prior to their event, and replace approximately 500–1000 millilitres of fluid per hour during the actual event. Athletes should begin drinking early in exercise and consume small volumes (200–300 millilitres) every 15–20 minutes if possible.
- Sports drinks can be classified as isotonic (4–8 per cent carbohydrate), hypotonic (low level of carbohydrate; less than 4 per cent) or hypertonic (high level of carbohydrate; greater than 8 per cent).
- Intravenous (IV) infusions for rehydration are only permitted under the World Anti-Doping Agency (WADA) code for medical reasons, not for convenience or faster rehydration of an athlete.

Psychological strategies

- Sports psychologists focus on techniques that athletes can use in competitive and training situations so as to optimise their performance.
- Performance anxiety and arousal are both emotional control factors that can impact on performance. Techniques to manage these include reduction techniques such as progressive muscle relaxation, controlled breathing and meditation, as well as promotion techniques including acting energetically, elevating breathing rate and energising imagery.
- Concentration involves focusing on the task at hand and can be improved via mental imagery and rehearsal, positive self-talk, cue words and using pre-performance routines.
- Sleep is very important as lack of sleep can have both physiological and psychological effects on the body. Establishing a pre-sleep routine and paying attention to nutrition can assist with better sleep.
- SMARTER is the acronym used to assist athletes to set goals to work towards achieving specific objectives. SMARTER stands for Specific, Measurable, Accepted, Realistic, Timeframed, Exciting and Recorded.
- Biofeedback is a tool that provides information to the athlete about their physiological responses, which enables them to acquire some skills that enhance the relationship between their physical and mental performance.
- Stress inoculation training allows the athlete to learn to prepare for any stressors, control their responses to the stressors and maintain their focus in competition.
- Simulation and mental imagery used together enhance the athlete's psychological readiness for competition.

EXAM PREPARATION

MULTIPLE CHOICE QUESTIONS

1 **(ACHPER Trial Exam 2016, question 2)**

Positive self-talk is a psychological skills strategy that could be used when a performer is experiencing

(A) over-arousal.
(B) ideal arousal.
(C) under-arousal.
(D) neutral arousal.

2 A Collingwood Magpies netball player is sitting on the bench at quarter-time in the National Netball League competition. Her sports psychologist requires her to undertake an arousal reduction technique during the break. Which of the following is not an example of a suitable arousal reduction technique for the netball player?

(A) Listening to motivational music
(B) Biofeedback
(C) Positive self-talk
(D) Breathing control

3 **(ACHPER Trial Exam 2015, question 15)**

Jeffrey Symonds of Canada won the Asia–Pacific Ironman Triathlon held in Melbourne in March 2015.

His winning time for the event was 8 hours, 4 minutes and 29 seconds. Two to four hours following the event, Symonds would best enhance his recovery by eating

(A) high glycaemic index foods as this would better assist in the replenishment of depleted glycogen stores.
(B) low glycaemic index foods as this would better assist in the replenishment of depleted glycogen stores.
(C) a mixture of high and low glycaemic index foods, as well as foods high in fats to replace lost glycogen and triglyceride stores.
(D) a mixture of high and low glycaemic index foods as well as foods high in protein.

4 Combining carbohydrates and protein enhances recovery by

(A) reducing insulin secretion and maximising the absorption of carbohydrates.
(B) allowing muscle repair and catabolic adaptation to training to occur, and also for the restoration of muscle glycogen levels.
(C) stimulating insulin release, which acts as a catabolic hormone to increase the uptake of amino acids and enhance muscle recovery and growth.
(D) allowing muscle repair and anabolic adaptation to training to occur, and also for the restoration of muscle glycogen levels.

eBook*plus*

Interactivity
Performance enhancement and recovery strategies: psychological, nutritional and hydration quiz
Searchlight ID: int-6829

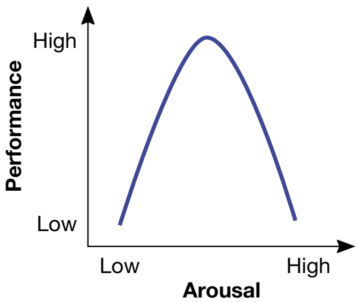
studyon

Sit VCAA exam

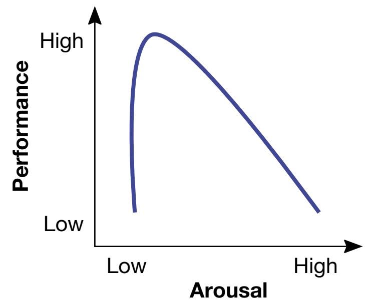
5 **(ACHPER Trial Exam 2013, question 7)**

An archer competing at the Olympics in the gold-medal round would require which of the following arousal levels for the best chance of success?

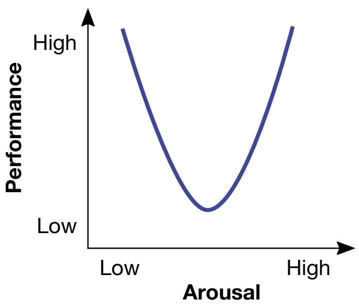
(A)



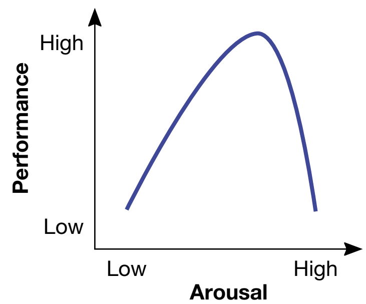
(B)



(C)



(D)



6 **(ACHPER Trial Exam 2013, question 8)**

Sleep is an essential part of the recovery process. Lack of sleep (sleep debt) is known to cause

(A) increased levels of stress hormones, such as cortisol.
(B) decreased perceived exertion.
(C) increased activity of human growth hormone.
(D) increased ability to metabolise glucose.

7 **(ACHPER Trial Exam 2011, question 14)**

In goal setting, the ‘A’ in the acronym ‘SMARTER’ refers to

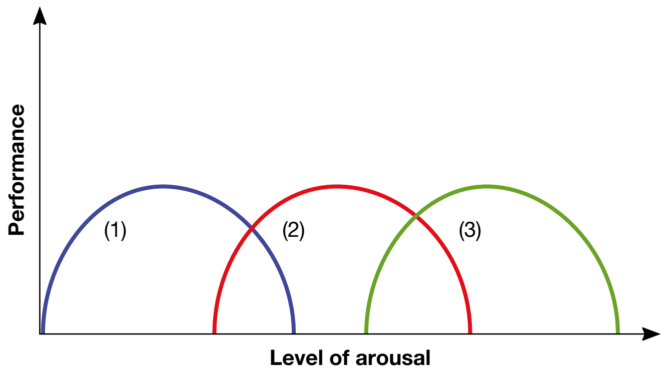
(A) Accepted.
(B) Achievable.
(C) Activity.
(D) Advantage.

8 **(ACHPER Trial Exam 2012, question 9)**

An elite netballer has a history of ‘choking’ when involved in intense game situations, which leads to a decrease in her performance, thus affecting the overall team performance. Which of the following would be the most effective to reduce the problem of ‘choking’ in a game?

(A) Stress inoculation training
(B) Undergoing meditation at half-time
(C) Consuming high GI foods and drinks prior to the game
(D) Employing biofeedback throughout the game

9 **(ACHPER Trial Exam 2012, question 13)**



The above graph represents the performance arousal curve for three different sports. Arousal curves 1, 2 and 3 are best represented by

(A) (1) Boxing (2) Basketball (3) Archery
(B) (1) Basketball (2) Archery (3) Boxing
(C) (1) Archery (2) Basketball (3) Boxing
(D) (1) Netball (2) Basketball (3) Soccer

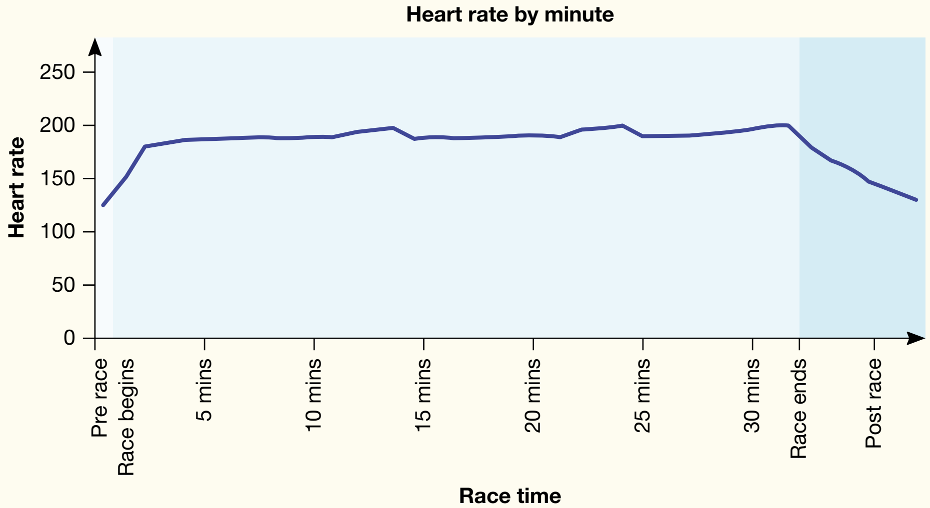
10 Goals can be categorised into three classifications. The type of goal that is generally out of an athlete's control is a

(A) performance goal.
(B) outcome goal.
(C) conditional goal.
(D) process goal.

TRIAL EXAM QUESTIONS

Question 1
(ACHPER Trial Exam 2016, question 4)

The graph below shows the heart rate of an athlete who completed an 8-km fun run in 32 minutes.



Following the 8-km event, the runner consumed a sports drink and a protein bar. Discuss how these products may lead to enhanced recovery following the event. **3 marks**

Question 2
(ACHPER Trial Exam 2016, question 10)

The 2016 Australian Open Tennis Championships were held in Melbourne from January 18 to January 31. During some of the matches, the players were required to compete in temperatures above 35 degrees Celsius. Sometimes players' performances are negatively affected because of the heat.

In the past, some players have used intravenous (IV) fluid ingestion following matches played in extreme heat. Evaluate the effectiveness of this procedure and compare it to oral hydration practices. **4 marks**

Question 3
(ACHPER Trial Exam 2016, question 13)

Nick Kyrgios usually enters a tennis match listening to music. Utilising a diagram, explain the benefit of listening to music from a psychological perspective. **3 marks**

Question 4
(ACHPER Trial Exam 2009, question 7)

There a number of different sports drinks on the market but they fall mainly into two categories: isotonic and hypertonic.

a. Outline the difference between an isotonic sports drink and a hypertonic sports drink. **2 marks**

b. Under what circumstances would it be preferable for an athlete to ingest a hypertonic sports drink in preference to an isotonic one? **1 mark**

c. Identify **three** guidelines an athlete should follow to ensure they remain adequately hydrated before, during and after exercise. **3 marks**

Question 5 **(ACHPER Trial Exam 2008, question 14)**

The Under-21 Australian women's hockey team has just completed a tournament in The Netherlands playing a series of games over a 10-day period. The Australian coach instructed her athletes to consume a snack consisting of bananas, muffins and Gatorade drinks within 30 minutes after each game.

a. Briefly explain why it is important to consume this type of snack within 30 minutes after the game. **2 marks**

b. Many athletes drink specially designed sports drinks during the game. Briefly explain the benefit of consuming a drink with 4–8 grams of carbohydrates per 100 mL. **2 marks**

GLOSSARY

1 RM (1 repetition maximum) the maximum amount of force that can be generated in one maximal contraction. This is commonly used to measure strength.
absolute VO_2 max. a measurement of the total amount of O_2 consumed in L/min
accelerometer an instrument for measuring the rate that an athlete changes velocity
acetyl coenzyme A an important molecule in metabolism. It is produced during the second stage of aerobic metabolism, which occurs in the mitochondria.
active recovery low-intensity (60–70% MHR) activity completed at the end of an exercise bout that allows the body to recover by maintaining an elevated blood flow to the muscles and preventing venous pooling, gradually returning the body to its resting physiological state
activity analysis the recording and analysis of movement and skill data from a game, sport or activity
acute responses the body's immediate, short-term responses that last only for the duration of the training or exercise session and for a short time period (recovery) afterwards
adenosine diphosphate (ADP) a by-product that results when ATP breaks down and loses one of its phosphate groups located at the end of the molecule
adenosine triphosphate (ATP) a high-energy molecule stored in muscle cells and other parts of the body. It is the energy currency for biological work.
aerobic metabolism when ATP resynthesis occurs via energy pathways that require the presence of oxygen
aerobic power the maximum rate of energy production from the aerobic energy system (i.e. energy produced in the presence of oxygen)
aerobic system provides energy for the resynthesis of ATP through the breakdown of various energy fuels (mainly glycogen and triglycerides) through a series of chemical steps that require oxygen
agility a combination of flexibility and speed, which allows the performer to change direction with maximal speed and control
agonist muscle that is the prime mover of the muscle action. It causes the movement to occur.
amino acids the building blocks of protein. Protein is broken down through the process of digestion into amino acids.
anaerobic capacity the total amount of energy obtainable from the anaerobic energy systems (the combined capacity of the ATP–CP system and anaerobic glycolysis system)
anaerobic glycolysis system provides energy for the resynthesis of ATP through the breakdown of glycogen through a series of chemical steps that do not require oxygen
anaerobic metabolism when ATP resynthesis occurs via energy pathways that do not require the presence of oxygen
angular motion takes place when a body moves along a circular path
antagonist a muscle that works in opposition to the agonist muscle
anticipatory response when the heart rate rises above resting values just before the start of exercise
anxiety an emotional state associated with heightened arousal
arousal is the readiness an individual experiences when faced with a sporting situation or task.
arteriovenous oxygen difference (a-VO_2 diff.) a measure of the difference in the concentration of oxygen in the arterial blood and the concentration of oxygen in the venous blood. It is measured in millilitres per 100 millilitres of blood.
associative stage of learning the second phase in the learning of a new skill, in which movement patterns become more refined and consistent through practice
ATP–CP system provides energy for the resynthesis of ATP through the breakdown of creatine phosphate without oxygen being involved
ATP demand refers to how much ATP is required during an activity and the rate at which it is expended and, therefore, needs to be resynthesised
attention refers to the amount of mental concentration or thought required to complete a task
augmented feedback information about a skill performance that comes from an external source
balanced diet the appropriate balance of nutrients needed to supply the body with energy for physical activity and to aid in recovery after exercise
balance the ability of the body to remain in a state of equilibrium while performing a desired task
barrier something or someone that has a negative effect on one's movement skills
beta oxidation the process by which fatty acids are broken down in the mitochondria to generate acetyl coenzyme A, the entry molecule for the Krebs cycle.
biomechanics the study of the mechanical principles that govern human movement
blocked practice a type of practice in which each skill component is practised repetitively as an independent block

block periodisation involves designing a training program with highly specific, targeted blocks of work.
blood pressure (BP) the pressure exerted by the blood against the arterial walls as it is forced through the circulatory system by the action of the heart. It has two components: systolic blood pressure and diastolic blood pressure.
body composition refers to the relative proportions of bone, muscle and fat within the body
buffering capacity the ability of the muscle cell buffers to resist changes in pH (acidity)
capillarisation an increase in the capillary density and blood flow to skeletal or cardiac muscle as a result of aerobic training
carbohydrate loading involves the manipulation of training and nutrition prior to endurance events to maximise muscle glycogen (carbohydrate) stores
carbohydrates naturally occurring compounds that consist of carbon, hydrogen and oxygen
carbohydration the combination of hydration with the replenishing of carbohydrate lost during activity, in order to avoid dehydration
cardiac hypertrophy an enlargement of the heart muscle as a result of training.
cardiac output ($\dot{Q}$) the amount of blood ejected from the left ventricle of the heart per minute. It is the product of stroke volume (SV) multiplied by heart rate (HR), $\dot{Q} = SV \times HR$.
choking when an athlete fails to perform effectively under pressure conditions
chronic adaptations the body's long-term responses of the cardiovascular, respiratory and muscular systems that develop over a period of time when training is repeated regularly
circuit training involves working at a variety of activity stations in sequence, training a number of fitness components at once.
closed motor skills motor skills that are performed in a predictable, self-paced environment
cognitive stage of learning the initial phase of learning of a motor skill where the emphasis is on conscious understanding of the task requirements
competition phase (in-season phase) the phase of training in which the emphasis is on maintaining fitness and skill level developed during the preparatory phase, and further developing and refining strategies, tactics and game plans
concentration the ability to focus on the task at hand and ignore distractions
concurrent feedback information that is given during a skill performance
continuous motor skills skills that have no distinct beginning or end
continuous training involves continuous activity that lasts a minimum of 20 minutes at the required intensity using the aerobic energy system. It is submaximal and requires an intensity of 70–85 per cent of maximum heart rate (Also known as long, slow distance training.)
cool-down low-intensity activity completed at the end of an exercise bout that allows the body to recover by maintaining an elevated blood flow to the muscles and preventing venous pooling, gradually returning the body to its resting physiological state
coordination the ability to use different parts of the body together smoothly and efficiently
Cori cycle the metabolic pathway in which lactate produced by anaerobic glycolysis in the muscles moves via the bloodstream to the liver, where it is converted to blood glucose and glycogen
creatine an organic substance that occurs naturally in humans and helps to supply energy to muscle
creatine phosphate (CP) a chemical compound found in muscle cells that is capable of storing and releasing energy that can be used to resynthesise ATP from ADP and Pi
data collection the process of gathering information
dehydration the deficiency in the body's fluid stores caused by the lack of fluid replacement demanded by physical activity
deliberate play a form of sporting activity involving early developmental physical activities that are intrinsically motivating, provide immediate satisfaction, and are designed to maximise enjoyment. They are activities that are regulated by rules adapted from standardised sport rules and are set up and monitored by the participants themselves.
deliberate practice any activity that is undertaken with the specific purpose of increasing performance, requires cognitive and/or physical effort and is relevant to promoting positive skill development in a particular sport
detraining a period of time when training is ceased or there is a reduction in training load beyond what is required for fitness to be maintained
diastolic blood pressure the blood pressure recorded during the relaxation phase of the heart cycle. It is the lower of the two blood-pressure values.
diminishing returns a principle that states that as a performer becomes more competent in their skill performance and progresses to the latter stages of learning, there is a gradual reduction in the rate of improvement in skill performance in response to practice
discrete motor skills involve movements of brief duration that are easily defined by a distinct beginning and end

displacement the difference between the initial position and final position of an object
distributed practice a form of practice in which smaller practice time intervals are interspersed with rest periods
dynamic equilibrium the state in which a body is in motion with a constant velocity
early specialisation the participation in a single sport from a very young age, involving a high level of structured practice and a low level of deliberate play in an attempt to fast-track skill development and gain a competitive advantage
eccentric a contraction in which the muscle lengthens as it contracts
economy describes the quantity of oxygen (mL/kg/min) required to generate movement at any given speed or intensity
electron transport chain the third and final stage in aerobic metabolism in which hydrogen ions are converted into water and carbon dioxide while generating energy for ATP resynthesis
enabler something or someone that has a positive effect on one's movement skills
excess post-exercise oxygen consumption (EPOC) the amount of oxygen consumed during the recovery period after the cessation of an exercise bout that is over and above the amount usually required during rest
explicit a type of learning that takes place as a result of direct instruction, where the performer is told what to do and when to do it
fartlek training a type of training that works both the aerobic and anaerobic energy systems by interspersing continuous low/ medium intensity efforts with high intensity efforts
fascia a densely woven connective tissue that covers and bonds internal sections of the body
fast decay exponential taper involves reducing the training load progressively, with a greater reduction at the beginning of the taper and sustaining the low training load
fatigue physical and/or mental lethargy or exhaustion triggered by stress, exercise, overwork, illness or disease
fats (lipids) are an essential component of a balanced diet that should comprise about 20–25 per cent of the daily food intake
feedback frequency refers to how often an external source (e.g. coach) provides feedback to the skill learner
feedback information concerning the performance and/or outcome of a movement skill, including information about errors and how to correct them
fibre hyperplasia an increase in the number of fibres within a muscle
field tests fitness tests that are carried out in team training or class activity settings
fine motor skills delicate, precise movements that engage the use of small muscle groups
fitness conditioning phase the part of a training session that focuses on the development and/or maintenance of specific fitness components, muscle groups and energy systems required for a particular sport or activity
flexibility the ability of specific joints to move through the full range of motion.
force summation the correct timing and sequencing of body segments and muscles through a range of motion
force the product of mass and acceleration
free fatty acids a broken-down transportable form of fats
frequency the number of training sessions needed per week to ensure improvements are achieved in the desired fitness components and energy systems
fundamental movement skills (FMS) movement patterns that involve different body parts. They are the foundational movements to more specialised sports-specific skills.
game sense a method of teaching tactical awareness and effective skill performance through game constraints modification and the use of guiding, open-ended questions
glucose the simplest form of carbohydrate and the basic ingredient for anaerobic and aerobic glycolysis
glycaemic index (GI) a ranking of carbohydrates on a scale from 0 to 100 according to the extent to which they raise blood-glucose levels after eating
glycogen sparing the process whereby glycogen stores are not used as early in an exercise bout due to the increased ability to use triglycerides to produce energy. This delays depletion of these stores, and thereby delays the time to exhaustion due to glycogen depletion
glycogen the storage form of glucose found in the muscles and in larger quantities in the liver
goal setting involves setting plans to work towards achieving specific and beneficial objectives and results
GPS Global Positioning System. A sensor is worn that uses satellites to identify position and movement. This can provide an indication of speed and distance covered.
gross motor skills movements involving the use of large muscle groups that result in a coordinated action

gyroscope a sensory device that explains the direction of gravity and determines the position of an athlete
haemoglobin a substance in blood that transports oxygen around the body
heart rate (HR) the number of times the heart contracts or beats per minute
heart rate reserve the difference between resting heart rate and maximum heart rate
high-intensity interval training (HIIT) involves repeated work intervals that are relatively brief in duration, performed at a high level of intensity close to VO_2 maximum followed by less intense recovery/rest intervals
hitting the wall a term used in endurance sports to describe a condition caused by the depletion of glycogen stores in the muscles and liver, which manifests itself as precipitous fatigue and loss of energy
hydrogen ions the presence of these ions makes the muscle acidic and will eventually fatigue muscle function
hypertension high blood pressure
hypertrophy an increase in the cross-sectional area of a muscle: an increase in the muscle size
hypoglycaemia when blood sugar levels have dropped too low due to prolonged strenuous exercise and depleted glycogen stores
implicit a type of learning that is acheived through doing. The participants learn through completing a task.
impulse the product of force and time
individuality a principle that suggests that individual responses to physical activity are highly varied
inertia the resistance of a body to a change in its state of motion
in-laboratory tests fitness tests that are carried out under controlled sports-science laboratory conditions
intensity the exertion level or how hard the training is being performed. It is commonly measured as a percentage of maximum heart rate (MHR), which is determined by beats per minute (bpm).
interplay of energy systems refers to the energy systems working together, but at different rates, to supply the ATP required for an activity
interval training consists of repeated periods of work followed by periods of rest or recovery
intravenous (IV) hydration the provision of fluids, usually saline, into a vein to correct fluid and electrolyte deficits in people unable to do this normally by eating and drinking
intrinsic feedback sensory information the learner receives directly from skill execution
isoinertial contraction a type of dynamic muscle contraction where the resistance against the muscle remains constant
isometric a contraction in which the muscle length remains the same as it contracts under tension
kinematics the description of motion
kinetics the study of forces that cause motion
knowledge of performance feedback regarding how a skill is performed; assessing performance on the basis of process and skill technique
knowledge of results information about the outcome of skill performance; information regarding the relative success or failure in regard to the intended goal of the movement skill
Krebs cycle a series of enzymatic reactions involving the oxidative metabolism of acetyl coenzyme A, which releases energy for the resynthesis of ATP
lactate inflection point (LIP) the point beyond which a given exercise intensity or power output cannot be maintained by the athlete
lactate inflection point the highest intensity point where there is a balance between lactate accumulation and removal from the blood. It represents a person's highest steady state intensity.
lactate shuttles the processes by which lactate is shuttled from one location to another where it is converted to glucose that can then be used to provide further energy
law of diminishing returns states that the rate of fitness improvement diminishes as a person approaches their genetic potential
lever a rigid structure that rotates around an axis
linear motion motion that occurs either in a straight line or curved path
lipolysis the metabolic breakdown of triglycerides into free fatty acids and glycerol within muscle cells
magnetometer a device that measures the direction and strength of magnetic field.
maintenance a principle that suggests that once a required level of fitness has been achieved, the level of effort to maintain that level of fitness is not as great as was required to achieve it

massed practice a form of practice in which there is little or no rest between repeat performances of a skill
mass the quantity of matter found within a particular body
maximum heart rate (MHR) the highest heart rate value achieved in an all-out effort to the point of exhaustion
maximum oxygen uptake (VO_2 max.) the maximum amount of oxygen per minute that can be taken in, transported and utilised by the body for energy production
mental imagery involves an athlete visualising that they are performing a skill flawlessly without making any physical movements
metabolic by-product (or metabolite) a substance produced as a result of chemical reactions within the body associated with the production of energy for ATP resynthesis
metabolic equivalents a system for classifying exercise intensity. 1 MET is equal to resting levels.
mitochondria cell structures or organelles that can be viewed as the power generators of the cell, converting nutrients into ATP
moment of inertia a measure of an object's resistance to change in its rate of rotation
momentum the product of mass and velocity; for example, a body with greater mass moving faster will have greater momentum than a lighter object moving slower
motion refers to the change in position of a body in relation to time
motivation a reason for participating in an activity
motor skill any activity involved in moving the body (or some parts of the body) to achieve a specific goal
motor unit consists of one motor neuron and all of the muscle fibres that it innervates
movement constraints factors related to the individual, task and environment that influence movement
movement patterns the typical movements completed by a performer during a game or an activity
muscle acidosis a condition in which the pH of the muscle decreases as a result of the accumulation of metabolic by-products such as hydrogen ions within the muscle cells
muscle excitation–contraction (E–C) coupling the physiological process of converting an electrical stimulus to a mechanical response
muscular endurance the ability of a muscle or group of muscles to sustain repeated contractions against a resistance for an extended period of time
muscular power the ability of a muscle or group of muscles to exert a maximum amount of force in the shortest period of time
myofibrils small fibres that run through each muscle fibre
myoglobin an oxygen-binding protein in skeletal muscle cells that attracts oxygen from the bloodstream and shuttles it to the mitochondria in the muscles for aerobic energy production
Newton's first law of motion states that an object will stay at rest or continue to travel in the same direction at a constant velocity unless acted on by an unbalanced force
Newton's second law of motion states that the rate of acceleration of a body is proportional to the force applied to it and in the direction in which the force is applied
Newton's third law of motion states that for every action, there is an equal and opposite reaction
observational learning the learning that takes place as a result of watching and imitating others
open motor skills motor skills that are performed in an environment that is constantly changing and is externally paced
oxidative enzymes enzymes that, with the use of oxygen, speed up the breakdown of nutrients to resynthesise ATP
oxygen deficit the state in which there is a discrepancy (shortfall) between oxygen supply and demand and the oxygen needed to meet the energy requirements of the activity. Under these conditions the anaerobic pathways must supplement the energy demands of the activity. The size of oxygen deficit an be reduced by decreasing intensity, completing a warm-up and completing aerobic training.
oxygen uptake (VO_2) the amount of oxygen transported to, taken up by and used by the body for energy production
peaking refers to the planning of training so that an athlete reaches their optimum state of readiness to perform at a particular predetermined time
perception–action coupling describes the reciprocal relationship between perception and action.
pH a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity

phosphorylation a biochemical process that involves the addition of a phosphate group to an organic compound or molecule. It involves the addition of phosphate to ADP to form ATP (ADP + Pi + Energy → ATP).
physiological training data provides information about the body's physical functioning in response to training
plyometrics involves the use of the stretch-shortening muscle cycle to produce powerful and explosive movements
potential energy the capacity of the muscle to do work based upon its position. This happens in the eccentric phase of contraction. The greater the stretch, the greater the capacity of the concentric muscle contraction.
practice distribution refers to the ratio between time spent actively practising and time spent resting during a practice session
preparatory phase (pre-season phase) the first phase of training within a yearly training program. The major objective of this phase of training is to provide a suitable fitness and skill base for the phases of training that follow.
protein an essential component of a balanced diet. Protein allows for muscle growth and repair, fights disease, helps chemical reactions and transports materials.
psychological training data provides the athlete with an understanding of their mental readiness and mental capacity to train and perform: thoughts, feelings and cognitive characteristics that affect behaviour
pulmonary diffusion the process whereby oxygen is taken in via the lungs to the blood, and carbon dioxide is diffused from the blood to the lungs
pyruvic acid (also referred to as pyruvate) an intermediate product in the metabolism of carbohydrates, formed by the anaerobic metabolism of glucose
qualitative analysis the systematic observation of the quality of human movement for the purpose of providing the most appropriate intervention to improve performance
random practice a form of practice that involves rehearsing a number of different skills in an unpredictable sequence
rate coding refers to the frequency of impulses sent to a muscle
rate refers to how quickly ATP is resynthesised
reaction time the time between a stimulus and the first response.
real time means that data is processed straight away and is available virtually immediately as a source of feedback
rebound hypoglycaemia low blood glucose followed by a rapid rise of blood glucose
recovery the overcoming or reversal of the fatigue experienced as the result of participation in a training session or some form of exercise bout, where body systems repair damaged tissue and replenish energy stores
relative VO_2 max. takes into account body weight and is measured in mL/kg/min
Repetition Maximum is the maximum amount of weight that a person can lift in one muscular contraction
resistance training training that aims to build muscle strength, muscle power or local muscular endurance by exercising muscles or muscle groups against a resistance
respiratory frequency (RF) the amount of times a person breathes in and out each minute
resting heart rate (RHR) refers to the number of heartbeats per minute while the body is at rest — usually an average of 70 beats per minute for an adult
reversibility the fitness and/or performance loss after a period of detraining
RPE (rating of perceived exertion — Borg Scale) a subjective rating of how hard the athlete feels that they are working. It is a numerical scale ranging from 6 to 20, with 6 being no feeling of exertion and 20 being extremely hard. 13–14 is classified as moderate intensity and 15–16 is classified as vigorous.
SAID stands for Specific Adaptations to Imposed Demands
self-confidence what an individual has when they believe that they can successfully perform a task and achieve their goal
sequential force summation the activation of body parts that are used in sequence to produce force
serial motor skills a series or group of discrete skills strung together to create a more complicated, skilled action
serial practice a form of practice that involves rehearsing different skills but in a fixed and relatively predictable sequence
simulation the practice of training in an environment that is specifically designed to emulate actual conditions during competition
simultaneous force summation the use of multiple body parts at the same time to produce force

size principle the principle by which motor units are recruited in order of their size from smallest to largest
skill development phase includes activities designed to develop and/or provide practice of skills, game plans, tactics and strategies
sleep hygiene the routine that an individual goes through before falling asleep
sociocultural influences the combination of social and cultural factors that impact on an individual's opportunities to participate in particular sports or recreational activities and, in turn, develop the relevant movement skills
sociological training data provides context about the broader social, cultural and environmental factors that contribute to an athlete's performance
specificity the process of replicating the characteristics of physical activity in training to ensure it benefits performance.
speed the rate of motion (distance/time)
sports drinks specially formulated drinks in which carbohydrates and/or electrolytes are dissolved
sport-specific skills utilise a range of fundamental movement skills in a sequence
sports psychology the sports science that seeks to understand psychological and mental factors that affect performance in sports, physical activity and exercise, and apply these to enhance individual and team performance
stability the degree to which a body resists changing its equilibrium
standardised tests tests that follow clear protocols that allow them to be confidently and successfully repeated
static equilibrium the state in which a body has zero velocity and zero acceleration. A body is in equilibrium when the sum of all forces and the sum of all moments acting on the body are zero.
static stretches involve holding the end point of a stretch for up to 30 seconds
steady state the state in which oxygen supply equals oxygen demand so that virtually all of the required ATP to maintain the current exercise intensity is being supplied aerobically
strength the peak force that a muscle can develop
stretch reflex occurs when an impulse is immediately sent to the spinal cord for a muscle to contract when it is stretched in order to prevent overstretching
stroke volume the amount of blood ejected from the left ventricle with each beat (contraction) of the heart
synergist muscles that stabilise movements to and maintain control within the desired range of motion
systemic blood flow the blood flow around the body. Blood leaves the left ventricle of the heart via the aorta, and then travels via the arteries and capillaries to the body, returning to the right atrium of the heart via the superior and inferior vena cava
systolic blood pressure the blood pressure recorded as blood is ejected during the contraction phase of the heart cycle. It is the higher of the two blood-pressure values.
tapering a reduction in training that allows the athlete time for extra recovery and for their energy stores to be fully restored
terminal feedback information that is given at the completion of a skill performance
tidal volume (TV) the amount of air breathed in and out in one breath
time/duration can refer to the length of a training session, the length of a work interval within a training session and/or the length of the overall training program
timing of feedback when feedback is provided to the skill learner in relation to their performance
training zone describes the intensity range that is required for specific adaptations to occur
transition phase (off-season phase) designed to provide the athlete with a break from the physiological and psychological demands of competition and training. The aim in this phase is for an athlete to remain reasonably active through participation in recreational and low-intensity activities.
triglycerides the stored form of fats found in adipose tissue and skeletal muscle
t-tubule system a network of tiny tubes in muscle fibres that allows electrical signals to move deep inside the muscle and excite the muscle fibre
type 1 slow-twitch oxidative fibres contain large and numerous mitochondria, high levels of myoglobin and a high capillary density. They are very resistant to fatigue and have a high capacity to generate ATP by oxidative metabolism.
type 2A fast-twitch oxidative fibres red, and have a very high capacity for generating ATP by oxidative metabolic processes. They split ATP at a very rapid rate, have a fast contraction velocity and are resistant to fatigue.

type 2B fast-twitch glycolytic fibres white, and are geared to generate ATP by anaerobic metabolic processes. They split ATP at a very rapid rate, have a fast contraction velocity and fatigue easily.

Valsalva manoeuvre occurs when an individual attempts to exhale while the mouth, nose and glottis (part of the larynx) are closed

variability the amount of change and uncertainty in an environment or in the performance of a skill

variety providing different activities, formats and drills in training, while still addressing the aims of the training program. Its focus is to maintain the motivation levels of the performer and thereby optimise their fitness gains.

vasoconstriction the process where blood vessels narrow or constrict as a response to a decreased demand for oxygen delivery to muscle tissue

vasodilation the process whereby blood vessels increase their internal diameter as a response to an increased demand for oxygen delivery to muscle tissue

velocity the rate of the speed an object moves its position

venous pooling an accumulation of blood in the veins in inactive muscles following activity

ventilation the amount of air inspired or expired per minute by the lungs. Ventilation (V) = tidal volume (TV) × respiratory frequency (RF).

warm-up activities and exercise undertaken at the beginning of a training session that are designed to prepare the body both physiologically and psychologically for the conditioning phase of the training session

work-to-rest ratio a summary of the time an athlete spends physically working compared to the time spent resting or recovering

yield the total amount of ATP that is resynthesised during an exercise bout

INDEX

absolute VO_2 max. 440
acceleration
  angular acceleration 52
  linear acceleration 51–2
accelerometers 362
acetyl coenzyme A 170
acting energetically 495–6
active recovery 168–9
activity analysis 228–9
  data analysis 243–4
  data collection 229–30, 242–3
  heart rates 237
  movement patterns 233–5
  netball case study 242–5
  and planning training programs 346
  skill frequency 231–2, 243
  work-to-rest ratios 240, 243
activity trackers 373
acute responses
  cardiovascular system 198–202, 203–5
  muscular system 216–17
  respiratory system 206–7
adenosine diphosphate *see* ADP (adenosine diphosphate)
adenosine triphosphate *see* ATP (adenosine triphosphate)
ADP (adenosine diphosphate) 146, 147, 168
aerobic glycolysis/slow glycolysis 170
aerobic metabolism 147
aerobic power 254
  factors affecting 255
  testing 255
aerobic power tests 292–99
aerobic system 155, 170, 176
  and exercise 172
  and fatigue 174–6
  impaired muscle excitability 176
  metabolism of carbohydrates 170–1
  metabolism of fats 171
  metabolism of protein 171
  and recovery 176
aerobic training
  cardiovascular adaptations 427–30, 439–40
  chronic adaptations 424–5
  methods 255
  muscular adaptations 435–7, 439–40
  respiratory adaptations 433–4, 439–40
age
  aerobic power and 255
  anaerobic capacity and 256
  maximum oxygen uptake (VO_2 max.) 210, 211
  reaction time and 274
  speed and 266
  strength and 260
agility 267–9
agility tests 321
  5-0-5 agility test 324–5
  Illinois agility test 321–2
  Semo agility test 323–4
agonist muscle 447
air resistance 36, 52, 53, 54
amino acids 152, 466
anaerobic capacity 256
  factors affecting 256–7
  testing 257
anaerobic capacity tests 299–4
anaerobic glycolysis system 155, 156, 164
  400-metre athletic event 164–5
  and ATP replenishment 168
  exercise and 164–6
  fatique 167–8
  recovery 168–9
anaerobic metabolism 147
anaerobic training
  chronic adaptations 425, 442–4
  methods 257
angular acceleration 52
angular distance, and displacement 49–50
angular kinematic concepts 34–41
angular momentum 40–1
angular motion 33
angular speed, and velocity 51
ankle extension/dorsiflexion test 336–7
antagonist muscles 447
anticipatory response 199
anxiety 490–1
application software (apps) 364–5
ARF acronym 59
arousal
  and performance 492
  promotion techniques 495–6
  reduction techniques 493–5
arteriovenous oxygen difference (a-VO_2 diff.) 204–5, 216, 435–6
associative stage of learning 88
Astrand–Ryhming cycle ergometer test 297
ATP (adenosine triphosphate)
  function of 146
  production at rest 178
  production during exercise 178–81
  rate 155–6, 157, 158
  resynthesis 146–7, 155–8
  stores 442
  yield 155–6, 157, 158
ATP demand 155–8
ATPase 442
ATP–CP system 155, 159
  anaerobic training and 442
  CP depletion 162
  exercise 158–60
  fatigue 162–3
  post-exercise recovery 163
attention 87
augmented feedback 129–32
autonomous stage of learning 89

balance 270–1
  factors affecting 271
  stability and 60–3
ballistic flexibility 408
bandwidth feedback 135
barriers to movement 14
base of support 62
baseline data 285
basketball throw test 309–10
biofeedback 494–5
biomechanical principles 32
biomechanics 32
blocked practice 117, 119
blood flow
  increase in muscles 216
  redistribution to working muscles 204
blood pressure (BP) 203
  aerobic training and 430
  decreases in 430
  diastolic blood pressure 203
  increase in 203
  systolic blood pressure 203
blood volume, aerobic training and 430
body composition 272–3
body composition tests 326
  bioelectrical impedance 330
  body mass index (BMI) 326
  DEXA and TOBEC scans 330–1
  hydrodensitometry (underwater) weighing 329
  skinfold measurement 327–29
  waist circumference test 327
body mass index (BMI) 326
body size, and maximum oxygen uptake 209
buffering capacity 444

capillarisation
  heart muscle 427
  skeletal muscle 430
carbohydrate gels 463–4
carbohydrate loading 471
carbohydrates
  aerobic metabolism of 170–1
  in the body 150
  complex carbohydrates 148
  dietary intake 150
  as energy source 150
  functions 460
  glycaemic index (GI) 148–9, 461–3
  nutritional classication 462
  nutritional needs of athletes 460–1
  and protein 153, 467–8, 474
  and recovery 474
  simple carbohydrates 148
  types 148
carbohydration 472
cardiac hypertrophy 427, 444
cardiac output
  aerobic training and 428, 429
  increase in 201–2
cardiovascular system
  acute responses 198–201, 203–5
  adaptations to aerobic training 427–30, 439–40

increased cardiac output 201–2
integrated response to exercise 201–2
Catapult digital technology 362
centre of gravity (COG) 61
choking 486
chronic adaptations to training 424
aerobic training 424–5, 427–30, 433–4, 435–7, 439–40
anaerobic training 425
resistance training 425, 446–7
circuit training 413–14
closed motor skills 6
closed/discrete movement skills practice 112–15
coach-regulated feedback 135–6
coaching
applying Newell's model of movement constraints 11
associative stage of learning 88
autonomous stage of learning 89
cognitive stage of learning 88
comparison of approaches 84–5
constraints-based approach 76–85
direct/traditional approach to instruction 72–5
explicit vs. implicit instruction 81
game sense approach 82–3
indirect approach 75, 76, 85
instructor-orientated approach 72–5
cognitive stage of learning 87–8
community, influence on skill development 99
competition phase of training 348–9
complex carbohydrates 148
concentration 497–8
concurrent feedback 137
conditioning 355
fitness conditioning phase 356
skill development phase 355
confidence 486–7
conservation of momentum 36
constraints-based approach to instruction 76–7
advantages 81
environmental constraints 77, 78
individual constraints 77, 78
perception–action coupling 77
task constraints 77, 79
using constraints to teach skills 79–80
continuous motor skills 9
continuous training 389–90
controlled breathing 493
cool-down 356
Cooper 12-minute run test 295–6
coordination 273
core strength/stability training 399–400
Cori cycle 183
correct feedback 131
creatine phosphate (CP) 148
depletion 162
increased stores 442
culture, influence on skill development 95–6
curlup (crunch) test 316–17

data collection 229–30
baseline data 285
dehydration 477
deliberate play 93, 122–3
deliberate practice 94, 121
deliberate programming 124–5
descriptive feedback 132
detraining 386–7
developmental model of sports participation 122–3
DEXA scans 330–1
diastolic blood pressure 203
diet, balanced diet 458–9
digital activity trackers 361–3
digital recording 230
diminishing returns 386
direct observation 229
direct tests 283
direct/traditional approach to instruction 72–5
advantage 75
versus game sense approach 84–5
versus indirect approach 75, 85
discrete motor skills 8
discrete/closed movement skillspractice 112–15
displacement
angular distance and 49–50
linear distance and 48–9
distance training 389–90
distributed practice sessions 111–12
dorsiflexion test 336–7
drive theory 492
duration of training sessions/programs 380, 402
dynamic equilibrium 59–60
dynamic stretching 408

early specialisation 121
eccentric muscle contraction 399
eccentric overload training 399
electron transport chain 171
elevated breathing rate 495
enablers 14
energising imagery 496
energy systems
intermittent exercise 180
interplay of 178–81
and pathways 155–7
rest-to-exercise transitions 178–80
time–energy system continuum 180–1
environmental constraints
and instruction 77, 78
on movement 11
enzyme activity 216
equilibrium 59–60
excess post-exercise oxygen consumption (EPOC) 214–15
exercise
and aerobic system 175
and anaerobic glycolysis system 164–6
ATP production 178–81
and ATP–CP system 158–61
fuelling during 471–3
intermittent exercise 180
rest-to-exercise transitions 178–80
exercise training sessions
components 353
conditioning 355–6
cool-down 356
stretching 252–3
warm-up 353–55
explicit instruction 81
explicit learning 74
extrinsic motivation 488

faded feedback 135
family, influence on skill development 93–4
fartlek training 414–15
fast decay exponential taper 351
fatigue
and aerobic system 174–6
and anaerobic glycolysis system 167–8
and ATP–CP system 162–3
fats 150
aerobic metabolism of 171
in the body 150
in diet 152
as energy source 150–1
saturated fats 150
unsaturated fats 150
feedback 128
augmented feedback 129–32
bandwidth feedback 135
coach-regulated feedback 135–6
concurrent feedback 137
correct versus incorrect feedback 131
descriptive feedback 132
faded feedback 135
frequency of 134–6
intrinsic feedback 128–9
knowledge of performance 129–30
knowledge of results 130
and learner type 138
performer-regulated feedback 135–6
prescriptive feedback 132
qualitative feedback 131
quantitative feedback 132
summary feedback 135
terminal feedback 136
timing of 134–6
types 128–32
fibre hyperplasia 446
field tests 283
50-metre sprint test 320–1

fine motor skills 8
first class levers 58
fitness testing
purpose 285–90
reliability and validity 91, 92
test protocols 289
types 282–6
fitness tests
2.4 km run test 296
30-second Wingate test 302–3
aerobic power tests 292–99
anaerobic capacity tests 299–304
battery of tests 288
choosing 286
Cooper 12-minute run test 295–6
Harvard step-test 298–9
multi-stage fitness test 292–3
phosphate recovery test 299–2
physiological perspectives 286
psychological perspectives 287–8
Repco peak power (phosphate power) test 305–6
Rockport 1.6 km walking test 297
sociocultural perspectives 288
standardised tests 291
VO_2 max. treadmill test 297
yo-yo test 293–4
FITT principle 382, 387
5-0-5 agility test 324–5
fixed load circuit training 413
fixed time circuit training 413
flexed arm hang test 317–18
flexibility 269
factors affecting 269–70
speed and 266
flexibility tests 270, 331
ankle extension/dorsiflexion test 336–7
groin flexibility test 334
shoulder rotation test 337
shoulder and wrist elevation test 334–5
trunk flexion (sit-and-reach) test 331–3
trunk and neck extension test 335–6
trunk rotation test 333
flexibility training 270, 406
ballistic flexibility 408
dynamic stretching 408
myofascial release 409
PNF stretching 407
slow active stretching 407
static stretching 406
stretching methods 406
food fuels
characteristics 158
converting to energy 153–4
force 35–6
force summation 37–40
Foundation Talent Elite Mastery (FTEM) Framework 94, 125
400-metre athletic event 164–5
free fatty acids 151
Freeman, Cathy 164–5
frequency of training sessions 380–1, 402
fuel depletion 172–3
fundamental movement skills (FMS) 4–6

game sense 82–3
gender, influence on skill development 97–8
gender stereotypes 97
Global Navigation Satellite System (GNSS) 362
Global Positioning System (GPS) 362
glucose 436
glycaemic index (GI) 148–9, 461–3
glycogen depletion 173–6
glycogen sparing 436
glycogen storage 442
glycolytic capacity 442
goal setting 488
golf drive, and function of ATP–CP system 159–60
GPS tracking 234–5
gravity
linear acceleration and 52
projectile motion and 53
grip strength dynamometer 306–7
groin flexibility test 334
gross motor skills 8
gyroscopes 362

haemoglobin 430
Harvard step-test 298–9
heart rate (HR) 198
anticipatory response 199
decreases during submaximal workloads 429
increased heart rate 198–9
maximum heart rate (MHR) 198
recovery heart rate 428, 429
resting heart rate (RHR) 198, 428
submaximal heart rate 428
heart rate monitors 237
heart rate reserve 376
Hewitt, Leyton 495–6
high-intensity interval training (HIIT) 391–3
'hitting the wall' 174
100-metre sprint, and function of ATP–CP system 159–60
hydration
de-hydration 478
estimating sweat rate and loss during exercise 477–8
functions of fluids 477
intravenous drips 481–2
needs of atheletes 477
over-hydration 478
sports drinks 478–81
water vs. sports drinks 481
hydrodensitometry (underwater) weighing 329
hydrogen ions 167, 444
hypertension 430
hypertonic sports drinks 480
hypertrophy 425, 427, 442, 444
hypoglycaemia 173, 462
hyponatremia 478
hypotonic sports drinks 480

Illinois agility test 321–2
imagery
energising imagery 496
mental imagery 497
immune system, nutrition and recovery 475
impaired muscle excitability 176
implicit instruction 81
implicit learning 76
impulse 45–6
in-laboratory tests 282
incorrect feedback 131
increased heart rate 198–9
indirect approach to instruction 75, 76, 85
indirect tests 283
individual constraints
and instruction 77, 78
on movement 11
individual load circuit training 413–14
individual responses to training 387–8
inertia 34
moment of inertia 40
informed consent 289, 290
inhibitory signalsreduction 447
inorganic phosphate (Pi) 168
instructor-orientated approach 72–5
intensity 376–7
intermittent exercise 180
interplay of energy systems 178–81
interval training 390
applying progressive overload 394–5
high-intensity interval training (HIIT) 391–93
planning 390
and work-to-rest ratio 390–1
intramyofibrillar glycogen cluster, depletion of 173
intravenous (IV) hydration 481–2
intrinsic feedback 128–9
intrinsic motivation 488
inverted-U hypothesis 492
isoinertial resistance training 397
isointertial muscle contraction 397–8
isokinetic muscle contraction 398
isokinetic resistance training 398
isometric muscle contraction 397
isometric resistance training 397–8
isotonic sports drinks 480

kinematics 32
kinetics 32
Krebs cycle 170–1

lactate 183–5
lactate inflection point (LIP) 184–5, 377, 440
lactate shuttles 183–4
lactate tolerance
anaerobic capacity and 256, 445
muscular endurance and 263
lactic acid 167
learning
associative stage 88
autonomous stage 89
cognitive stage 87–8
explicit learning 74
implicit learning 76
observational learning 94
stages of 87
levers 57
first class levers 58
second class levers 58
third class levers 58–9
types 58–9
using lever systems 59
line of gravity 62
linear acceleration 51–2
linear distance, and displacement 48–9
linear kinematic concepts 34–41
linear motion 33
linear speed, and velocity 50
local community, influence on skill development 99

Magaria Kalamen power test 313
magnetometers 362
maintenance of fitness levels 387
mass 34
massed practice 110–11
maximal tests 283
maximum heart rate (MHR) 198
maximum oxygen uptake (VO_2 max.) 168, 207
absolute VO_2 max. 440
aerobic training and 439–40
age and 210, 211
body size and 209
factors affecting 209–11
gender and 209, 211
genetics and 210
relative VO_2 max. 440
at rest 213
training status and 210–11
testing 283, 297
Meares, Anna 443
meditation 493–4
mental imagery 497
metabolic by-product/metabolites 167
metabolic equivalents (METs) 376–7
metaphoric analogyusing 81
mitochondria 172, 435
modified junior sports 80–1
Moffatt, Emma 443
moment of inertia 40
momentum
angular momentum 40–1
conservation of 36
definition 36
force summation 37–40
motion 33
motivation 487–8
motor skill development
familial advantage 15–16
participation and performance 14–16
motor units
firing rate or rate coding 447
recruitment 216, 444, 447
synchronisation 444, 447
movement constraints 11
movement patterns, activity analysis 233–5
movement skills
closed motor skills 6
continuous motor skills 9
discrete motor skills 8
fine motor skills 8
fundamental movement skills 4–5
gross motor skills 8
open/closed skill continuum 6–7
serial motor skills 8
sport-specific skills 5
types 4–9
see also skill development
multi-stage fitness test 292–3
muscle acidosis 167
muscle excitation–contraction (E–C) coupling 176
muscle fibre recruitment 216
muscle fibre types
adaptations to aerobic training 436
adaptations to resistance training 446
aerobic power and 255
anaerobic capacity and 256, 257
endurance and 263
speed and 266
strength and 260
type 1 slow-twitch oxidative fibres 183, 436–7
type 2A fast-twitch oxidative fibres 436–7, 442
type 2B fast-twitch glycolytic fibres 436–7, 442
muscle-use analysis 232
muscles
agonist muscle 447
antagonist muscles 447
changes in structure 446
decreased substrate levels 217
enzyme activity 216
increased blood flow 216
increased size *see* muscular hypertrophy
redistribution of blood flow to working muscles 204
synergist muscles 447
temperature 216
muscular endurance 262
factors affecting 263
resistance training 403
training 263
muscular endurance testing 263, 313
30-second sit up test 315–16
60-second push up test 314–15
curlup (crunch) test 316–17
flexed arm hang test 317–18
pullup/modified pullup test 317
muscular hypertrophy
aerobic training 425
anaerobic training 442
resistance training 403
muscular power 260–1
factors affecting 261
resistance training 403
training 261
muscular power testing 261, 309
basketball throw 309–10
Magaria Kalamen power test 313
standing long-jump test 312
vertical jump 310
muscular strength 259
factors affecting 259–60
resistance training 403
training 260
muscular strength testing 260, 305
grip strength dynamometer 306–7
one repetition maximum (1 RM) test 305–6
push–pull dynamometer 307–8
seven-stage abdominal strength test 308–9
muscular system, acute responses 216–17
muscular tissue, adaptations to aerobic training 435–7, 439–40
music, use of 496
myofascia 409
myofascial release 409
myofibrils 442
myoglobin 435
netball, activity analysis 242–5

NETFIT Netball 393–4
neural control 446–7
neuromuscular adaptations, resistance training 446–7
Newell's model of movement constraints 11–13
Newton's first law of motion 40, 43
Newton's second law of motion 43–4
Newton's third law of motion 44–5
nutrition
balanced diet 458–9
carbohydrates 460–4

fuelling during exercise 471–3
immune system support 475
preparation for different sports 470–1
protein 466–8
recovery from exercise 473–5

observational learning 94
one repetition maximum (1 RM) test 305–6
1 RM (1 repetition maximum) 260
open motor skills 6
open/closed skill continuum 6–7
optimum arousal theory 492
over-hydration 478
overtraining 383–4
oxidative enzymes 436
oxidative system *see* aerobic system
oxygen
excess post-exercise oxygen consumption (EPOC) 214–15
increased supply and use by muscles 217
increased utilisation 435
see also maximum oxygen uptake (VO_2 max.)
oxygen deficit 213

PAR-Q (Physical Activity Readiness Questionnaire) 287–8
passive recovery 163, 169
passive stretching 357
peaking 350–1
peers, influence on skill development 96
perception–action coupling 77
performance, arousal and 492
see also psychological strategies for performance and recovery
performance anxiety 490–1
performer-regulated feedback 135–6
periodisation of training 346–48
competition phase 348–9
peaking and tapering 350–1
preparatory phase 348
transition phase (off-season phase) 349–350
pH 167
phosphate recovery test 299–2
phosphocreatine (PC) 148
phosphorylation 147
physical literacy 6
physiological training data 359
play, deliberate play 93
plyometrics 409
low impact vs. high impact exercises 410–11
phases 409
training guidelines 410–11
PNF (proprioceptive neuromuscular facilitation) stretching 407
positive self-talk 496
post-program testing 286
potassium 176
potential energy 409
power *see* muscular power
practice
amount of 108–10
blocked practice 117, 119
deliberate practice 94, 121
diminishing returns 110
discrete/closed movement skills 112–15
distributed practice sessions 111–12
distribution of 110–15
massed practice 110–11
maximising practice time 109
random practice 118–19
serial practice 118, 119
time on task 110
variability 116–17
varying for skill learning 120–1
pre-competition workouts 496
pre-fitness assessment 346
pre-training program testing 285
preparatory phase of training 348
prescriptive feedback 132
progressive muscle relaxation (PMR) 493
progressive overload 382–4, 394–5, 402
projectile motion 52–3
angle of release 54
height of release 55
speed of release 53–4
proprioceptive neuromuscular facilitation (PNF) 357
protective reflex 447
protein 152
aerobic metabolism of 171
in the body 152
and carbohydrates 153, 467–8, 474
in diet 153
as energy source 153
functions 466
nutritional needs of athletes 466–7
and recovery 474
supplementation 468
types 466
psychological strategies for performance and recovery
concentration 497–8
confidence 486–7
maintaining control 490–6
mental imagery or visualisation 497
motivation 487–8
sleep 484–6
psychological training data 359
pullup/modified pullup test 317
pulmonary diffusion 207, 433
pulmonary ventilation 206, 207, 433
push–pull dynamometer 307–8
pyruvic acid/pyruvate 164
qualitative analysis
error correction 19–20
evaluation 19
four task model 18–20
observation 19
overview 17
preparation 18–19
tennis service 21–3
qualitative feedback 131
quantitative feedback 132

random practice 118–19
rate of ATP 155–6, 157, 158
rate coding (motor units) 447
reaction time 266, 274–5
real time 362
rebound hypoglycaemia 462
recovery
active recovery 168–9
aerobic system 176
anaerobic glycolysis system 168–9
ATP–CP system 163
immune system and 475
nutrition and 473–5
passive recovery 163, 169
see also psychological strategies for performance and recovery
recovery heart rate 247, 428
reinvestment 81
relative VO_2 max. 440
Repco peak power (phosphate power) test 303–4
repetition maximum 377
resistance training
basic guidelines 403–4
chronic adaptations 425, 446–7
core strength or stability training 399–401
eccentric overload training 399
isoinertial resistance training 397
isokinetic resistance training 398
isometric resistance training 397–8
muscular endurance 403
muscular hypertrophy resistance training 403
muscular power 403
muscular strength 403
neuromuscular adaptations 446–7
specificity in 400–402
terminology 402
and training principles 402–3
types 397
respiratory frequency (RF) 206, 433
respiratory system
acute responses 206–7
adaptations to aerobic training 433–4, 439–40
rest-to-exercise transitions 178–80
resting heart rate (RHR) 198, 428
reversibility 386–7
Rockport 1.6 km walking test 297
RPE (rating of perceived exertion–Borg Scale) 360

SAID principle 373
saturated fats 150
second class levers 58
self-confidence 486
self-regulated feedback 135–6
Semo agility test 323–4
sequential force summation 38–40
serial motor skills 8
serial practice 118, 119
seven-stage abdominal strength test 308–9
sex
  aerobic power and 255
  anaerobic capacity and 256
  flexibility and 269
  maximum oxygen uptake (VO_2) 209
  muscular endurance and 263
  reaction time and 274
  speed and 266
  strength and 260
shoulder rotation test 337
shoulder and wrist elevation test 334–5
simple carbohydrates 148
simple direct observation 229
simultaneous force summation 38
sit-and-reach test 331–3
60-second push up test 314–5
skill development
  sociocultural influences 91–2
  transferable elements 123
skill frequency, activity analysis 231–2, 243
skill movement, three 'B's of 114–15
skin resistance 269
skinfold measurement 327–29
sleep, and sports performance 484–6
slow active stretching 357, 407
slow glycolysis *see* aerobic glycolysis
sociocultural influences on skill development 91–2
  cultural norms, traditions and beliefs 95–6
  family 93–4
  gender 97–8
  local community 99
  peers 96
  socioeconomic status 98–9
socioeconomic status, and skill development 98–9
sociological training data 359
somatotype 269
specificity 362–3
  in resistance training 400–2
speed 265–6
  factors affecting 266
  training 266
  and velocity 50–1
speed testing 266, 319
  20-metre sprint test 319
  50-metre sprint test 320–1
  35-metre sprint test 320
Sport Competition Anxiety Test (SCAT) 491
sport-specific skills 5
sports drinks
  guidelines for consuming 480
  hypertonic sports drinks 480
  hypotonic sports drinks 480
  isotonic sports drinks 480
  types 479
  vs. water 481
sports participation developmental model 122–3
sports psychology 484
stability and balance 60–1
  base of support 62
  centre of gravity (COG) 61
  increasing 62
  line of gravity 62
  reducing 62–3
standard release forms 290
standardised tests 284, 291
standing long-jump test 312
static equilibrium 59–60
static stretching 357, 406
steady state (aerobic) 213–14
strength *see* muscular strength
stress inoculation training (SIT) 495
stretch reflex 409
stretching 252–3
  ballistic flexibility 408
  dynamic stretching 408
  methods 406
  myofascial release 409
  PNF stretching 407
  slow active stretching 357, 407
  static stretching 357, 406
stroke volume (SV) 199
  aerobic training and 427
  increased stroke volume 199–200, 427
submaximal heart rate 428
submaximal testing 283–4
summary feedback 135
sweat rateestimating 477–8
synergist muscles 447
systemic blood flow 204
systolic blood pressure 203

t-tubule system 176
tapering 350–1
task-related constraints
  and instuction 77, 79
  on movement 11
Teaching Games for Understanding Model (TGFU) 82
10 000 Hours Rule 108
terminal feedback 136
testing during training 285
third class levers 58–9
30-second sit up test 315–6
30-second Wingate test 302–3
35-metre sprint test 320
tidal volume (TV) 206, 433
time/duration principle 380
time–energy system continuum 180–1
TOBEC scans 330–1
traditional approach to instruction 72–5
training
  monitoring and recording 359–61
  testing during 285
training diaries 360–1
training methods
  circuit training 413–4
  continuous training 389–90
  distance training 389–90
  fartlek training 414–5
  flexibility training 406–9
  interval training 390–5
  plyometrics 409–11
  progressive overload 382–4
  selecting 345, 378
  variety 384
  see also resistance training
training principles
  detraining 386–7
  diminishing returns 386
  FITT principle 382, 387
  frequency 380–1
  individuality 387–8
  intensity 376–7
  maintenance 387
  resistance training 402–3
  reversibility 386–7
  selecting 345
  specificity 374–5
  time/duration principle 380
training program matrix or planners 346
training programs
  periodisation 346, 348–51
  planning 344–6
  planning for netball 244–5
training sessions
  frequency 380–1
  planning 346
training zones 376
transition/off-season phase 349–50
triglycerides 151, 436
trunk flexion (sit-and-reach) test 331–3
trunk and neck extension test 335–6
trunk rotation test 333
2.4 km run test 296
type 1 slow-twitch oxidative fibres 183, 436, 437
type 2A fast-twitch oxidative fibres 436, 437, 442
type 2B fast-twitch glycolytic fibres 436–7, 442

underwater weighing 329
unsaturated fats 150

Valsalva manoeuvre 203
variety, in training activities 384
vasoconstriction 204
vasodilation 200
velocity 34
  angular speed and 51
  linear speed and 50
venous pooling 168
ventilation 206, 207, 433
vertical jump 310
visualisation 497
VO_2 max. testing 283
VO_2 max. treadmill test 295

waist circumference test 327
warm-ups 353
  benefits 355
  phases 354
weight training *see* resistance training
work-to-rest ratios 240, 243
  interval training and 390–1

yield of ATP 155–6, 157, 158
yo-yo test 293–4