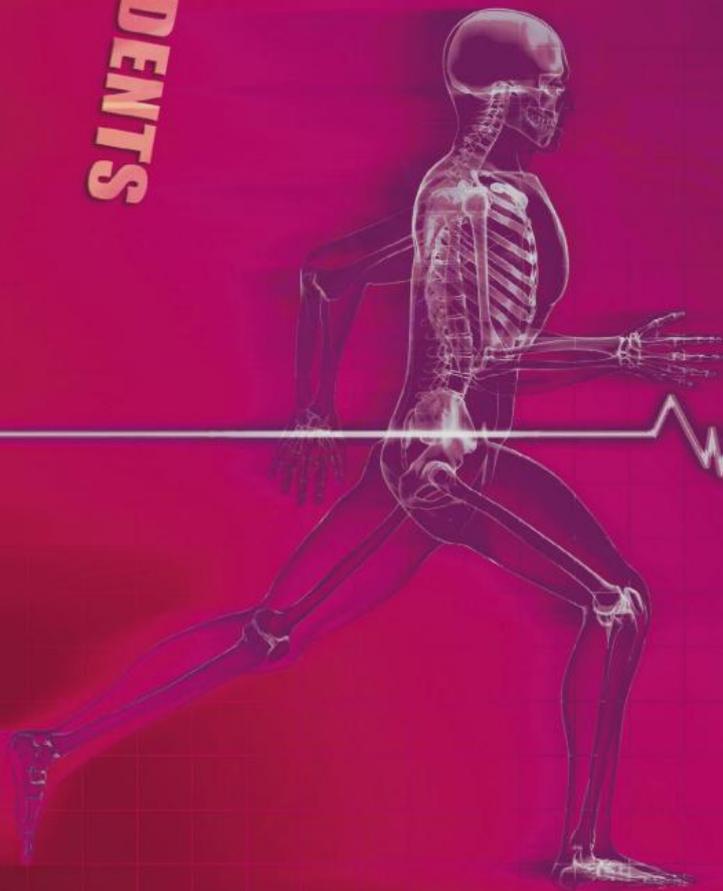


**ATAR UNITS
3 AND 4**

A TEXTBOOK FOR STUDENTS

PHYSICAL EDUCATION STUDIES



**EDITOR
Dr. Peter Whipp**

**PHYSICAL
EDUCATION
STUDIES**



THE UNIVERSITY OF
**WESTERN
AUSTRALIA**

**ATAR UNITS
3 and 4**

A TEXTBOOK FOR STUDENTS

PHYSICAL EDUCATION STUDIES

Associate Professor Peter Whipp

Professor Bruce Elliott

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**WESTERN
AUSTRALIA**

First published in 2010 by UWAP Custom
UWAP Custom is an imprint of UWA Publishing, a division of
The University of Western Australia
This revised ebook edition first published in 2015.



UWA Publishing
Crawley, Western Australia
www.uwap.uwa.edu.au

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National Library of Australia Cataloguing-in-Publication entry
Physical education studies : a textbook for teachers and
students ATAR Units 3 and 4 / Peter Whipp ... [et al.]
9781742588162 (pbk.)

Includes index.
Physical education and training--Australia.
Physical education and training--Study and teaching
(Secondary)--Australia.
613.70430994]

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Authors' Profile

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Professor Bruce Elliott (B.Ed; M.Ed; Ph.D) is one of the world's leading sport scientists. He is a fellow of the Australian Council for Physical Education, Health and Recreation; the American Association for Kinesiology and Physical Education; and the International

Society of Sport Biomechanics. In 2000 he was selected by the IOC to administer the applied sport research projects at the Sydney Olympics and in 2003 he was awarded the Centenary Medal by the Australian Government for 'Service to Sport Research and Policy Development'. Although he has published over 200 refereed articles and fifty books/book chapters, his desire to promote the application of sport science – to meet the needs of teachers and students of PE – is the motivating factor in playing a role in this book.

Dr Kym Guelfi (BSc (Hons); Ph.D) is a lecturer and researcher in exercise physiology at the School of Sport Science, Exercise and Health, at The University of Western Australia. She is currently involved in teaching a number of units at both an undergraduate and postgraduate level. Her research interests include the role of exercise in disease prevention and management (particularly obesity and diabetes mellitus). She has also been involved in the delivery of PE Studies professional development activities for teachers and student revision seminars. Dr Guelfi is an enthusiastic teacher and researcher with a passion for sharing knowledge and stimulating interest in the area of exercise physiology.

Dr James Dimmock (BSc (Hons); BCom; Ph.D) is a Senior Lecturer in sport and exercise psychology at the School of Sport Science, Exercise and Health, at The University of Western Australia. As well as teaching sport and exercise psychology, he also teaches units in sport, exercise and health management/marketing at the School. Dr Dimmock is currently undertaking research on motivation in exercise, but has undertaken research in the past on topics such as spectator psychology, mental toughness, and 'choking' in sport. Dr Dimmock has also been involved in the presentation of PE Studies revision seminars to high school students

Dr Brendan Lay (B.App.Sci; Hons; Ph.D) is a Senior Lecturer and researcher within the Biomechanics, Motor Control and Development Group at the School of Sport Science, Exercise and Health. He completed his Ph.D in Motor Learning at Deakin University before moving to The Pennsylvania State University where he worked as a postdoctoral researcher. His research centres on how people learn motor skills with particular interests in visual perceptual skill in elite sportspeople through to children with coordination difficulties. Dr Lay is currently researching technology-driven ways to improve and assess fundamental movement skills in children. Dr Lay has been a regular contributor and presenter at PES professional development days for teachers and revision seminars for students.

Dr Grant Landers (BSc (Hons); Ph.D) is a lecturer and researcher in functional anatomy and exercise physiology at the School of Sport Science, Exercise and Health, at The University of Western Australia. His research interest relates to improving endurance performance and has represented Australia in adventure racing

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Associate Professor Jacqueline Alderson (Ph.D) is a lecturer in biomechanics at The University of Western Australia. A fellow and current director of the International Society of Biomechanics in Sport, she is an active researcher and has published over 100 peer reviewed book chapters, journal papers and conference proceedings. She was a member of the IOC's medical commission biomechanics projects at the Sydney Olympics and from 1995-2014 served as biomechanics consultant to the International Cricket Council. She is a passionate advocate for the promotion of science in schools and serves as a biomechanics consultant and writer for the Australian and New Zealand Learning Federation as a biomechanics educator for the secondary teacher's enrichment program at The University of Western Australia (SPICE).

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Dr Peter Peeling (BSc (Hons); Ph.D) is a Senior Lecturer in exercise physiology at the School of Sport Science, Exercise and Health, at The University of Western Australia. Dr Peeling's primary research interest relates to applied sports physiology and nutrition, with a focus on enhancing human performance. Previously, he worked as an applied sports physiologist with the Australian Hockey team (The Kookaburras) leading into the 2008 Beijing Olympic Games, and also with the Western Australian Institute of Sport during the 4-year cycle to the 2012 London Olympic Games. During this time, Dr Peeling was involved in the daily training environment of many athletes competing at an International level, providing advice on aspects of training programming, recovery, nutrition and ergogenic aids.

Ms Monica Leslie (BSc) graduated from The University of Western Australia in 2014 with a double major in Psychological Science and Psychology in Society. After receiving a WACE Certificate of Distinction for 3A/3B PE Studies in 2011, Ms Leslie went on to continue her study of sport science through the School of Sport Science, Exercise and Health at UWA. She has been the recipient of numerous university awards, including the 2012 UWA Physical Education Students' Association Prize and the 2012 Convocation of UWA Graduates Prize for Human Movement. She is a regular presenter at high school PE Studies workshops and contributed to resources presented as part of the 2014 PE Studies Teachers' Conference at UWA. She is currently completing Honours research in the field of psychology, with a specific focus on elucidating the mechanisms of treatment action in anorexia nervosa.

Preface

Each chapter is preceded by a section that provides background information. These ‘Key point summaries’ relate to concepts identified in the ATAR Units 1 and 2 Physical Education Studies curriculum.

The authors acknowledge that content related to ‘Developing physical skills, strategies and tactics’ is best defined and delivered by the expert class teacher. Teachers are best placed to embed these concepts into the specific sports undertaken in the practical components of the course. However, when evaluating skill technique, the ‘motion analysis procedural format’ and ‘video analysis’ sections in the Biomechanics and Motor Control and Learning Chapters provides structured methods for a qualitative evaluation.

A similar approach is followed for each section of the ATAR Units 3 and 4 Physical Education Studies curriculum. Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the ‘Content that follows’ and the theory and application for each content area. Suggested class tasks and practical activities can be found within the sections of the text. A ‘Key point summary’ box is presented at the end of each section. Local and contemporary research is presented under the headings ‘UWA research snapshot’.

Two practical investigations are included as Appendix B1 (ATAR Unit 3 content) and Appendix

B2 (ATAR Unit 4 content). A format for report writing can be located at the end of each chapter (Appendix A), to assist students with their preparation of the practical investigation. Marking matrices are also included in Appendices B1 and B2. A test related to one of practical investigations offered in each chapter has also been prepared. Answers for both the practical investigation questions and the test questions are provided for teachers and these can be found in the *Physical Education Studies ATAR Units 3 and 4: A Textbook for Teachers*.

Revision questions (with answers) are included near the end of each chapter (Appendix C).

Two ‘Personalised projects’ are included in the textbook. These assessment tasks are framed by the principles of Bloom’s taxonomy. The first project can be located at the end of Chapter 3, and a second project can be found at the end of Chapter 5. The first project requires students to display knowledge and understanding from Biomechanics, Functional Anatomy and Exercise Physiology (Chapter 3: Appendix D), while the second project focuses on ‘Sport Psychology and Motor Learning and Coaching’ (Chapter 5: Appendix D). Even if these tasks are not undertaken for assessment purposes, they are a valuable tool for revision.

A ‘Glossary of key terms’ appears on the final pages of each chapter (Appendix E).

Acknowledgements

Reference group: Many thanks to our team of Physical Education Studies teachers for their insight and contribution through ideas, direction, editing and feedback to the first edition of this textbook (*Physical Education Studies 3A-3B: A Textbook for Teachers and Students*). The reference group consisted of Ms Brooke Haendel (All Saints' College), Mr Theo Gummery (Belmont City College), Mr Peter Webster (Shenton College), Ms Sandra Botica (St Mary's Anglican Girls' School), Mrs Sharon Sinclair and Miss Jo Swain (St Hilda's Anglican School for Girls).

Professor Brian Dawson (The University of Western Australia) for his contribution to Chapter 3: Exercise Physiology.

Ms Kelly Ma and Mr Don Gordon for their creation of images.

Mr Brendan Chapman (Aquinas College) for editing and providing marks allocation for all examination style questions found in the PowerPoint slides.

Interview subjects: Mr Matthew Pavlich (AFL), Ms Kobie McGurk (Hockey), Miss Kelly Harrison (Gymnastics), Ms Jessica Jordan (Taekwondo), Mr Ben McKinley (AFL), Ms

Emma Beckett (Netball).

Photography:

Acorn Photo, Subiaco: Mr Robert Frith
GoPix, Perth: Mr Simon Harris

Photographic models: The University of Western Australia Diploma of Education (HPE) students of 2010, Dr Nat Benjanuvatra (The University of Western Australia), Miss Kelly Harrison, Ms Jessica Jordan (John Septimus Roe Anglican Community School), Ms Jay Lee Longbottom (The University of Western Australia), Mr Mike De Rossi, Mr Cyrus Hands, Miss Chantelle James (Presbyterian Ladies College), Ms Kylie Wheeler, Cassandra Bleakley, Michaela Bleakley.

The authors wish to express gratitude to the staff at UWA Publishing and their team of editors and associate staff and Brown Cow Design for their unstinting support and professional guidance. Their generous contributions were infinite. This book would not be what it is, without these people.

Image Sources

All graphs, illustrations, and diagrams courtesy of the School of Sport Science, Exercise and Health, The University of Western Australia.

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Features of this textbook

Domain specific chapters: Colour coded for each chapter

Chapter 1: Biomechanics

Prof Bruce Elliott, Dr Jacqueline Alderson and Dr Peter Whipp

Chapter 2: Functional Anatomy

Dr Grant Landers, Dr Peter Whipp and Dr Kym Guelfi

Chapter 3: Exercise Physiology

Dr Kym Guelfi, Dr Peter Whipp and Dr Peter Peeling

Chapter 4: Sport Psychology

Dr James Dimmock, Dr Peter Whipp and Ms Monica Leslie

Chapter 5: Motor Learning and Coaching

Dr Brendan Lay and Dr Peter Whipp

Background information: ‘Key point summaries’ related to concepts identified in the ATAR Units 1 and 2 Physical Education Studies curriculum.

ATAR Units 3 and 4 course specific content, with identification of content specific to Units 3 and 4.

Text learning outcomes: Statements that identify what students, on completion of engaging in class-related activities and studying the unit content, should be able to do. These are consistent with the needs of the course, as defined by the School Curriculum and Standards Authority and PES Course Syllabus of Western Australia.

Content that follows: Identifies the specific content that defines the section of work that follows within a chapter.

Key point summary: Statements that revise key content covered in each section of the chapter.

UWA research snapshot: Identifies recent research findings from experiments undertaken in the School of Sport Science, Exercise and Health.

Class task: A class-based task that facilitates students to access the concepts identified and requires no equipment.

Practical activity: A class-based or homework experiment that facilitates students to access the concepts identified. A list of the equipment required is provided.

Practical investigation: An in-depth, class-based experiment that facilitates students to access the concepts identified. Each task is differentiated for ATAR Unit 3 or ATAR Unit 4 content. Questions, with allocated marks, are presented to access both the experimental data and to extend students through application of their learning to alternative movement and sporting contexts. A format for report writing and marking matrices are also included. A test related to one of practical investigations offered in each chapter has also been prepared. Answers for both the practical investigation questions and the test questions are provided for teachers and these can be located in the *Physical Education Studies ATAR Units 3 and 4: A Textbook for Teachers*. A list of the equipment required is provided.

Revision questions (with answers): Are included near the end of each chapter. Links to content-specific questions are identified in each chapter.

Personalised project: Two ‘Personalised projects’ are included in the textbook. These assessment tasks are framed by the principles of Bloom’s taxonomy. These tasks require students to display knowledge and understanding from multiple content domains.

Glossary of key terms: Definitions of the words and concepts are provided.

PowerPoint slides: A PowerPoint slideshow that summarises all of the key concepts provides a valuable teaching and learning tool.

The Teachers’ edition:

The teachers’ edition of: *Physical Education Studies ATAR Units 1 and 2: A Textbook for Teachers*; and *Physical Education Studies*

ATAR Units 3 and 4: A Textbook for Teachers contains answers to the practical investigation questions. The teachers’ editions also contains test questions and answers that are offered as an in-class alternative to students completing a practical investigation report.

Updates and revised content

At the time of publication, many of the authors of this textbook are active researchers at the School of Sport Science, Exercise and Health at The University of Western Australia. They are constantly seeking new knowledge and to clarify our understanding through experimentation. When additional understanding of the content in this book is defined, it will be publicised through the UWA student revision seminars held on-campus each year, the teacher professional development seminars and the Physical Education Studies Teachers’ Association (PESTA) website.

Things you should do in preparation for the theory examination

Whilst this book serves primarily as a tool for teaching and learning, ultimately it is important that students develop an awareness of how to best represent their learning outcomes. This will require written examination. The following are some considerations for responding to written questions.

- Set yourself a realistic study timetable—for all of your subjects.
- Confirm what content is examinable—use a summary page and list the key words or concepts (content) that you have covered.
- Use the ‘Key point summary’ boxes that are embedded in each chapter as a guide to the important content

and concepts. Consider copying the content in each summary box and placing it on your study wall.

- Identify and clarify the content that you do know and that which you need to further revise.
- Create summary notes. These should be all in the same format. Use **HEADINGS, Sub-Headings** and **dot-points**. Also use small graphs and diagrams to reinforce content. As part of your preparation try and visualise what is on the page of summary notes. Visualisation and mental imagery can be useful when trying to remember!
- Revise the content and use exam-style questions to reinforce how the content is applied as part of your revision.
- Maintain a personal exercise schedule.
- Consider a writing warm-up prior to going in to the written examination. Prepare to write with well formed legible handwriting.

What is the external examiner thinking?

- The course content being examined has come from the ATAR Units 3 and 4 PES Syllabus as defined by the School Curriculum and Standards Authority and PES Course Syllabus (<http://www.scsa.wa.edu.au>). The examiners will have used it to determine their choice of content to be examined.
- The examiners will have ensured that the questions require that you write a specific answer. They will know what information they are seeking in the answer. Therefore, you must answer the question – don't forget to revisit the question as you record your answer so that you stay on track.

What will the external marker do?

- The external marker will most likely not have written the question or the answer. They will be given the answer key and required to assign a mark for every time you make an appropriate point in your answer. Make it easy for them:
 - Record answers on the lines and within the space provided. This may need you to write with smaller letters than normal.
 - If you need additional space, try and fit it in under the lines provided.
 - Don't use faint pencil; a pen is far easier for the marker to read.
 - If you wish to cross something out, keep it as neat as possible and direct the marker with arrows or words to where your answer is located.

Things you should do in the examination

Use the reading time to:

- Affirm yourself and build self-confidence by reading to identify what you do know—not what you don't know.
- Decide what optional essay questions you will answer.
- If you need to write down acronyms of content cue words, do this as soon as the writing time begins.

Answering questions:

- Write an answer that, at minimum, matches the marks on offer. Generally, there is one mark on offer for each content area or point covered in your answer. For example, in an extended answer worth fifteen marks that requires five areas to be covered, you could be expected to record three different pieces of information under each area.

- **Definitions:** You can choose to write the word to start the answer but don't use the word you are defining in your answer.
- **List:** Normally just a dot-point will suffice. List is often accompanied by the word 'explain'. In that case you need to give more than a dot-point.
- **Identify:** Avoid just a list here. A sentence is required rather than just a one- or two-word dot-point.
- **Suggest:** There is generally more than one answer to this question. Each suggestion will need a definition and explanation.
- **Explain:** Often needs an application to a specific example. You should identify how the suggestion is useful or applied to the specific question or a problem.
- **Describe:** Similar to 'explain'.
- **Discuss:** With each point that you raise, you need to define, explain and justify your response. A discussion brings together facts and considers or examines by providing a comment or argument.
- Re-read every answer you have given. Consider using a highlighter—when you have finished answering all of the questions on the paper to reinforce your key points or words in your answer.
- The question: Save space and time by not writing the question in your answer. For example:

Q4. An athlete is seeking answers from the coach to assist future learning, but the coach said that they will be a better athlete in the long term if they firstly try reflective learning strategies to sort it out for themselves. Explain

the position taken by the coach and identify two different self-reflective methods that the athlete could use. (6 marks)

Don't repeat the question

Poor answer: For example,

'The athlete is seeking answers, but the coach said that they would be better to sort it out for themselves. The coach said this so they would use reflective learning like thinking it through and watching a video so they don't rely too much on the coach.'

These methods and the proposed rationale recorded in the poor answer above are described with general language. Use language that reflects that you have studied the topic and have an understanding. Also, try and respond in a logical order, that is, provide a rationale to explain the position taken by the coach first. Secondly, provide two very clearly identified self-reflective learning methods.

Good answer: For example,

Sometimes learners become dependent on the augmented feedback from the coach and will not utilise task-intrinsic feedback or reflective learning to improve. For augmented feedback to be most effective, it is important to allow learners to try to problem-solve for themselves. This is why the coach is encouraging the athlete to self-reflect and

self-learn. Two self-reflective learning methods include:

1. Reflective journal – to reflect on error detection using their own task-intrinsic visual, auditory and proprioceptive feedback.
2. Video self-analysis – comparing their own performance with previous performances, others, and an expert.



Biomechanics

Dr Bruce Elliott (Emeritus Professor), Dr Jacqueline Alderson (Associate Professor)
and Dr Peter Whipp (Associate Professor)

BACKGROUND INFORMATION

The following dot-points provide a revision of the key concepts from ATAR Units 1 and 2.

Linear kinematics

- When running on a treadmill, although you are covering a distance, your displacement is zero because you have not ‘gone anywhere’. If the speed of the treadmill belt is not increased you will run at a constant velocity and your acceleration will be zero.

Projectile motion 1

- Gravity does NOT influence horizontal motion; it only applies vertically and affects all objects at a constant rate of $9.8 \text{ m}\cdot\text{s}^{-2}$.
- Two objects of a similar surface area and shape, (a shot put and a softball), although of 2 different masses, when dropped from a height of 10 m, would both hit the ground at a similar time.

Projectile motion 2

There are three features in projectile motion (projection velocity, angle and height of take-off/release); however, the key concepts are:

- Optimal take-off velocity varies for each sport.
- Horizontal velocity is lower in vertically oriented sports (spike in volleyball) and higher for horizontally oriented activities (long jump).
- Angle of release is also critical for success in most examples of projectile motion and should be matched with the requirement of the activity (angle of projection is lower for a golf 3-iron versus a 9-iron, as the 9-iron is designed to produce height and the 3-iron is designed for gaining distance – length).
- When the release height is greater than the landing point, the optimal projection angle (release angle) is generally lower than 45° .
- Optimal projection angle (release angle) is generally greater than 45° when the landing point (or target in basketball) is higher than the release height.

Angular kinematics

When linking linear and angular motion, there are four things to consider when building speed of the hand or foot:

- How fast is the body moving forward at the time of impact or release (run-up velocity)?
- How quickly do you rotate the segment(s) involved in the movement (remember you may need to consider more than one segment)?
- The number of body parts that contribute.
- What is the length of the segment (in a kicking example, the linear velocity of the ankle/instep compared with the knee would be calculated using the distance (length) between the knee joint (the point of rotation) and the instep of the foot)?

Newton's Law

Key point summary:

- Newton 1: A body remains in its state of motion unless acted on by an external force
- Newton 2: Force equals the mass multiplied by the acceleration
- Where you are stopping the momentum of an object (mass multiplied by velocity) it is important to do so over as long a time period as is practical. That is: $F = (m V_2 - m V_1)/t$ or $F = m (V_2 - V_1)/t$
- Any increase in time will reduce the value of the peak force required to stop the motion, as Ft (referred to as impulse) will be constant
- Newton 3: Every action has an equal and opposite reaction.

Centre of gravity & balance

- The centre of gravity (C of G) represents the 'weight centre' of the body and is determined by the positioning of all the parts of the body.
- The C of G may lie outside the body itself.
- When you want to be very stable (static balance), position your C of G, such that it is central to your base of support.
- When you are required to continually move, such as in football or soccer you position your C of G so that it is close to the edge of your base of support and generally lower than in the static situation.

Coordination & movement

If maximum velocity is required then segments should be added sequentially, when the previous segment has reached its maximum speed. The concept of summation of velocity involves the following principles:

- Incorporate as many body parts as possible moving through their maximum range of motion.
- Develop force over the longest period of time possible.
- Sequential movement of the largest and strongest body parts first.

- Sequentially stabilise each segment, so that the next accelerates around a stable base.
- Follow through to ensure no deceleration before release.
- Ensure all forces are directed toward the target. That is, step to the target and follow through to the target.
- If accuracy is the key to success then movement of involved segments (typically less than in movements sequenced for maximum velocity) should be added at approximately the same time – simultaneously.

Biomechanics: ATAR Units 3 and 4

Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the ‘Content that follows’ and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A ‘Key point summary’ box is presented at the end of each section.

Two practical investigations are included as Appendix B1 (Unit 3 content: The principles of linear momentum and angular momentum) and Appendix B2 (Unit 4 content: The principles of spin, Magnus effect and Bernoulli). A format for report writing can be located at the end of this chapter (Appendix A) to assist students with their preparation of a practical investigation. Marking matrices are also included in Appendices B1 and B2, with answers provided for teachers.

Revision questions (with answers) are

included near the end of this chapter, as Appendix C. A ‘Glossary of key terms’ appears on the final pages of the chapter (Appendix E).

At the end of the Chapter titled Exercise Physiology is a ‘Personalised project’, which requires students to apply knowledge and understanding from ‘Biomechanics, Functional Anatomy and Exercise Physiology’ (Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision.

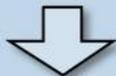
Introduction

The material within this chapter builds on that presented in the *Biomechanics Section* from the ‘Physical Education Studies ATAR Units 1 and 2: A Textbook for Teachers and Students’. The chapter in the previous book set the scene for an understanding of the role biomechanics plays in sport, everyday life and a clinical setting, by enabling the reader to describe motion (linear and angular kinematics) within an analytical framework (5-step analysis process). It also provided discussion of the causes of motion (Newton’s laws).

This chapter provides a deeper insight into the mechanisms that cause and alter motion. This approach, which begins with an expansion of linear kinetics, then explores the topic of angular kinetics, an area critical to the understanding of the mechanics of movement. A number of issues associated with fluid mechanics are then presented from an applied perspective. Students are challenged to re-visit the biomechanical analysis approach presented in ATAR Units 1 and 2 (Figure 1.1), such that it can be applied to movement, showing a greater understanding of the relationship between mechanical principles and manoeuvres commonly seen in sport and exercise.

Step 1: Preparation

- Understand the skill to be analysed, identifying the critical variables associated with 'ideal performance'.

**Step 2: Observation**

- Remember, you will need to observe the action from different locations to assess different variables.
- Observe performance under varied situations (fatigued vs non-fatigued; match vs practice).

**Step 3: Evaluation**

- Compare critical variables of your 'ideal performance' with observed performance.
- Prioritise practice time with regards to strengths in performance and observed weaknesses.

**Step 4: Intervention**

- Select the appropriate intervention to rectify weakness in performance.
- Provide feedback on the mechanical variables being practised.

**Step 5: Re-observe**

- Check that intervention strategies have been successful in modifying the movement.

An understanding of the material in ATAR Units 1 and 2 enabled you to describe the tennis serve (Figure 1.2) from the following perspectives:

- The types of motion observed during the service action.
- How balance varies during the different phases of the action.
- The displacement, velocity and acceleration profiles of the racquet.
- The coordination of the various body segments from the foot to the racquet.
- Newton's three laws, as they apply to this action.
- How the various segments of the body co-ordinate to create optimum velocity summation.

An understanding of this chapter will permit you to broaden your appreciation for biomechanics in movement and expand on concepts, such as how:

- Ball momentum is altered in the tennis serve.
- Moment of inertia and angular momentum play a role in the development of racquet velocity.
- The force-time profile (impulse) is developed as you push against the ground during the 'leg-drive'.
- The momentum of the ball changes from vertical to horizontal directions.
- The varying spin profiles applied to the ball cause different ball flight and rebound pathways.

Figure 1.1: *The 5-step analysis framework*



Figure 1.2: Roger Federer, the world's greatest tennis player hitting a serve (series of pictures published with permission of the International Tennis Federation)

Linear Kinetics

Text outcomes: *Linear kinetics* (Unit 3)

Define and show an understanding of biomechanics principles relating to:

- *Linear momentum*
- *Conservation of linear momentum*
(Newton's 2nd Law)
- *Impulse-momentum relationship*
- *Coefficient of restitution*
- *No calculations are required. However, some are included in the text where applicable to improve understanding of selected topics.*

Content that follows: *Linear kinetics (Unit 3)*

- *Linear momentum*
- *Conservation of linear momentum*
- *Impulse-momentum*
- *Coefficient of restitution*

Linear Momentum (m·v)

Linear momentum is the *product* (multiplication) of mass (m) and velocity (v). Remember velocity is a vector that has size (for example, $10 \text{ m}\cdot\text{s}^{-1}$ (m/s) and direction (for example, 45° to the horizontal, either forward or back). Let's consider animals that build linear momentum primarily through their mass or velocity.



Figure 1.3: The large mass and moderate running speed of an elephant create a very high linear momentum

- **Mass:** The elephant in Figure 1.3 has a mass of ~5,000 Kg, which when combined with the ability to run at moderate speed (e.g. $10 \text{ m}\cdot\text{s}^{-1}$ directly toward the person taking the picture), produces a huge linear momentum ($50,000 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1}$). Imagine preparing yourself for impact as this elephant charged toward you!

$$\begin{aligned}\text{Linear momentum } (p) &= \text{mass} \cdot \text{velocity} \\ &= 5,000 \text{ kg} \times 10 \text{ m}\cdot\text{s}^{-1} \\ &= 50,000 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1}\end{aligned}$$

- **Velocity:** The cartoon character Sonic the Hedgehog (Figure 1.4) with a mass of ~20 kg is able to build linear momentum based on ‘blistering’ velocity (for example, $100 \text{ m}\cdot\text{s}^{-1}$).

$$\begin{aligned}\text{Linear momentum } (p) &= \text{mass} \cdot \text{velocity} \\ &= 20 \text{ kg} \times 100 \text{ m}\cdot\text{s}^{-1} \\ &= 2,000 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1}\end{aligned}$$

With respect to linear momentum, the question may then be asked as to whether the key element in the equation is *mass* or *velocity*?



Figure 1.4: Sonic the Hedgehog from cartoon fame

Certainly the elephant relies more on mass, although it is quite capable of also running with moderate velocity, whereas Sonic the Hedgehog obviously has a clear bias to velocity. Hence the key elements; mass and velocity, vary for any given scenario.

What about humans and understanding linear momentum as it relates to your course outcomes? Let’s look at Usain Bolt, the fastest man in the world in 2014, who has a mass of approximately 95 kg. When running at his maximum velocity of approximately $12 \text{ m}\cdot\text{s}^{-1}$ (directly toward the finish line) he produces a linear momentum of $1,140 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1}$ (mass·velocity). This is still a relatively small number compared with the elephant; however, he compares

quite favourably with Sonic the Hedgehog. Think of the linear momentum created by rugby players; a winger builds momentum through velocity, whereas the momentum of a very large forward is created more by his mass (weight) – hopefully he can also run quickly.

An appreciation of the force required to generate movement (the linear momentum discussed above) or stop an object (person or ball) that possesses a given linear momentum, requires an understanding of the principle of ‘conservation of linear momentum’ discussed below.

Conservation of Linear Momentum

Newton’s 2nd Law ($F = m \cdot a$) relates to the behaviour of objects when all forces are unbalanced, resulting in the development of acceleration. That is, the acceleration of a ball may be increased by:

- applying more force for a constant mass; or
- applying less force but increasing the mass of the bat.

$$F = m \cdot a$$

F = the force applied

m = the mass of the object to which the force is applied (remember, this is not the weight of the object but the weight divided by gravity)

a = change in velocity/time $(v_2 - v_1)/t$

That is, $F = m \cdot a$ becomes

$$F = m (v_2 - v_1)/t$$

(change in momentum over time)

v_2 = velocity at the end of a movement

v_1 = velocity at the start of a movement

t = time from v_1 to v_2

Practical activity: Assessing the impact of mass on the resultant acceleration

Experiment by using a series of standard cricket bats that have a variety of weights taped to the back.

- Have a partner feed a series of tennis balls at a variety of speeds (slow to fast), whilst attempting to hit a conventional front-foot drive.
- Try the varying weighted bats.
- Discuss the impact on the batter’s ability to accelerate the ball.

Equipment:

- Series of cricket bats (at least 3).
- Variety of weights (for example, 500 g, 2 kg, 5 kg).
- Tennis balls.
- Electrical tape.

To create a change in momentum ($m \cdot v$) force must be applied. Consider hitting a ball in tee-ball (Figure 1.5). In this situation, which is discussed in depth below, force is provided by the swinging bat. The momentum of the stationary ball, which is initially zero, as it sits on the tee, is increased following impact.

Now let’s look at how the momentum of an object (or objects) is influenced by such a collision. Newton’s 2nd Law may be re-stated as:

Force is equivalent to the time rate of change of linear momentum.

The collisions between two objects may be **perfectly elastic**, in which case the total momentum of the ‘system’ (all objects combined) remains constant – it is conserved. This is the **Law of Conservation of (Linear) Momentum**. When two bodies collide, the momentum before the collision remains the same as the momentum after the collision and



Figure 1.5: Tee-baller changing the momentum of a stationary ball

therefore momentum is conserved.

The cue ball impacting another ball in a game of pool is a situation where momentum post-impact is conserved (Figure 1.6a – perfectly elastic collision). Conversely, attempting to bounce a ball in a sand pit is an example of a **perfectly inelastic** collision – there is no bounce and therefore linear momentum is not conserved (Figure 1.6b). In most situations, where the collision is an **imperfect elastic** collision (for example, golf drive, tennis forehand or bouncing a ball on the hard playground; discussed below) the total system momentum is not conserved and some energy is ‘lost’ to the collision, as exemplified by sound, heat and change of shape of the objects.

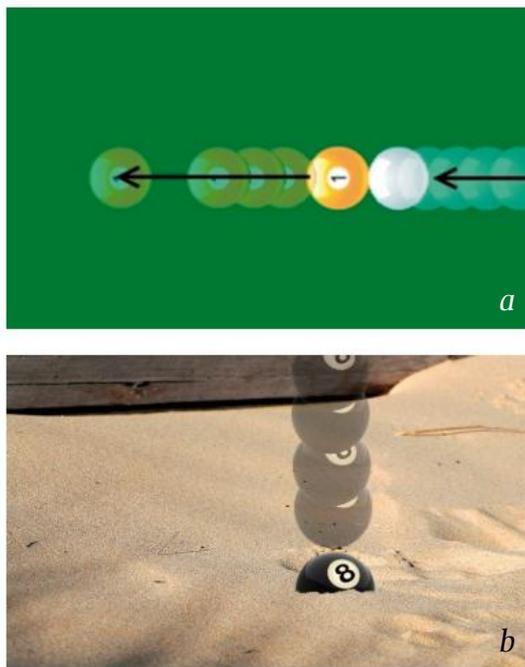


Figure 1.6a & b: *Impact between pool balls (a) are a close approximation to a perfectly elastic collision (linear momentum conserved), whereas when you drop a ball into sand (b) you have an inelastic collision*

Conservation of linear momentum

An understanding of this concept, where we consider collisions are perfectly elastic (uncommon in sport), requires consideration of two situations; firstly where one of the objects is at rest (no momentum, as in the tee-ball example) and the secondly where both objects are in motion, as with a cricket batsman hitting a bowled delivery or baseball (Figure 1.7).

In both cases the total linear momentum (p) before impact would then be:

$$(p) = p(\text{bat}) + p(\text{ball}).$$

If linear momentum is conserved:

$$\text{Pre-impact } p(\text{bat}) + p(\text{ball}) = \text{Post-impact } p(\text{bat}) + p(\text{ball}),$$

The above concepts would equally apply to hitting:

- a golf ball from a tee
- a penalty kick in soccer,
- hitting a forehand in tennis, or
- hitting a drive in cricket.

At the same time the impacting body slows down in direct proportion to the increase in momentum of the ball. Subsequently in all of these instances the total linear momentum of the colliding objects is conserved. For theoretical perfectly elastic collisions where impact occurs between a ball and club/stick/foot instep, momentum is transferred to the ball.

Class task: *Linear momentum*

Discuss the possibility of hitting a cricket ball into the grandstand from a fast bowler compared with facing a slow bowler.

Key point summary:

- In conservation of linear momentum the momentum of both objects before impact is not lost but remains the same for the combined momentum of both objects after impact.
- In a perfectly elastic collision the total momentum of the 'system' (all objects combined) is conserved.
- In a perfectly inelastic collision linear momentum is not conserved, it is zero after the collision.
- In an imperfect elastic collision the total system momentum is not conserved and some energy is 'lost' to the collision, as exemplified by sound, heat and change of shape of the objects.



Figure 1.7: The baseball drive is an example of a partial conservation of linear momentum between objects moving in different directions

impulse ($F \cdot t$) is equivalent to the change in momentum ($m \cdot v_2 - m \cdot v_1$) of the object, hence the relationship between impulse and momentum.

Impulse: Force production

Consider the rowing example in Figure 1.8. Force is applied to the oar with the blade placed in the water, from the time of the catch to the completion

Impulse–Momentum Relationship

The concepts of conservation of linear momentum and impulse are linked in *Newton's 2nd Law*, as shown in the formula $F = m [v_2 - v_1]/t$. If both sides of the equation are multiplied by time (t) you get:

$$F \cdot t = m (v_2 - v_1)$$

Impulse = change in momentum ($m \cdot v$)

This linking of force over time is termed *impulse* and is a mechanical variable used in the production of movement, such as hitting, kicking or 'exploding' from the blocks in sprinting. It is also used to stop movement, such as catching a ball or landing from a leap in netball or somersault in gymnastics. You can also see from the equation above that

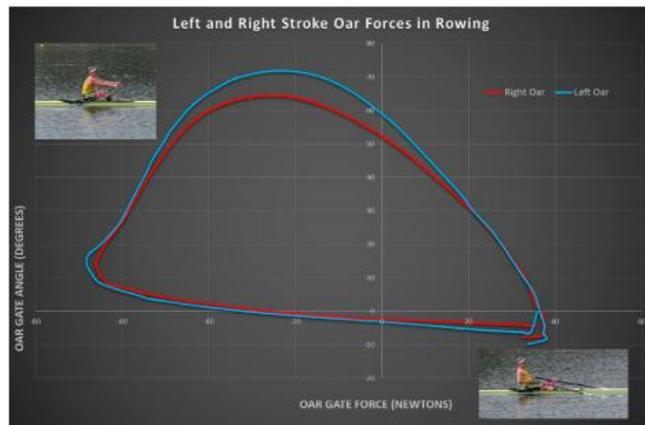


Figure 1.8: Oar gate left and right force traces plotted against gate angle during a complete rowing cycle (in and out of water phases). Photos and data courtesy of Matt Doyle, the Western Australian Institute of Sport.

of the stroke, to propel the boat through the water. You can see from this curve that varying magnitudes of force can be applied at different phases of the stroke cycle. Maximum force (torque or turning effect) is applied when the oar is approximately at right angles to the boat, which is also the best position to produce a moment of force (torque) discussed later in this chapter. The rowing coach is also interested in the shape of the curve. When selecting a rowing pair, you want both rowers to produce similar shaped impulse curves, so that the boat follows a straight line. The coach would also want the rowers to produce as large an area under the force-time (impulse) curve as possible, as more impulse results in a higher boat velocity.

In sprinting the impulse produced equates to your change in momentum from the blocks. However, because time is the key factor in running a 100 m, it is important to ‘build’ the force against the blocks relatively quickly (for example, impulse curve will have a large peak force over a small time period) to change the momentum of the body from zero (no velocity in the blocks) to a relatively high value in accelerating the body.

Key point summary:

Impulse – momentum

$$F \cdot t = m \cdot v_2 - m \cdot v_1$$

- Impulse ($F \cdot t$) is the product of force and time. That is, how much force can be produced over a time interval. This impulse is then directly responsible for creating momentum (changing momentum from zero), changing momentum (increasing momentum in a slow jog to that required for a sprint) or stopping momentum (catching a ball).

Impulse: Force absorption

In a similar manner, the impulse curve during running reflects the ‘reaction’ force from the ground (*Newton’s 3rd Law*: You apply a force to the ground and the ground applies a reaction force back to you). Remember, this reaction force may be vertical (Figure 1.9a) or horizontal (Figure 1.9b). The vertical impulse curve represents the force applied vertically over contact with the ground. The peak or maximum vertical force is often used as an indicator of the load imparted onto the body for a given activity. In order to compare the magnitude of these forces between people of different weights, biomechanists often report the forces as *bodyweight equivalents*. For example, if a netballer had a standing weight of 588 Newtons ($60 \text{ kg} \times 9.8 \text{ m} \cdot \text{s}^{-2}$) and if the maximum vertical ground reaction force experienced on landing from intercepting a pass was 3000 N (Figure 1.10), then we say that the netballer experienced a vertical force equivalent of 5.1 bodyweights (BW) ($3000 \text{ N} / 588 \text{ N}$).

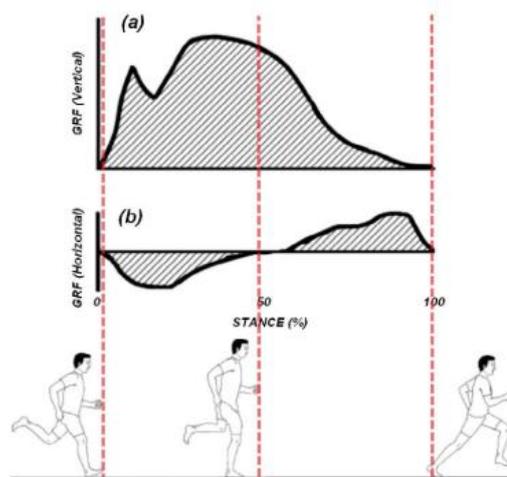


Figure 1.9a & b: The vertical (a) and horizontal (b) impulse curves associated with running

Some examples of peak vertical forces associated with different activities are:

- walking ~1.3 BW
- running ~3 BW
- landing following receiving a pass in netball ~5 to 6 BW
- take-off in jumping ~7 to 8 BW.

The lower peak force in walking compared with jumping means you can take many more walking steps than you can perform take-offs during jumping activities (high, long or triple jumps) before overuse injuries become an area of concern. Runners wear shoes that ‘cushion the forces at impact’, which help reduce the effect of the large forces mentioned above. Tennis players often prefer playing on grass and clay surfaces to reduce the peak reaction force from the court compared with playing on harder surfaces.

It is also the reason one should not perform plyometric exercises on very hard surfaces, as there will be a greater level of stress on the lower limbs if very high peak forces are experienced.

The shape of the curve in Figure 1.9b is also interesting, as the first part is negative, while the second part is positive. That is, the negative portion of the impulse curve represents the time when the runner is decelerating (remember the foot is placed out in front of the vertical line from the centre of gravity of the body to the ground – Figure 1.11). That is, the foot lands in front of the body which slows the body down (decelerates). It’s the major reason we should not ‘overstride’ when running. The positive impulse curve results from the force being applied backward to the ground, which accelerates the body toward the finish line (push-off). When running at a constant velocity you would have similar areas under both the negative, and the positive impulse curves. Imagine what the horizontal curve would look like if you wanted to stop suddenly while sprinting at maximum velocity. In this instance the negative part of the

Figure 1.10: A netballer landing after catching the ball

curve would be very large because you would be decelerating (slowing down very quickly).

Now let’s consider the absorption of impulse during catching a ball without (Figure 1.12a) and with (Figure 1.12b) backward movement. In catching a ball a player should ‘give’ with the hands (via flexing at the elbow together with other movements), so that there is an increase in the time taken for the hands to reduce the ball’s momentum to zero. Consider two situations where you stop a ball travelling at $30 \text{ m}\cdot\text{s}^{-1}$, immediately (a) (minimal time: over 0.001 s), compared with a gradual reduction to zero velocity (b) (over 0.05 s). How much force must be absorbed by the hands in these situations (ball mass does not change, so it has been removed from the equation)?

$$\begin{aligned} \text{a} \quad & F = (v_2 - v_1)/t \\ & F = [0 - 30]/0.01 \\ & F = -3,000 \text{ N (ignore sign)} \end{aligned}$$

$$\begin{aligned} \text{b} \quad & F = (v_2 - v_1)/t \\ & F = [0 - 30]/0.05 \\ & F = -600 \text{ N} \end{aligned}$$

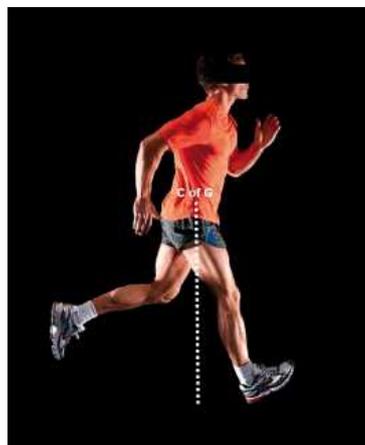
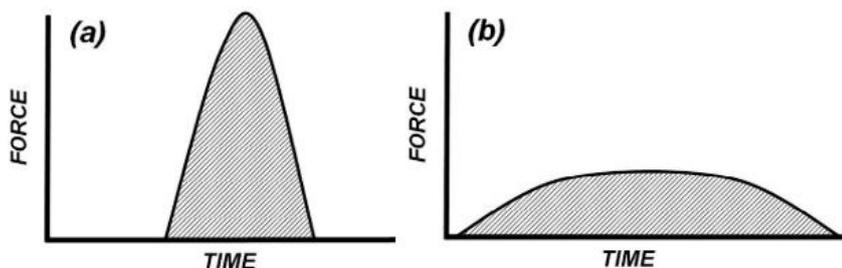


Figure 1.11: Position of the foot in front of the body in running



Figure 1.12: Impulse curves associated with a short duration stop (a) and reducing momentum to zero over a longer period (b)



Now you appreciate why it ‘stings’ so much when you catch a ball thrown with a high velocity and do not ‘give’ with your hand(s), to increase the time over which the linear momentum of the ball is stopped.

is reduced to zero and thus reduces the risk of injury. Imagine if the gymnast landed on a concrete surface, where the momentum would almost immediately be reduced to zero, a serious injury would likely follow.



Figure 1.13: Large mats used to assist force absorption

Class task: Force absorption and impulse

Discuss both of the following situations.

- The value of a netballer flexing at the knee when landing.
- When teaching someone to receive a forearm pass (dig shot) in volleyball, you might instruct students to ‘give’ with the arms.

When running we typically flex at the knee to increase the time over which force is absorbed by the body, that is we bend at the knee during impact to absorb force (Figure 1.11). We also use large mats (Figure 1.13) to assist the reduction in linear momentum of the body when falling, such as in landing in the pole vault or high jump. The foam that fills the training pit in a gymnast landing area helps increase the time over which momentum

UWA research snapshot: Evaluating impulse curves

- The WAIS biomechanist; a School of Sport Science, Exercise and Health (UWA) graduate, continually evaluates rowing performance through assessment of the size and shape of impulse curves produced from the oar. Impulse curves are used to select rowers in the Australian rowing teams such that best matched impulse curves are used to find the best rowing teams for fours and eights.
- Studies on landing in gymnastics and dance have both shown the need for ‘soft’ landings, where the knees must be flexed by 20–30° to reduce the peak vertical force on the body.

Key point summary:

- The impulse needed to stop the momentum of a falling gymnast or diver is constant; it is the time and therefore the peak force that may be altered. That is, the area under the impulse curve stays the same irrespective of whether you land in a foam pit or on concrete – it is the shape of the curve that changes.

Coefficient of Restitution

When a ball rebounds from the ground, each subsequent bounce is to a lesser height – why is this so (Figure 1.14)? If you watch a tennis ball impact the racquet or a football impact the foot, there is an initial change in the shape of the ball and to a lesser extent the surface of the striking implement and this represents a loss of energy. What is the relationship between this loss of energy due to a body or both impacting bodies changing shape and the conservation of linear momentum? The answer to this question lies in the concept of *coefficient of restitution* between two interacting bodies.

The *coefficient of restitution (COR)*, or bounciness of an object, is a value representing the ratio of the velocity after an impact compared with the velocity before the impact. An object with a COR of 1 collides *elastically* (linear momentum fully conserved), while an object with a $COR < 1$ experiences an *imperfectly elastic collision*. For a $COR = 0$, the object does not bounce at all.

Most collisions in sport or during everyday life are *imperfectly elastic*. This means that

some energy is ‘lost’ to the impact because of the energy needed to change the shape of the impacting objects. The concepts of *perfectly elastic* collisions (for example, pool balls interacting) and *perfectly inelastic* collisions (for example, ball not rebounding when dropped into sand) were previously discussed. With respect to imperfectly elastic collisions, conservation of linear momentum does not really occur, as some energy is lost during the collision. This is in-part due to the coefficient of restitution between the two interacting bodies. The actual value of the coefficient is influenced by such factors as:

- **The materials of the interacting bodies:** New tennis balls will have a higher coefficient than old and different surfaces (clay vs grass tennis courts) will also influence bounce height (the different surface influences the value of the coefficient).
- **The velocity of the collision:** The velocity between the oncoming ball and the swinging implement will also alter the COR – higher velocities will reduce the COR because of the greater compression of the ball. That is, there is

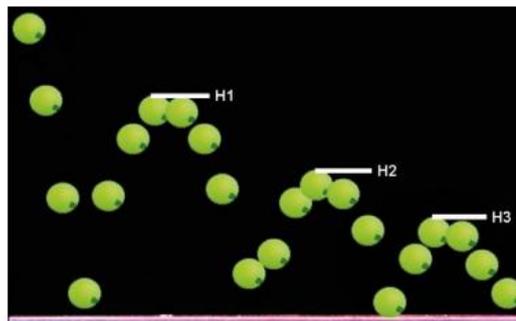


Figure 1.14: The reduced height with each subsequent bounce is the result of the coefficient of restitution between the ball and the impact surface

more likelihood of energy being ‘lost’, as the ball changes its original shape.

- **The temperature of the materials involved:** As the temperature of a ball increases so does the COR (think of the bounce height of a cold and hot squash ball). Golf caddies on the professional tour carry a spare ball in their pocket to keep it warm particularly when the air temperature is cold. They will often provide the player this warm ball at the tee for the commencement of each hole.

Practical activity: Coefficient of restitution and the impact of heat

- Assess the rebound height and impact of heat on two identical squash balls dropped from a height of 2 metres.
- The first squash ball should be presented and tested after being placed in a refrigerator.
- The second squash ball should be pre-heated by placing it in boiling water before testing.
- Drop the balls and measure the maximum vertical rebound height on the first bounce.
- Discuss your observations and the implications for a variety of sporting activities.

Equipment:

- Identical squash balls.
- Tape measure.
- Refrigerator.

In an endeavour to reduce the potential catastrophic injury to a baseball pitcher from a batted ball, many coaches have called for a change from aluminium to wooden bats (Figure 1.15). This change, which already occurs at the professional level in the USA, is based on the wooden bat having a lower COR than that of an aluminium bat. Therefore, the two bats produce different resulting ball velocity profiles. The aluminium bat produces about a $3.5 \text{ m}\cdot\text{s}^{-1}$ ($12.5 \text{ Km}\cdot\text{hr}^{-1}$) higher ball velocity (if all other factors are held constant) compared with a wooden bat. This small but significant decrease in the velocity of a batted ball gives a pitcher that extra time (reaction time) to get out of the way of a ball hit directly at them.



Figure 1.15: Different bat types have a different coefficient of restitution profile

Practical activity: Coefficient of restitution and type of ball

Initial class question: Predict which ball will bounce the highest?

Task

- With students working in teams of three, nominate one to be the person dropping the ball, a 2nd to measure bounce height and the 3rd may act as the recorder. Drop and measure each ball 3 times so that each participant plays all roles (use the average of the 3 measures in your results).
- Drop each ball (basketball, golf ball, new tennis ball, old tennis ball, and superball) from a height of 2 m onto a hard section of the class floor.
- Have students calculate the COR for each ball, for a hard surface.
- Discuss your observations and the implications for other sporting activities.

Equipment:

- Tape measure.
- Basketball.
- Golf ball.
- Tennis balls – old and new.
- Superball (high density solid rubber ball).

Key point summary:

- The COR is the ratio of the velocities after compared with before an impact, and this value will change for different impact situations.
- Rebound to the same height or with same velocity (e.g. collision during game of pool) = Coefficient of 1; perfectly elastic collision.
- No rebound = Coefficient of 0; perfectly inelastic collision.
- Rebound to a lesser height = Value > 0 and < 1 ; imperfectly elastic collision. This is the most common in sporting activities. For example, best shown by the decreasing height of a ball dropped onto a hard surface.
- A number of factors alter the COR:
 - impact surfaces
 - heat of colliding objects
 - velocity of the colliding bodies.

Revision questions:

Test yourself on revision questions 1–11 located at the end of this chapter.

Angular Kinetics

Text outcomes: *Angular kinetics (Unit 3)*

Define and show an understanding of biomechanics principles relating to:

- *Moment of inertia*
- *Angular momentum*
- *Levers in the body*
- *Moment of force: Torque.*

Content that follows: *Angular kinetics (Unit 3)*

- *Moment of inertia as it applies to the participant and equipment used in sporting manoeuvres*
- *Angular momentum in sport*
- *Three classes of levers and use in sporting activities*

Moment of Inertia

In angular motion, while the mass of an object (bat, stick, or body) is important, the critical factor in being able to swing this object is the ***distribution of the object's mass about the point that is used to rotate the object*** (the grip or centre of rotation). In angular motion this is termed the ***moment of inertia*** of the object (**I**). **Moment of inertia** (**I**) = $\sum(\text{Sum}) \text{ mass} \cdot r^2$

r = distance from mass concentration (e.g. head of hammer) to the axis of rotation (e.g. grip hand position on handle of hammer).

There are therefore critical mechanical differences in the measures of mass and its angular equivalent; moment of inertia. The mass of the hammer in Figure 1.16 is constant no matter how it is weighed. However, its moment of inertia is very different if one swings the hammer with the metal-head in the hand, compared with swinging it in the normal way, by its handle. That is, the distribution of mass from the point of rotation (the grip) is the key to understanding its moment of inertia.

- The hammer in Figure 1.16a swung by the handle has a relatively large moment of inertia. That is, most of the weight, which is in the head of the hammer, is a distance from the grip or pivot point (axis of rotation). From the equation above you can see that the distance of the large mass in the head of the hammer to the pivot point (grip) is **squared** in the calculation of moment of inertia. This further increases the influence of having the majority of the mass a distance from the pivot point.
- When swung with the metal-head in the hand (Figure 1.16b) the hammer has a lower moment of inertia because most of the mass is close to the grip (the axis of rotation) and is therefore easier to swing.

Moment of inertia of sporting equipment

Consider an adult's tennis racquet (Figure 1.17a) compared with that of a child (Figure 1.17b). Here, the reduced length of the handle (lesser

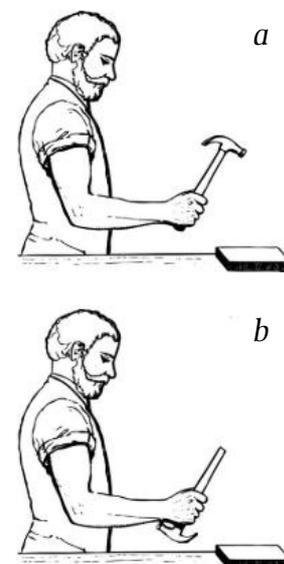


Figure 1.16: *The moment of inertia (I) of a hammer varies depending on if it is swung by the handle (a) (higher I), compared with when it is swung by the head (b) (lower I)*

distance from grip to primary mass concentration in the head of the racquet d) lowers the child's racquet moment of inertia (referred to as the swing moment of inertia) making the racquet easier to manoeuvre for better performance. Many children, who use an adult racquet 'choke up' on the handle to effectively reduce the distance from the head of the racquet to the grip. Adults have more strength, so they can use a longer racquet to create more velocity of the impact point and more angular momentum. In a similar manner cricket and baseball bats are reduced in length to make them easier to swing for the young player.



Figure 1.17: Child's racquet with reduced length handle (b) (lower I) compared with that used by an adult (a) (higher I)

Moment of inertia of the human body

Moment of inertia also applies to the body during sporting movements. In throwing, during the early forward swing the baseballer flexes at the elbow to reduce the moment of inertia of the upper limb (ball closer to the shoulder and therefore a reduced value of 'r' see equation on the previous page), thus making the arm easier

to rotate. In a similar manner a girl throwing a vortex (see Figures 1.43b-d) flexes her elbow to reduce the moment of inertia of the upper limb, again making it easier to rotate.

Practical activity: *Testing moment of inertia whilst throwing*

- Throw a vortex for maximum distance using no run-up for:
 - a cricket bowling technique (throwing with a straight arm), and.
 - a normal throwing action.
- Discuss the application of the principle of moment of inertia to these two throwing techniques.
- Discuss these observations with respect to other sporting activities.

Equipment:

- Vortex.

The moment of inertia of a diver, dancer or gymnast can also be modified by altering the relative positions of the body parts about the total body's centre of gravity (the pivot point calculated by summing all the individual segment centre of mass positions) (Figure 1.18a, b & c). Consider the following positions of a diver, who is rotating about the horizontal axis:

- **Layout:** Mass distributed away from the body's axis of rotation (centre of gravity of body) – highest I , hardest body position to rotate (Figure 1.18a).
- **Tuck:** Mass distributed closest to the centre of gravity – lowest I , making it the easiest body position to rotate – this is why triple somersaults are nearly always performed in the tuck position (Figure

1.18b). A diver who moves their knees apart to enable the trunk to tuck (flex) more tightly reduces moment of inertia that little bit more, thus enhancing the ability to rotate.

- **Pike:** This posture produces an intermediate level of difficulty between the layout and tuck (Figure 1.18c).

A diver prior to entering the water adopts a layout posture to increase their moment of inertia, reduce their rate of spin and thus make a ‘clean’ vertical entry into the water more likely.

The same principle applies to rotation about the vertical axis. The dancer or ice-skater (Figure 1.19a) keeps the arms close to the trunk to reduce their moment of inertia and enhance their ability to spin (Figure 1.19a), whereas they spread their arms to reduce the rate of the spin (more control) by increasing their moment of inertia (Figure 1.19b).

Figure 1.19: Skater with her arms close to her trunk (a) (lower I) and with her arms extended (b) (higher I)

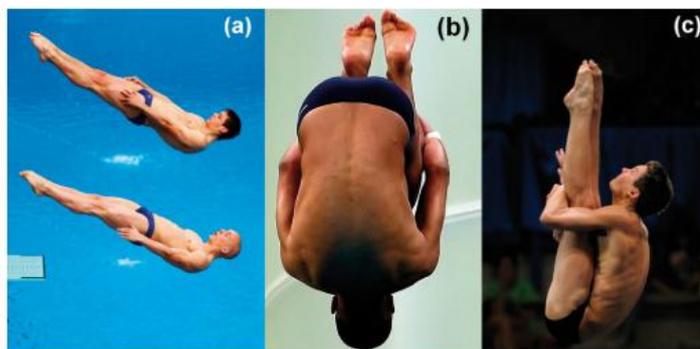
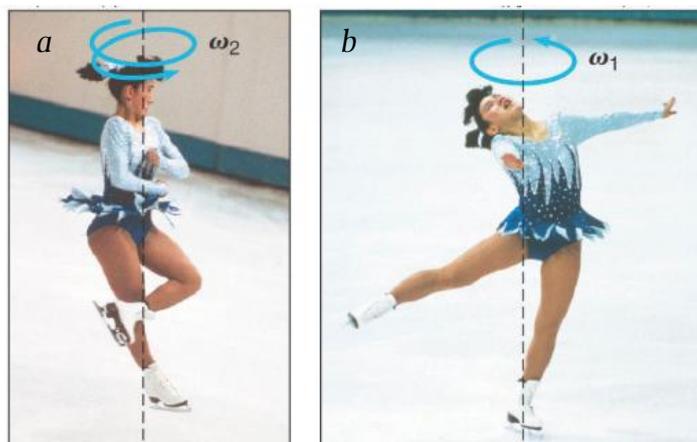


Figure 1.18: Diver in layout (a), tuck (b) and piked (c) positions during an aerial manoeuvre



Practical activity: Testing moment of inertia whilst spinning

- Place a swivel chair on carpet and lock the wheels (if possible).
- Have a student sit in a swivel chair, holding a small hand-weight in each hand.
- While the student has their feet off the ground, and the hand-weights held in their lap, spin the chair.
- Whilst spinning have the student extend their arms out to the side, so they are parallel to the floor.
- Before the chair stops spinning, ask the student to return their arms to their lap.
- Ask the student to explain the results.
- What do you think would be the outcome of the task if the hand-weights were increased in mass?
- What do you think would be the outcome if the student in the chair starts with the weights extended out to the side, the chair is spun, and the weights are pulled into their lap?

Equipment:

- Hand-weights (relatively small).
- Swivel chair.

Class task: Moment of inertia and body size/shape

Discuss the possible advantages/disadvantages of the different size and shape of a rhythmic gymnast (Figure 1.20a) who performs on the floor with hoop/ball/rope and so on, when compared with an artistic gymnast (Figure 1.20b), who rotates and spins on equipment such as floor, beam, uneven bars, vault etc).

Key point summary:

- Moment of inertia is all about:
 - the size or mass of an object (related to inertia), and
 - the distribution of mass about an axis of rotation (centre of mass, grip on implement or external point of rotation, such as a gymnast holding onto a high bar and performing a swing).

Angular Momentum

Angular momentum ($I \cdot \omega$) is logically the angular equivalent of **linear momentum** ($m \cdot v$) (Table 1.2).

Table 1.2: Linear and angular momentum equivalents

Linear motion	Angular motion
Mass (m)	Moment of inertia (I)
Velocity (v)	Angular velocity (ω)
Momentum (m·v)	Angular momentum ($I \cdot \omega$)

Angular momentum is therefore the product (multiplication) of the moment of inertia of the object/body and its angular velocity (rotational velocity).

Simply, this applies to sport in the following manner:

- The angular momentum ($I \cdot \omega$) of a diver or gymnast during an aerial manoeuvre, is a combination of the distribution of

mass (shape) of the diver about their centre of gravity (**I**) multiplied by how quickly they are rotating, their angular velocity (**ω**). In Figure 1.21 the interrelationship of moment of inertia and angular velocity is as follows:

- At the start of a dive (a) **I** is large and **ω** small.
- Midway through the dive (b) by tucking the body **I** is reduced and **ω** increases rapidly.
- To enter the water (c) the diver again increases **I** and thus reduces **ω** , so that a ‘clean’ entrance can be made to the water.

More angular momentum at take-off is required to perform a triple compared with a single somersault. **When in the air the angular momentum of the body remains constant – it does not change.**

- The dancer or ice-skater, who wants to perform a quick rotation, reduces their moment of inertia by pulling the arms



Figure 1.20a & b: A rhythmic gymnast (a) and an artistic gymnast (b)

across the chest (mass distributed close to axis of rotation) and therefore angular velocity increases for a constant angular momentum. Conversely, when this athlete wishes to stop their rotation they simply put their arms out horizontally to increase their moment of inertia (mass now distributed away from the axis of rotation) and their angular velocity is reduced.

You need angular momentum to develop rotary motion. If the activity is on the ground, such as a throw from the boundary in cricket, then angular momentum needs to be developed from the legs through the trunk to the arm. In aerial movement, angular momentum must be produced prior to leaving the ground, such as in the run-up prior to take-off in a gymnastic floor routine (Figure 1.22).

Therefore, in a vault the gymnast applies an impulse against the floor (application of force over time) to increase the linear momentum from zero (stationary position at start) to a high level at the end of the run-up. This high value then enables the gymnast to take-off from the beat-board (mini tramp/spring board) and create appropriate levels of angular momentum (body shape I multiplied by ω) to perform the required vault. Remember, angular momentum may be altered when the gymnast's hands are placed on the vaulting box (Figure 1.23).

Class task: *Conservation of momentum*

Some activities, such as a double somersault (in a gymnastics floor routine, springboard dive or freestyle snow skiing) are doomed for failure right from take-off. Discuss the above statement, using your understanding of the principle of conservation of momentum.

UWA research snapshot: *Moment of inertia*

Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia investigated the ability of children to learn tennis with a racquet related to their size showed that:

- Children learning tennis were more successful when taught with a reduced length racquet (lower I) compared with a longer length racquet (higher I).

A number of gymnastics studies have also been performed investigating such questions as:

- The role of size and strength on the ability to perform tumbling manoeuvres, that is, greater power to weight ratio is related to higher performance.
- The appropriateness of selected lead-up drills in helping to develop more complex skills.

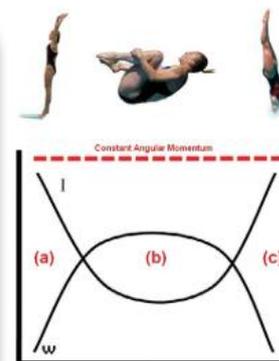


Figure 1.21: A diver varies their moment of inertia at various stages of the activity (a) (high I in early flight phase); (b) (low I at maximum tuck); (c) (high I on entering the water)

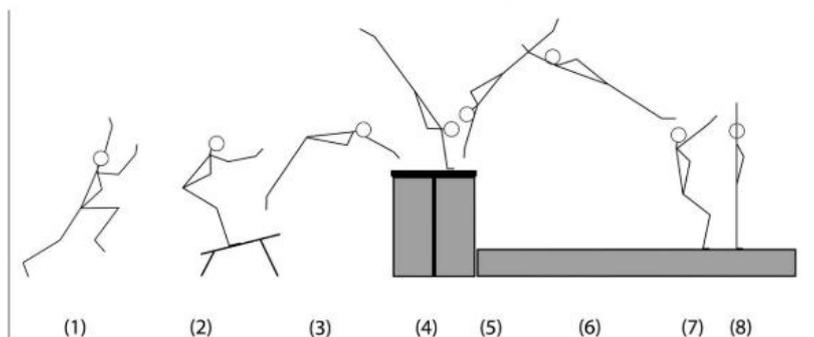


Figure 1.22: A gymnast performing a vault where the angular momentum must be generated prior to leaving the ground, but it can be altered when in contact with the vaulting box

Key point summary:

- As angular momentum is constant when airborne, moment of inertia and angular velocity are inversely proportional. As one increases the other decreases.
- This relationship between moment of inertia and angular velocity is based on Newton's 1st Law: 'A body will rotate about its axis with constant angular momentum, unless acted upon by an external force'.

Practical investigation

The principles of linear and angular momentum

See Appendix B1 for a practical investigation, along with questions and report-writing format recommendations.

Levers in the Body

A **lever** consists of a rigid bar pivoted on a fixed point and used to transmit force, as in raising or moving a weight at one end by pushing down on the other. They have two main functions in the body:

1. To **increase the load moved** for a given effort, for example using a shovel to move sand.
2. To **increase the velocity** of a body or body parts, for example the velocity of the hand in fast bowling in cricket.

Components of a lever

To fully understand how levers benefit movement requires an understanding of the three components that make up a lever (Figure 1.23):

1. A pivot point or axis: This is the point about which the two lever arms (*force and resistance – discussed below*) operate.
2. A weight/load/resistance to be moved.
3. The applied force required to move the weight/load/resistance.

The distance between the force and the pivot point or axis of rotation is termed the **force arm**, whereas the distance between the weight/load/resistance and the axis of rotation is termed the **resistance arm** (Figure 1.23).

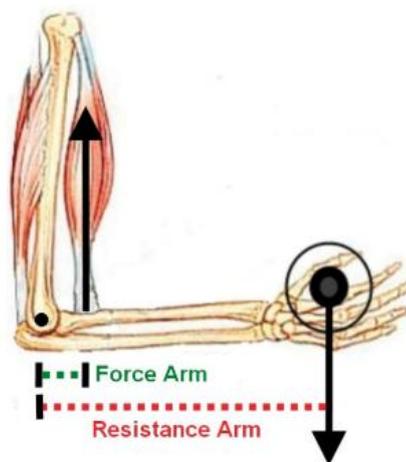


Figure 1.23: Movement about the elbow in a 'biceps curl' showing various components of the lever system about this joint

Types of levers

With an appreciation of the way a lever operates it is possible to differentiate between classifications of levers found within the body.

- **1st class lever** (Figure 1.24a): In this lever type the axis of rotation (the fulcrum) is between the force and the load (for example, a seesaw). Functionally not many examples exist in the body; however, holding one's head erect is an example of this type of lever. The fulcrum, in the centre, is the connection between the head and the spine, while the load is the weight of the head acting through its centre of gravity, with the force being the muscle force pulling on the back of the skull (to assist in keeping the head erect). In sport the diving board is a good example of a first class lever and in ancient times the catapult also relied on this lever system.
- **2nd class lever** (Figure 1.24b): For this type of lever the weight/load/resistance is located between the fulcrum and applied force, such as in a wheelbarrow. Again this lever type is not common in the body though a good example is a when an individual takes a walking step. The toes act as the fulcrum and the body weight (for part of the walking cycle) is positioned centrally, as the gastrocnemius muscle contracts and pulls upward – 'effort'. As the weight of the body (line of the centre of gravity) moves forward of the

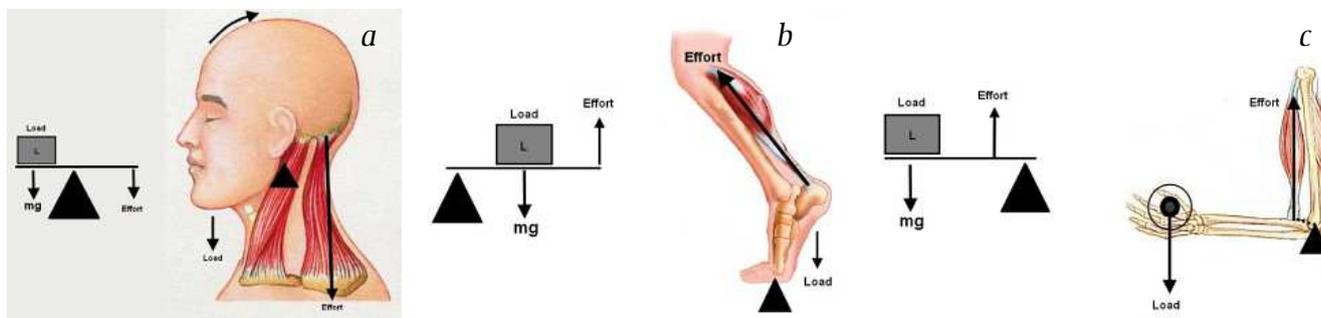
toes (fulcrum) in walking (you then set off in pursuit of your centre of gravity), this 2nd class lever then becomes a 1st class lever as discussed above. In rowing a 2nd class lever is used to move the boat: at one end of the lever the blade of the oar is locked in the water (fulcrum), while at the other, force is applied by the athlete to the oar. In the middle, the load or resistance is applied at the oarlock, the brace that attaches the oar to the boat.

- **3rd class lever** (Figure 1.24c): This is the most *common type of lever in the body*, with the applied force (the muscle attachment), somewhere between the axis of rotation (e.g. the elbow) and the weight/load/resistance (for example, a dumbbell in the hand). A biceps curl is an excellent example of a 3rd class lever. Think of throwing a softball for distance. The ball represents the resistance in the hand, the shoulder acts as the fulcrum and the muscle(s) attachment needed to create the motion is between these two ends.

Modifying lever lengths (force arm and resistance arm) in performance

If the body comprises primarily 3rd class levers then humans are typically not

Figure 1.24: Levers in the body and movement; (a) 1st class lever, (b) 2nd class lever and (c) 3rd class lever





mechanically efficient – the **force arm** is always going to be shorter than the **resistance arm**. In an attempt to overcome this deficiency we try to reduce the length of the **resistance arm** as much as possible when performing ‘force related activities’, such as in weight/power lifting (Figure 1.25a) or when attempting to increase the force on an object (for example, the water), during the pull in freestyle swimming (Figure 1.25b). This reduction in the effective length of the resistance arm is our attempt to increase the effectiveness of the **force arm**.

However, where velocity of movement is required, such as in the tennis serve (Figure 1.26a), fast bowling in cricket (Figure 1.26b) or in a throw at release, you increase the length of the **resistance arm** by extending the upper limb, to increase the speed of the impact or release point. Therefore, in throwing you decrease the length of the lever system early in the throw (flex the elbow) to decrease the moment of inertia of the upper limb system, thus making it easier to rotate. You then increase

the lever arm closer to release, which increases the velocity of the endpoint (the hand) and therefore the velocity of the throw. You follow a similar movement pattern in the tennis serve, where the elbow is flexed in the early forward swing and then extended closer to impact.

Figure 1.25:
In force-based movements we try to reduce the length of the resistance arm in weight lifting (a) and pull phase in swimming (b)



Figure 1.26: In speed-based activities we increase the length of the resistance arm as shown in tennis (a) and cricket fast bowling (b)

Class task: Child versus normal tennis racquet

Discuss the advantages and disadvantages of you (a Year 12 student) using a relatively short tennis racquet that was made for a child to serve versus a normal adult size racquet.

Key point summary:

- **Force arm:** This is the perpendicular distance between the fulcrum and the muscle attachment.
- **Resistance arm:** This is the perpendicular distance from the fulcrum to the load (resistance) to be moved.
- Most levers in the body are 3rd class, where the applied force (muscle attachment) is between the fulcrum (axis of movement) and the load (resistance).
- To produce forceful movement: Reduce the length of the resistance arm to effectively increase the proportional length of the force arm.
- To obtain speed in movement: Increase the length of the resistance arm.

Moment of Force (Torque) – Turning Forces

If a force is applied directly through the centre of gravity of an object (Figure 1.27a), no rotation will occur and the object moves in a straight line (it translates). However, if a force is applied away from this point (off-centre) you get a combination of linear and angular motion (Figure 1.27b), unless one end is fixed where in that case, you only produce a **turning effect**, or moment of force.

The amount of turn (rotation) produced when force is applied away from the centre of gravity is the result of two factors:

- The size of the force – **the higher the force** the greater the angular rotation.
- The position of the force application – **the greater the perpendicular distance of the application of this force** from the point of rotation (called the moment arm), the greater the resulting angular rotation.

Key point summary:

- The applied force and perpendicular distance to the axis of rotation is termed a moment of force or torque.
- Moment of force (N·m) = Applied force (N) × perpendicular distance (m) between the line of the force and the axis of rotation.

Pushing on the pedal of a bike (Figure 1.28a), pulling on an oar in rowing (Figure 1.28b) or rotating (flexing or extending) the forearm at the elbow (Figure 1.28c) are all examples of creating a turning effect or a **moment of force** (torque).

In Figure 1.29 the moment arm changes across various elbow angles, which alters the resultant moment of force.

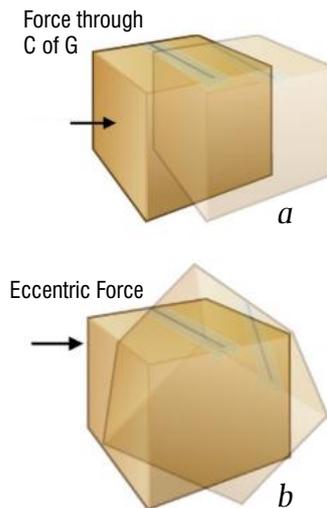


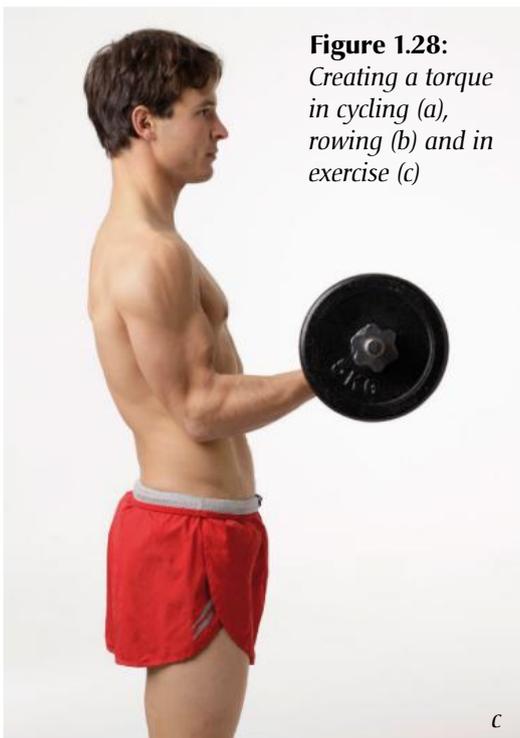
Figure 1.27: Force applied through the centre of gravity (a) produces linear motion, whereas an off-centre force (b) produces linear and angular motion



a



b



c

Figure 1.28:
Creating a torque
in cycling (a),
rowing (b) and in
exercise (c)

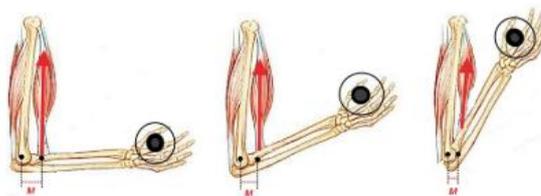


Figure 1.29: The moment arm changes with various elbow angles

In Figure 1.30 the force applied to a bicycle pedal is shown. It is evident that the greatest force and the greater turning moment on the crank is produced when the crank is horizontal (parallel to the ground). That is, the moment of force (torque) is at its greatest between the top and bottom of the pedalling phase.

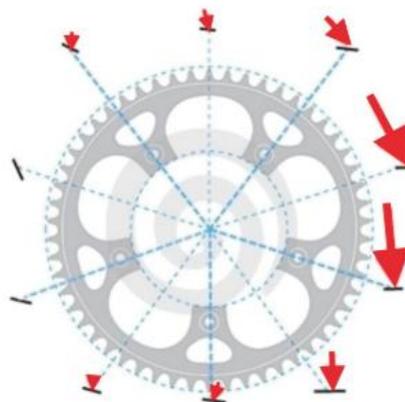


Figure 1.30: Moment of force (torque) varies as the perpendicular moment arm of the crank changes throughout the cycling action

Revision questions:

Test yourself on revision questions 12–19 located at the end of this chapter.

Fluid Mechanics

This is simply the study of how a person or object moves through a fluid (water or air) and the forces associated with creating this movement.

Text outcomes: Fluid mechanics (Unit 4)

Define and show an understanding of biomechanics principles relating to:

- Fluid mechanics
- The types of drag experienced by the body during sporting activities
- How Magnus effect relates to various types of spin
- The application of Bernoulli's principle to spin.
- Laminar and turbulent airflow

Content that follows: Fluid mechanics (Unit 4)

- Drag in sport
 - pressure drag (form), surface drag (skin friction), and wave drag.
- Spin – Magnus effect
- Bernoulli's principle

Drag and Sporting Performance

In an endeavour to enhance performance by 'shaving' fractions of a second from a race time athletes attempt to reduce the affect of

air resistance or drag. They may modify their equipment as follows:

- In swimming, some suits are still legally acceptable, and may reduce surface and/or form drag, while others have been banned (Figure 1.31a).
- In cycling specially shaped helmets help reduce form and surface drag, respectively (Figure 1.31b).
- Australia's Cathy Freeman at the Sydney Olympics wore a full body suit, to reduce surface drag (Figure 1.31c).



Figure 1.31:
Swimming (a),
cycling (b) and
running (c)
equipment may
be modified to
reduce drag



Manufacturers go to great expense to reduce the drag experienced by their products. The drag coefficient for a typical car is about 0.3, (the lower the number the lower the drag), whereas an aeroplane wing is only 0.05. Figure 1.32 shows the drag coefficients for a variety of shaped objects. It is obvious from this Figure that selected shapes (for example, a streamlined body) have a lower form drag coefficient than other shapes, such as a cube.

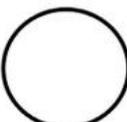
Shape	Drag Coefficient
Cube → 	1.05
Sphere → 	0.47
Streamlined Body → 	0.04

Figure 1.32: Form drag coefficients for various shaped objects

Wind tunnels, which are commonly used to test drag, form an integral part of the development process of new vehicles. About 60% of the power used by a car travelling at freeway speed is used to overcome drag. Obviously less drag makes a car more fuel efficient and therefore more appealing to the consumer.

Key point summary:

- The shape of an object impacts on its form drag coefficient.
- The higher the velocity of an event (cycling vs running), the more important is the need to reduce drag. Remember, drag increases with the square of the increase in velocity. That is, if the velocity of a body was doubled, drag would increase fourfold.

You may also attempt to reduce drag by modifying technique in sport. For example:

- Drafting in cycling or car racing is an attempt to reduce drag and conserve energy (Figure 1.33).
- Cyclists reduce form drag by adopting a more streamlined technique, where riders do not sit upright but bend over to reduce their frontal surface area.
- In ski jumping athletes tuck down, as they come down the ramp to reduce the influence of air resistance (Figure 1.34a) – allowing them to travel at higher velocities. On leaving the ramp they adopt an extended posture that attempts to decrease form drag and increase lift (Figure 1.34b) thereby maximising the distance jumped.



Figure 1.33: Cyclists ride one behind the other to reduce drag for all but the leading rider



Figure 1.34: Ski jumper on the ramp (a) and during flight (b)

UWA research snapshot: Drag in swimming

Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia worked to reduce drag and determine the best depth to glide out of the turn off the wall in swimming. A swimmer, like a submarine, experiences less drag at 0.4 m than at the surface. It is therefore important in turning to start your glide at approximately this depth. Coaches equally attempt to reduce various forms of drag in swimming:

- **Surface drag (frictional)**– Swimmers shave the hair off their body to reduce this component of drag. Frictional drag is influenced by the immersed surface area of the body; however, because of the irregular shape of the body this means that the flow around the body is turbulent. Frictional drag is generally considered to be small.
- **Form drag** – A combination of eddy and frontal resistance. Objects that are blunt and smooth at the front and tapered at the back produce the least drag. Currently, making adjustments to technique to reduce frontal surface area remains the best way to reduce form drag.
- **Wave drag** – Energy lost due to the creation of waves. Swimmers reduce up and down movements of the head to reduce wave drag.

Basic fluid mechanics

A fluid is a substance that has no fixed shape, such as air and water, although in this section we will focus on air. A ball deviates in air during various sporting activities (e.g. tennis, golf, cricket, football, baseball and soccer) because of uneven pressures created around the ball. The ‘boundary’ layer of air around the ball is particularly susceptible to both the type of air flow (laminar and turbulent) and spin of the ball (Bernoulli principle and Magnus effect). So when a ball is not spinning the type of airflow is the key, whereas once spin is introduced the Magnus effect must also be considered. One must also study the speed, orientation, shape

and skin of an object to fully understand the influence of air.

Magnus Effect and Spin

The *Magnus effect* explains the change in flight path of a projectile and particularly relates to a ball that is spinning. The soccer player curves the ball to confuse the goalkeeper and golfers/tennis players use spin to assist in changing the flight path of the ball to enhance performance. However, in golf, spin can also be a problem, as inappropriate spin may slice or hook the ball and ‘take’ it into the trees.

*The curving effect of spin on the flight of a ball is termed the **Magnus effect**.*

As the ball spins it ‘pulls’ around with it a boundary layer of air (Figures 1.35 and 1.42). The differences in pressure between the particles in the boundary layer above-and-below or side-to-side, depending on the direction of spin of the ball, create the different flight paths mentioned above.

Practical activity: Observing the impact of spin on flight path

Using a table tennis ball and bat impart a variety of spin on the ball and watch the impact on the flight phase of the ball.

Equipment:

- Table tennis bat.
- Table tennis ball.

Class task:

Using spin to your advantage

Explain the rationale for using backspin when executing a drop shot in tennis, as compared with using topspin.

Bernoulli’s Principle

*Bernoulli’s principle states that an **increase** in the speed of fluid occurs simultaneously with a **decrease** in pressure.*

For a topspin shot, as the boundary layer rotates with the ball, the particles on top of the ball decrease in speed (crash into the particles of air that the ball is moving through, (see Figure 1.35) and thus you have an increase in pressure. Conversely the particles under the ball increase in speed, as they are moving in the same direction as the general airflow, producing a decrease in pressure. Therefore, the ball hit with topspin will suddenly move in the direction of the low pressure and drop, particularly as the velocity of the ball is reduced. Check the trajectory of the topspin shot hit by the former world’s number one female player Justine Henin (Figure 1.39a).

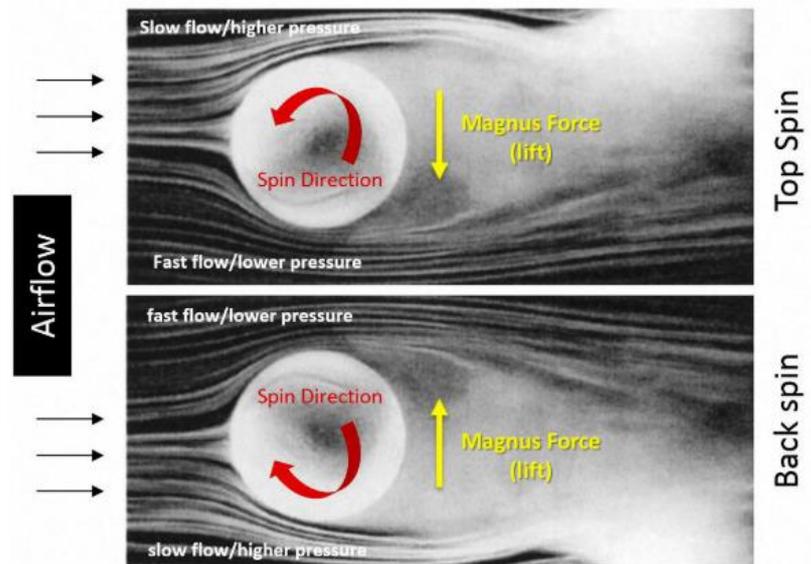


Figure 1.35 *Topspin (top) and Figure 1.36* *backspin (bottom) air pressure differentials and resultant Magnus force (lift) effects. Image courtesy of NASA.*

Consider a tennis shot that is hit with backspin (Figure 1.36). The particles on the bottom of the ball experience a decrease in speed and therefore experience an increase in pressure, whereas those on top experience an increase in speed and consequently a decrease in pressure, hence the ball rises.

Bernoulli's Principle also applies when air moves over a surface, such as an airfoil of an aeroplane (Figure 1.37). The air particles that have to move a greater distance over the top of the airfoil shaped wing of a plane, must increase in speed and therefore a decrease in pressure is produced. Those that move the shorter distance, along the base of the airfoil, move at a lower speed resulting in greater pressure. This pressure differential causes the upward lift of the aircraft. Air direction on the top of an aircraft wing is changed to go down wards via the shape of the wing in combination with adjustable aircraft flaps. This causes an upward force on the wing. Similarly, Newton's approach suggests that the racing car airfoil is designed to create enough downward force to keep a car on the track at very high speeds.

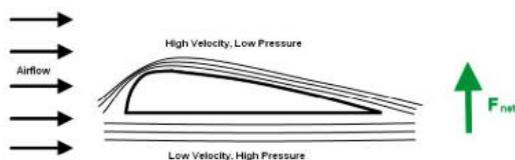


Figure 1.37: Flow of air and pressure differences associated with an airfoil on a plane

In a similar manner the airflow about a discus, if thrown at the appropriate angle creates a lift on the discus (Figure 1.38), while at the same time minimising drag.

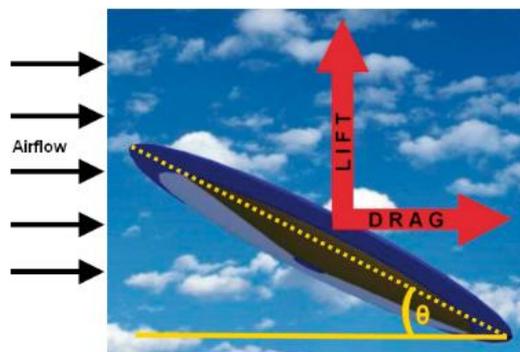


Figure 1.38: Lift and drag forces associated with the flight of a discus

Key point summary:

- While the spin applied and the subsequent curving effect on a ball is termed the Magnus effect, the cause of this effect is related to the linking of air speed and pressure described by Bernoulli and Newton.

When viewing the bounce heights in Figure 1.39a (in situations where the approach angle is not the same), one can see that a ball hit with topspin bounces higher than that of a ball hit with no spin (flat), while a ball hit with backspin (called slice in Figure 1.39a) bounces the lowest. The power 1st serve in Figure 1.39b also bounces lower than the 'topspin' 2nd serve hit by Roger Federer. Why is this so? There are two issues that need to be considered:

- First, it is evident that the **approach angle** of the 3 shots is different. The topspin ball approaches at a steeper angle than the backspin and the no spin ball is in-between these 2 extremes.

- Secondly, the *spin* on the ball varies the flight path and it is this phenomenon that is called the Magnus effect.

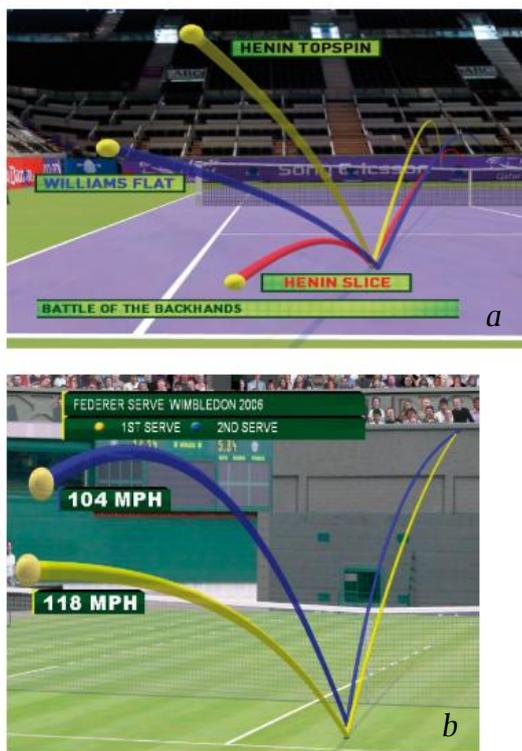


Figure 1.39: Bounce heights for balls hit with topspin, no-spin and backspin (slice) by International female tennis players (a) and power and spin serves hit by Roger Federer (b) (Picture published with permission of the International Tennis Federation)

If the ball was to come in at the same approach angle then the type of spin the ball possesses will influence the rebound angle (Figure 1.40). If one compares the topspin and backspin rebound with the no spin situation you find that the ball rebounds lower when hit with topspin and rebounds steeper for the ball hit with backspin. That is, when the ball with topspin impacts the surface it rebounds

more horizontally. However, the ball hit with backspin ‘bites’ and rebounds more vertically.

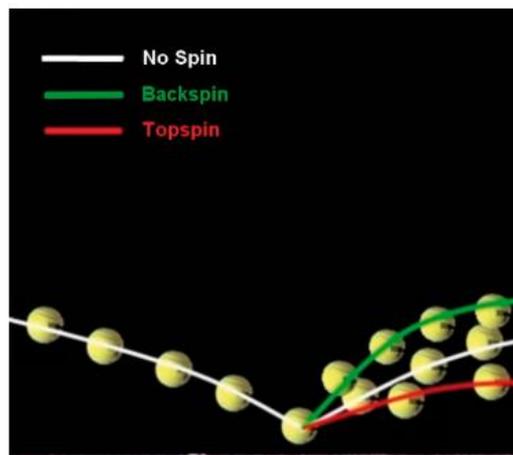


Figure 1.40: Rebound angles, for balls that have the same approach angle, hit with no spin, topspin (red) and backspin (green)

Practical investigation

The principles of spin, Magnus effect and bounce.

See Appendix B2 for a practical investigation, along with questions and report-writing format recommendations.

Revision questions:

Test yourself on revision questions 20–26 located at the end of this chapter.

Laminar and Turbulent flow

In laminar flow, the air flows in *parallel layers*, with no disruption between the layers (Figure 1.41a), whereas in turbulent flow the air mixes

and is *irregular in flow* (Figure 1.41b). When an object moves through the air, the air which is closest to the ball interacts with the surface ('sticks to the surface') creating what is termed a '**boundary layer**' (see Figures 1.42).

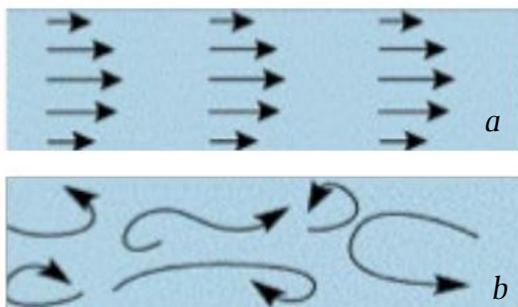


Figure 1.41: Laminar (a) and turbulent flow (b)

As the ball travels through the air this boundary layer separates from ball's surface creating a wake behind the ball and causing a drag affect in the ball (causing it to slow down). The type of airflow around the ball, combined with the velocity of the ball determines how quickly the boundary layer separates from the ball's surface (i.e. the separation point changes position). For a **smooth ball at low velocity** (Figure 1.42a), where the airflow is laminar this separation point is near the back of the ball and the drag is minimal, whereas at a higher velocity it separates earlier (Figure 1.42b) and the drag increases. However, for an object such as a golf ball with dimples (Figure 1.42c) the initial laminar airflow becomes turbulent as the dimples help the boundary layer 'stick' to the surface of the ball. This means that the separation point occurs later, ultimately leading to a decrease in drag (smaller wake) compared with that recorded for the smooth ball in Figure 1.42b. A fast bowler orientates the seam of the ball to create turbulent airflow on one side, while the other remains as laminar flow - the different airflow patterns on the two sides of the ball cause the ball to move (swing) in the air because of air pressure differences.

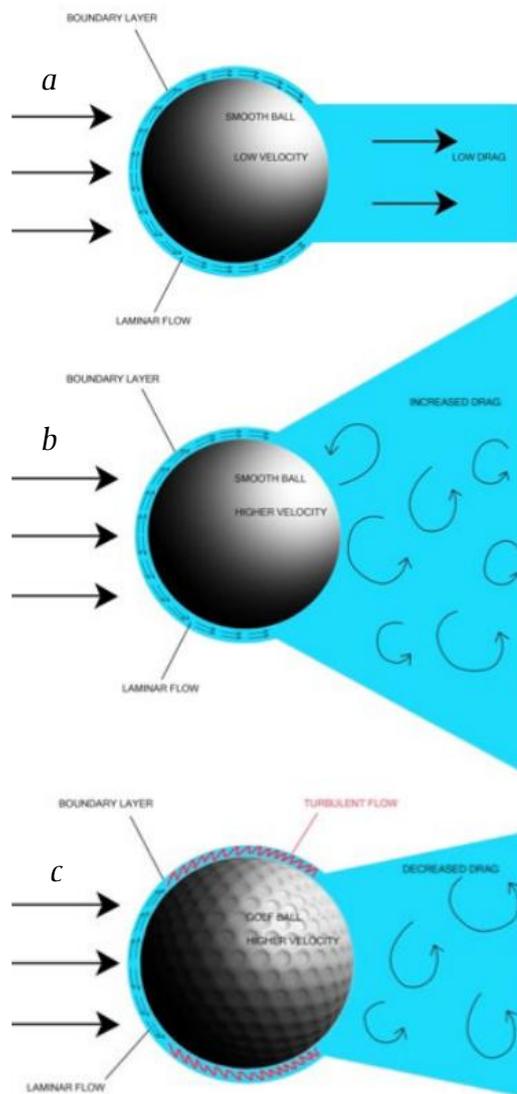


Figure 1.42: Smooth ball and Low velocity (a), smooth ball and Higher velocity (b) and golf ball and Higher velocity (c)

Revision questions:

Test yourself on revision questions 27 located at the end of this chapter.

Biomechanical Approach to Motion Analysis

The role of selected mechanical principles involved in throwing a vortex for distance (Figure 1.43a-f) and running (Figure 1.44a-f) are outlined in Table 1.3. These basic movements have been selected as they may easily be performed within a Physical Education lesson.

Text outcomes: *Analysis of movement (Unit 3)*

- Understand the biomechanical principles in the analysis of various sporting activities.

Content that follows: *Biomechanical analysis of movement (Unit 3)*

- *The application of biomechanical principles to human motion*
 - *Moment of inertia*
 - *Angular momentum*
 - *Levers*
 - *Torque*
 - *Balance*
 - *Coordination continuum/segment interaction*
 - *Force-motion*
 - *Force-time*
 - *Inertia*
 - *Optimal projection*
 - *Range of motion*
 - *Spin*

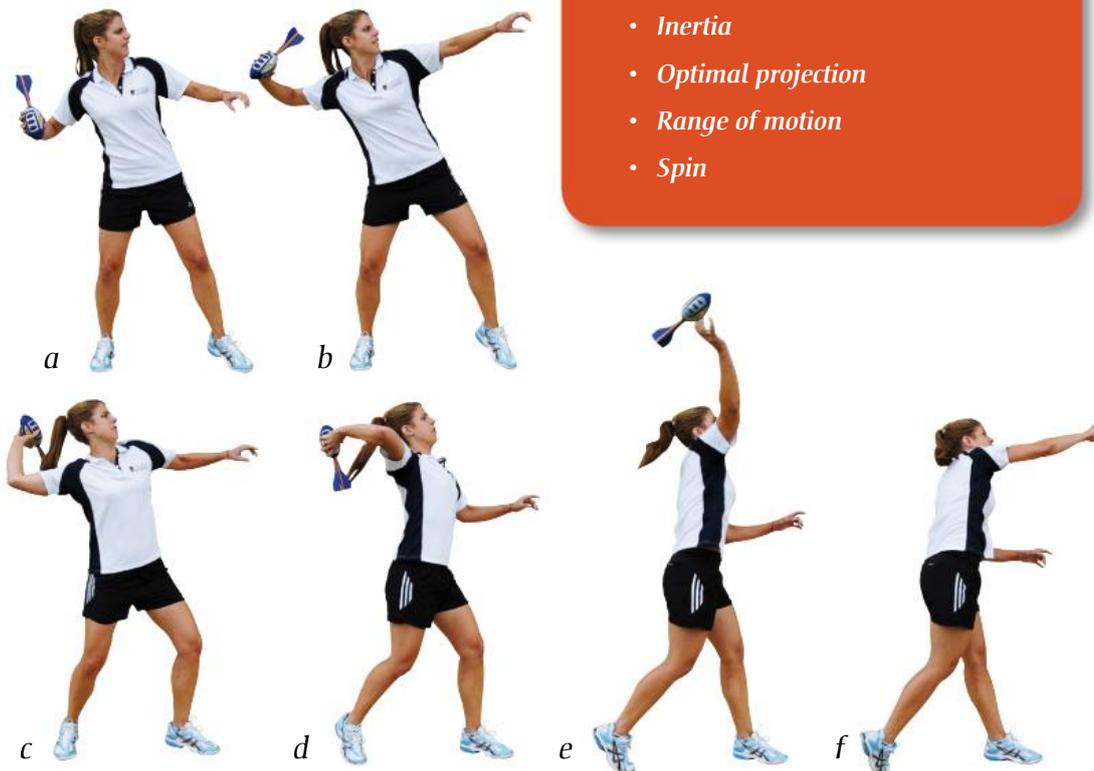


Figure 1.43: *Photographic sequence of a throw for distance with a vortex (a-f)*

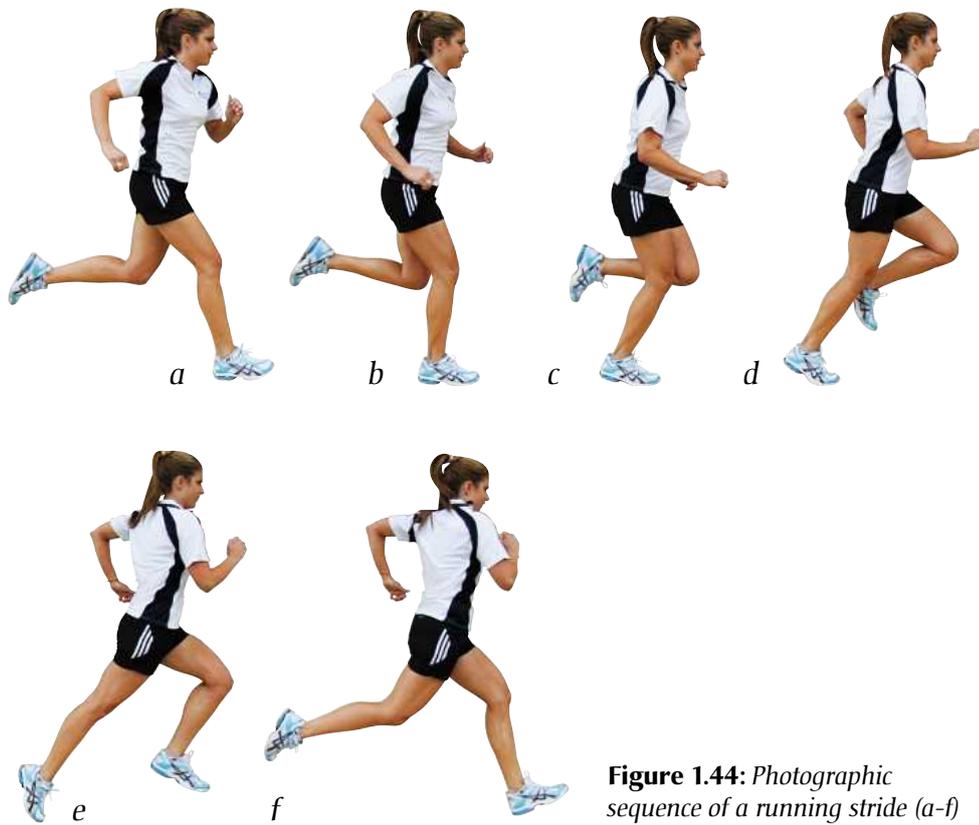


Figure 1.44: *Photographic sequence of a running stride (a-f)*

Table 1.3: Biomechanical analyses of two basic human motions (throw and run)

Biomechanical variable	Throwing (Figure 1.43)	Running stride (Figure 1.44)
Moment of inertia (I): The distribution of mass about the point of rotation.	The thrower flexes at the elbow (Figures 1.43 b-e) to reduce I of the upper limb, making it easier to rotate.	The runner flexes at the knee (Figures 1.44 b-c) to reduce I of the lower limb, making it easier to rotate.
Angular momentum: Combination of moment of inertia and angular velocity (rotational speed).	The reduced I mentioned above makes it easier to develop angular momentum during the forward swing, thus increasing the speed of release.	The reduced I mentioned above makes it easier to develop angular momentum during the swing phase, thus increasing stride rate.
Levers: Three levers in the body, 3 rd class most prevalent.	In throwing (Figure 1.43d) the upper limb acts as a 3 rd class lever. The resistance is the vortex, the fulcrum the shoulder and the muscle attachments are to the upper arm (between the fulcrum and the resistance).	In running (Figure 1.44e) reversing the direction of the thigh at the end of the swing phase, is a 3 rd class lever. The hip is the fulcrum, the resistance the mass of the lower limb (at the C of G) and the force the hamstring muscles, which attach to the back of the thigh.
Torque: A product of force and a moment arm (perpendicular distance to line of the force).	Using the lever discussed above. The muscle(s) applies a force to the upper arm and when multiplied by the perpendicular distance from the line of action to the shoulder this produces the moment of force or torque to accelerate the arm forward.	In the lever discussed above, the hamstring muscles apply a force to the thigh and when multiplied by the perpendicular distance from their line of action to the hip this produces the moment of force or torque to stop forward motion of the thigh.
Balance: May be static or dynamic (position of C of G to base of support).	Notice how the girl rocks back onto her back leg (Figures 1.43a-b) and then forward onto her front leg (Figures 1.43c-e) – this is dynamic balance as she keeps her C of G within her base of support provided by the legs.	In running you continually ‘chase’ your C of G to maintain dynamic balance. In Figure 1.44a the vertical line of the C of G is behind the front foot, whereas from Figures 1.44b-d you can see how this vertical line moves in front of the foot – a great example of dynamic balance.

<p>Coordinated movement: Either velocity (sequential) or accuracy (as one) based.</p>	<p>In throwing for distance you adopt a sequence approach to develop motion:</p> <ul style="list-style-type: none"> • Lower limbs and trunk rotate (Figures 1.43b-d). • Followed by forward movement of upper arm and hand (Figures 1.43d-e). • Then the follow through allows the arm to decelerate slowly (Figure 1.43f). 	<p>In running the ‘slowing’ of the forward movement of the thigh (Figure 1.44d), assists in the extension of the leg (Figures 1.44e-f).</p>
<p>Force-time: Impulse is the application of force over time (Impulse: force x time).</p>	<p>The hand applies a force over a time period (Figures 1.43c-d: impulse) to propel the vortex into the air.</p>	<p>The foot in Figure 1.44b applies force to the ground over time (Figures 1.44b-d) and this is termed impulse – see Figure 1.9 for typical impulse curves during running.</p>
<p>Inertia: The reluctance of a body to move.</p>	<p>Imagine the force required to throw a shot put with the same action as a vortex? This is an example of how inertia (greater mass) influences motion.</p>	<p>The acceleration of the body in running ($F=m \cdot a$), is directly related to the mass of the body being moved.</p>
<p>Optimal projection: Related to height of release and landing.</p>	<p>In projectile motion one needs to consider; height, angle and velocity of release (Figure 1.43e). In throwing for distance you need optimal velocity of the hand and a release angle of approximately 45°.</p>	<p>This relates to running when one wants to jump, such as in the long jump. In that situation take-off velocity and projection angles are the key to success. A high velocity and angle of about 25° is typically recorded.</p>
<p>Range of motion: Total range of movement at key joints related to the activity.</p>	<p>In throwing for distance it is essential to displace the vortex behind and away from the body (Figures 1.43a-c). This provides a large distance over which velocity can be developed for release – also puts the muscles across the shoulder on stretch, which is good for developing velocity.</p>	<p>The left thigh is ‘driven’ forward (Figures 1.44c-e) during the swing phase to increase stride length. Remember, running velocity is a combination of stride length and stride rate. So if you can increase stride length and not decrease stride rate you will increase your velocity – this only holds true up to a point where over-striding may be detrimental to performance.</p>
<p>Spin: If possible consider spin in the air and bounce following landing.</p>	<p>If thrown correctly the vortex will spin and this will assist in creating an efficient flight pattern. In Figure 1.43e the angle of the vortex to the horizontal creates an ideal balance between creating ‘lift’, while minimising ‘drag’.</p>	<p>Not related to running.</p>

Class task: *Application of biomechanical principles*

In groups of three complete the above table for an activity of your choice involving hitting a ball and an aquatic-based movement.

Appendix A: Writing the practical investigation report

Writing the report

If you are required to write a report as part of your practical investigation, you may choose to use the following format.

Title: Title of the practical investigation.

Aim: State what you hope to achieve in the experiments (*30–50 words*).

Introduction: Define and discuss the sport science principles being investigated (*~200 words*).

Hypotheses: Identify the expected results or anticipated outcomes (*statements*).

Method: Identify the steps taken to complete the experiments (*~100 words*).

Results: Present the data and findings in the appropriate format (*for example, graphs, diagrams and tables*).

Response to the questions: Write the questions out and respond.

Discussion: Provide a detailed discussion of the results. Apply the sport science principles under investigation to other sporting contexts (*~400 words*).

Conclusion: Summarise the discoveries made. Make links to each hypothesis and include limitations of the experiment (*~100 words*).

Appendix B1

Practical Investigation and Report: Biomechanics

The principles of linear momentum and angular momentum

Weighting: Unit 3

Type: Investigation

Content:

- Define and apply momentum to selected activities and sports in relation to:
 - levers
 - the collision of two objects and the conservation of linear momentum
 - moment of inertia and angular velocity of a bat, and
 - a rotating body.

Total marks = /30

Task outline

When completing the experiment outlined below you are to analyse a person swinging a softball bat as a lever. The collision of the bat and ball will be evaluated as an imperfectly elastic collision and the principle of conservation of linear momentum discussed. The bat will be discussed in relation to its moment of inertia and resultant angular velocity. You will also observe and consider the angular momentum of a person spinning in a chair, and that of a person rotating off a mini-tramp.

Experiment: Task one (A)

- In groups of three, you will be required to strike a basketball off a softball T-stand with a softball bat.

Condition A: Hold the bat with two hands placed at the end of the handle. Swing the bat to hit the basketball from the 'T' for maximum distance the ball will roll and measure the

distance from the T to the stationary position of the basketball.

Repeat this task three times.

Condition B: Repeat Condition A, but hold the bat with two hands placed in the middle of the bat.

Experiment: Task one (B)

- In groups of three, one of you will be required to sit in a swivel chair with your feet off the ground.

Place the chair on carpet and if possible lock the wheels so the chair cannot be displaced, while sitting on the chair. Hold a dumbbell hand weight in each hand. Place your hands in your lap. While one partner holds the back of the chair, the other holds the front of the chair (or your knees). Partners count to three and use an appropriate force (firm but safe) to spin the chair.

Whilst spinning, lift the dumbbell weights out to the side, so that the arms are parallel to the floor.

Before the chair stops spinning return the dumbbell weights to your lap.

Experiment: Task one (C)

Use a run-up to spring off a mini-tramp with maximum vertical height. When in the air, rotate or spin about the vertical axis, whilst performing:

- A star jump with legs apart, arms out parallel to the floor. Calculate, through observation, and record the approximate angular displacement (in degrees).
- A tin soldier jump with legs close together and arms in close to the body. Calculate, through observation, and record the approximate angular displacement (in degrees).

Questions: Task one

In presenting your findings to Task one: Condition A, B and C respond to the following:

- Draw a diagram/s of the upper body swinging a softball bat. Label the three components of a lever, including the force arm, resistance arms and fulcrum (2 marks).
- What type of lever is used while executing the forward swing of a softball bat? (1 mark).
- Explain, using biomechanical principles, the difference in the distance the basketball rolled when comparing the strike made when the bat was held at the handle end (Condition A) and when the bat was held in the middle (Condition B) (3 marks).
- Using the principles of angular momentum explain any differences when spinning in the swivel chair with the dumbbell hand weights held in the lap, and when spinning with the hand weights held out to the side (2 marks).

- Discuss, using biomechanical principles, any differences in the angular displacement attained whilst spinning in the air and performing a star jump, and a tin soldier (2 marks).

Questions: Task two

- Using the principles of levers, explain why the longest golf club (driver) is used for achieving maximum distance (2 marks).
- Explain how a tennis player executing a serve attains maximum linear momentum on the ball, by using the principles of angular momentum to develop maximum racquet-head velocity and changes to the length of the lever just prior to impact. This answer will require you to define and discuss:
 - conservation of linear momentum of an imperfect elastic collision,
 - lever lengths, and
 - moment of inertia and angular velocity (3 marks).

Equipment

- Tape measure (approximately 50 metres long).
- T-ball stand.
- Softball bat.
- Basketball.
- Two dumbbell weights (approximately 1-3 kg).
- Swivel chair.
- Mini-tramp.
- Crash-mat.

Task: The principle of optimal projection: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or outcomes in relation to the factors associated with striking objects and the angular momentum of rotating bodies.	1 mark
Provides clear statements of the expected results or outcomes in relation to levers, striking an object and conservation of linear momentum, and the moment of inertia and angular velocity of a rotating body.	2 marks
Introduction (3 marks)	
Identifies and defines the variables associated with levers, linear momentum and angular momentum.	1 mark
Shows an understanding of the principles of levers, linear momentum, conservation of linear momentum and angular momentum (moment of inertia and angular velocity).	2 marks
Shows a comprehensive understanding of the principles of levers in the body, linear momentum, conservation of linear momentum and angular momentum (moment of inertia and angular velocity of a rotating body).	3 marks
Results (2 marks)	
Satisfactory presentation of data.	1 mark
Accurate and relevant presentation of data.	2 marks
Response to Questions (15 marks)	
<i>Task one: Question a: 2 marks, Question b: 1 mark, Question c: 3 marks, Questions d and e: 2 marks for each correct answer (10 marks).</i>	
<i>Task two: Question a: 2 marks, Question b: 3 marks (5 marks).</i>	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	1 mark
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	2 marks
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with linear and angular momentum.	3 marks
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with linear and angular momentum.	4 marks
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the principles of levers in the body, linear momentum, conservation of linear momentum and angular momentum (moment of inertia and angular velocity of a rotating body).	5 marks
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the principles of levers in the body, linear momentum, conservation of linear momentum and angular momentum (moment of inertia and angular velocity of a rotating body).	6 marks
Conclusion (2 marks)	
Summarises some of the factors associated with linear and angular momentum in relation to the hypotheses.	1 mark
Fully summarises the impact of levers, linear momentum, conservation of linear momentum and angular momentum (moment of inertia and angular velocity of a rotating body) in relation to the hypotheses. Limitations discussed.	2 marks
Comment:	Total
	/30

Appendix B2

Practical Investigation and Report: Biomechanics

The principles of spin, Magnus effect and Bernoulli

Weighting: Unit 4

Type: Investigation

Content:

- Define and apply fluid mechanics to selected activities and sports in relation to:
 - the flight paths of a ball released with topspin, backspin and no spin
 - the rebound angles of a ball released with topspin, backspin and no spin
 - a ball that curves in the air (Magnus effect)
 - the flow of air and pressure differences associated with an airfoil.

Total marks = /30

Task outline

When completing the experiment outlined below you are to observe and evaluate the Magnus effect on a spinning ball and the impact on its flight path. You will also consider the impact of spin on the rebound angle of a ball released with a variety of spins. A hit ball, which is struck with an eccentric force to elicit differences in the pressure between the particles in the boundary layer on the left and right side of the ball, will also be observed. A paper model that represents an airfoil will provide evidence of the impact of air particle speed and pressure differences.

Experiment: Task one (A)

NB: This task is best undertaken indoors, or in the absence of windy conditions.

- In groups of three, you will be required to measure the horizontal distance that a volleyball travels from release to landing, when it carries no spin, topspin and backspin.

Condition A: The thrower stands with feet shoulder width apart and holds the volleyball with two hands level with their waist.

A partner holds a hoola-hoop at a position of 3 m from the thrower with the middle of the hoop level with the thrower's head.

Throw the ball for maximum distance with no spin, ensuring that it travels through the hoop. Try to throw the ball with the same velocity for each condition.

Condition B: Repeat Condition A, but impart heavy topspin on the ball. This is best done by placing the fingers on top of the ball with the thumbs pointing to the body and palms facing down.

Condition C: Repeat Condition A, but impart backspin on the ball. This is best done by placing the fingers under the ball with the hands to the side of the ball. The thumbs point away from the body.

Experiment: Task one (B)

NB: This task is best undertaken indoors, or in the absence of windy conditions.

- In groups of three, you will be required to measure the angle of rebound of a volleyball following impact with a flat surface when it is released with no spin, topspin and backspin.

Condition A: The thrower stands with feet shoulder width apart and holds the volleyball with two hands level with their waist. A partner holds a hoola-hoop at a position of 3 m from the thrower with the middle of the hoop level with the throwers head.

Throw the ball for maximum distance with no spin, ensuring that it travels through the hoop. Try to throw the ball with the same velocity for each condition.

The third member of the group stands to the side of the landing point of the ball. They are to estimate the maximum vertical height that the ball reaches after the first bounce and before the second bounce. They are to also estimate the horizontal distance from the point of impact of the first bounce to the point where the ball reaches maximum vertical height after impact.

Repeat the task to record three measurements.

Use the mean rebound height estimated and the distance from the point of impact to point at which maximum vertical height was reached, and a protractor to calculate the mean rebound angle of the ball.

Condition B: Repeat Condition A, but impart heavy topspin on the ball. This is best done by placing the fingers on top of the ball, with the thumbs pointing to the body and palms facing down.

Condition C: Repeat Condition A, but impart backspin on the ball. This is best done by placing the fingers under the ball, with the hands to the side of the ball. The thumbs point away from the body.

Experiment: Task one (C)

NB: This task is best undertaken indoors, or in the absence of windy conditions.

- Hit a table tennis ball such that you impart side spin to the ball.

In groups of three, you will be required to hit a

table tennis ball with a bat for a distance in the air that equates to the length of a badminton court.

Drop the ball and strike it such that you make it curve. Observe the flight path.

Repeat the shots, but vary the flight path of the ball such that it moves in the air from the left and the right hand side.

Determine the impact of spinning the ball to the left and right hand sides at impact on the flight path of the ball.

Experiment: Task one (D)

NB: This task is best undertaken indoors, or in the absence of windy conditions.

- In groups of three, you will be required to build a model airfoil and whilst using a hair drier, observe the Magnus effect.

Build the airfoil by:

- Cut a piece of paper (5.5 cm x 13 cm).
- Measure 3 cm from one end and draw a line across the width.
- Take the other end of the paper and fold it over to the drawn line. Don't crease the paper.
- Sticky tape the end down in that position.
- Gently press a bamboo skewer through both layers at the centre, approximately 1.5 cm from the folded end (not the sticky tape end). Remove the skewer.
- Thread a thin wire (60 cm) through the holes made with the skewer. Have a partner hold both ends of the wire tight.
- Use the hair drier to blow on the folded end from the front. Try and get the wing to rise (Figure 1.45). Try blowing, although be careful that you don't get dizzy!

Questions: Task one

In presenting your findings to Task one: Condition A, B, C and D respond to the following questions.

Using the results from the task undertaken in Condition A:

- Explain, using the principles related to fluid mechanics (spin, Magnus effect and Bernoulli's principle), the impact on the flight path of the ball, when released with no spin, topspin and backspin (4 marks).

Using the measured results and observations from the task undertaken in Condition B:

- Explain, using the principles related to fluid mechanics (spin), the impact on the rebound angle of a ball after it bounces

when released with no spin, topspin and backspin (2 marks).

Using your observations from the task undertaken in Condition C, with hitting a table tennis ball with different side spin:

- Explain, using the principles related to fluid mechanics (spin, Magnus effect and Bernoulli's principle), the behaviour of the table tennis ball when in flight (2 marks).

Using your observations from the task undertaken in Condition D, with a model airfoil, respond to the following question.

- The airfoil was created and positioned to experience a Magnus effect in the form of lift. Explain how lift was created such that the model airfoil used in Condition D moved up the wire (2 marks).

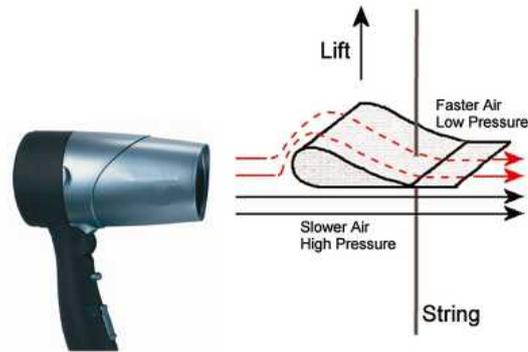


Figure 1.45:
An airfoil

Questions: Task two

- A soccer player may choose to impart a side spin on the ball when shooting for goal. Using the principles related to fluid mechanics (spin, Magnus effect and Bernoulli's principle) explain the in-air behaviour of the soccer ball when kicked with side spin. A diagram with labels of the ball's direction of travel, spin and resultant airflow and pressure differences are needed (2 marks).
- A discus, when thrown correctly, will experience a Magnus effect – lift. Explain in words, with the assistance of a diagram, the fluid mechanics that enhance the distance a well-thrown discus will travel (3 marks).

Equipment

- Tape measure (approximately 30 metres long).
- Volleyball.
- Hoola-hoop.
- Protractor (large if possible).
- Table tennis bat.
- Table tennis ball.
- Airfoil: sticky tape, paper (5.5cm x 13 cm), ruler, pencil, scissors, thin wire (60 cm), bamboo skewer.
- Hair drier.

Task: The principles of spin, Magnus effect and Bernoulli: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to most of the principles associated with the Magnus effect and Bernoulli's Principle.	1 mark
Provides clear statements of the expected results or anticipated outcomes in relation to objects in flight with spin, the Magnus effect and Bernoulli's Principle. Provides a clear statement in reference to the outcome of an airfoil experiencing lift.	2 marks
Introduction (3 marks)	
Identifies and defines the principles of objects in flight with spin.	1 mark
Shows an understanding of the principles that govern the behaviour of objects in flight with spin.	2 marks
Shows a comprehensive understanding of the principles of spin, Magnus effect and Bernoulli and the application of these principles to objects in flight and their rebound angle.	3 marks
Results (2 marks)	
Satisfactory presentation of data.	1 mark
Accurate and relevant presentation of data.	2 marks
Response to Questions (15 marks)	
<i>Task one: Question a: 4 marks, Questions b-d: 2 marks for each correct answer (10 marks).</i>	
<i>Task two: Question a: 2 marks, Question b: 3 marks (5 marks).</i>	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	1 mark
Limited discussion of the results found and few links made to the variables associated with objects in flight with spin and a few of the factors affecting the activities addressed.	2 marks
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with the behaviour of objects in flight with spin and some of the factors affecting the activities undertaken.	3 marks
Uses other sporting contexts to discuss the results found and identifies and defines variables associated with the behaviour of objects in flight with spin and most of the factors affecting the activities undertaken.	4 marks
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the principles of spin, Magnus effect and Bernoulli. Specifically revises how these principles apply to objects in flight with topspin, backspin and no spin and their rebound angle. Reviews the principles that permit lift of an airfoil.	5 marks
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the principles of spin, Magnus effect and Bernoulli. Specifically discusses how these principles apply to objects in flight with topspin, backspin and no spin and their rebound angle. Applies the principles that permit lift of an airfoil.	6 marks
Conclusion (2 marks)	
Summarises some of the factors associated with the behaviour of objects in flight with spin in relation to the hypotheses.	1 mark
Fully summarises the principles of spin, Magnus effect and Bernoulli and the application of these principles to objects in flight and their rebound angle in relation to the hypotheses. Limitations discussed.	2 marks
Comment:	Total
	/30

Appendix C (I)

Revision questions

- Why would it be better to be hit by a bicycle compared with a car, if both were travelling at $20 \text{ m}\cdot\text{s}^{-1}$?
- Suggest how a snail and a large dog develop linear momentum.
- Discuss how a hail stone is able to cause so much damage?
- Why does a new tennis ball bounce higher than an old one, if dropped from the same height?
- Why do squash players ‘warm’ the ball during the initial hit-up?
- What mechanical factors at impact play a role in determining the length of a golf drive?
- A perfect elastic collision between two objects will see
 - the pre-impact momentum of the two colliding objects equal the combined post-impact momentum of the objects.
 - some momentum lost after the impact.
 - the velocity of the smallest object decrease.
 - the velocity of one object will increase while the other stays the same.
- When hitting a golf drive, what type of collision occurs between the ball and the club-head? How does this influence the concept of conservation of linear momentum?
- What two mechanical factors make-up impulse?
- A high jumper landing on a mat compared with concrete experiences a different peak vertical force. Explain how the shape of the two impulse curves influences the peak force experienced by the jumper in each of these situations.
- A soccer player, when using their foot to trap a high velocity pass, is told to absorb the ball by moving their foot backward as the ball makes contact. This is a good idea because
 - it will ensure the linear momentum will be conserved and help ball control.
 - the coefficient of restitution of the foot is higher than the ball.
 - this action will increase the time over which the collision force occurs and therefore will reduce the peak impulse force of the collision allowing for better ball control.
 - it will ensure a perfect elastic collision occurs.
- The mass of an adult tennis racquet may not be particularly heavy. However, why is it that the same racquet may be very difficult for an 8-year old to use, when hitting a forehand?
- Explain how the length of the handle of a ‘sledge hammer’ affects your ability to swing the hammer.
- Why does a sprinter flex the lower limb at the knee during the swing phase of running and a cricketer throwing a ball, flex at the elbow during the early swing phase of throwing?
- Use a diagram and labels to explain why is it so difficult to hold a 10 kg weight at shoulder height with the arm stretched directly out to the side?
- If one wished to move a boulder, why would they use a long crowbar rather than a short one?
- If you wanted to test an athlete for their maximum elbow flexion strength, would the elbow angle be important?
- The point at which a force is applied and the perpendicular distance to the axis of rotation is called
 - an impulse curve.
 - a moment of force.
 - torque.
 - Both answers (b and c).

19. In rowing a boat, which of the following positions allows you to apply a greater moment (torque) to the oar: (a) at the catch (oar in the water); (b) when the oar is at right angles to the boat or (c) at the finish of the stroke – assume you can apply equal force at each position?
20. Over the years the shape of motor cars has changed significantly from squared bodies to more rounded and flatter designs. What effect might this have on drag and what impact do you think this might have on fuel economy?
21. A cyclist wears tight fitting lycra clothing to reduce drag, but they also adopt a low profile position on the bike to reduce drag. Which of the following options correctly labels in order the types of drag identified for the cyclist?
 - a. Friction drag and wave drag
 - b. Form (pressure) drag and surface drag
 - c. Surface drag and form (pressure) drag
 - d. Wave drag and form (pressure) drag
22. Why must the cyclist pay far more attention to the fit of their clothing than the race-walker, both of whom are keen to win their respective races?
23. In the Tour de France cyclists commonly stay in the pack to conserve energy; why would this be advantageous?
24. A soccer player attempts to deceive the goal keeper by having the ball ‘bend in the air’. What causes the ball to change its horizontal flight path (remember gravity only works vertically)?
25. How do coefficient of restitution and topspin affect the bounce of a tennis ball?
26. Why is a ball hit with backspin an advantage to the golfer?
27. A ball with a smooth surface when travelling at low velocity has what type of airflow in the boundary layer?
 - a. Laminar
 - b. Turbulent
 - c. Irregular
 - d. Wave

Appendix C (II)

Revision answers

- Momentum is a combination of mass and velocity. As the momentum of the car is greater than the bike because of its greater mass (velocity is constant), it would be better to be run into by the bike.
- A snail can only develop a small linear momentum, as it is both light and slow, whereas a dog can develop a relatively high linear momentum because it may be both large and quite fast.
- Many hail stones are quite large and together with their very high velocity, this produces a relatively high linear momentum at impact and a significant level of damage.
- The coefficient of restitution of a new ball is greater than that of the old (that is the old one has lost some of its elasticity and ability to regain its shape when deformed); hence the new ball will bounce higher.
- This increases the coefficient of restitution, making the ball bounce higher – easier to hit.
- At impact the linear momentum of the club-head (mass and velocity) and the coefficient of restitution between the club and ball play key roles, as of course does the angle of the club-face to the ball.
- a. The pre-impact momentum of the two colliding objects equal the combined post-impact momentum of the objects.
- This is an imperfect elastic collision, meaning that conservation of momentum does not totally occur.
- Force and time.
- The total impulse for the jumper remains constant on landing; it is the shape of the curve that varies. The sudden stop with the concrete surface means that the peak will be very high, whereas when using a mat the momentum is slowed over a longer period and the peak in this situation is reduced.
Note: It is always a good idea to draw a diagram to show the two curves.
- c. This action will increase the time over which the collision force occurs and therefore will reduce the peak impulse force of the collision allowing for better ball control.
- When the child swings a racquet they must overcome the moment of inertia, not the mass of the racquet. The moment of inertia of the racquet depends on the distribution of mass about the position of the grip on the handle, which will be high because of the length of the handle.
- As the metal end of the hammer is a distance from the grip, and the distance factor is squared ($m \cdot r^2$), when calculating the moment of inertia, then the longer the handle the higher the moment of inertia.
- One flexes at the knee (runner) or elbow (cricketer) to reduce the moment of inertia of the lower or upper limb respectively, thus making it easier to move the limb (mass distribution is brought closer to the axis of rotation - hip or shoulder).
- Holding the arm to the side is an example of a 3rd class lever where the resistance arm is very long, the fulcrum is the shoulder, the force arm is created by the muscle (deltoid) attachment a short distance down the arm and the resistance arm is from the shoulder to the weight in the hand (high turning moment)



16. The long crowbar provides an increased force arm, and a better lever.
17. Yes, as the moment of force will depend on the applied force and the moment arm. The moment arm will change with different angles.
18. d. Both answers (b and (c).
19. You will get a better turning effect from the oar when it is at right angles to the boat (b), as in this position the moment arm (perpendicular distance) will be at its greatest.
20. They have changed the shape of cars to reduce drag and therefore improve running economy. Shape is particularly important at higher speeds as drag increases with the square for an increase in velocity.
21. c. Surface drag and form (pressure) drag
22. Drag increases to the square of increased velocity. Therefore if the peak speed for a race walker is $4 \text{ m}\cdot\text{s}^{-1}$ and a cyclist $16 \text{ m}\cdot\text{s}^{-1}$, then for a fourfold increase in velocity ($16 \text{ vs } 4 \text{ m}\cdot\text{s}^{-1}$) you have a 16-fold increase in drag (4^2). Examiners would not expect you to know these numbers – they are included just to improve understanding.
23. Drag plays a significant role in energy expenditure during cycling and therefore any opportunity to conserve energy by reducing drag (drafting) will conserve energy.
24. Rotation of the ball produces variations in the speed of the boundary layer of air around the ball compared with the air that it is passing through. On one side there will be a reduction in boundary layer speed and subsequent increase in pressure, while on the other there will be an increase in boundary layer speed and subsequent decrease in pressure (Bernoulli principle). The ball will therefore move to the area of less pressure (always good to draw a diagram in answering this question).
25. Coefficient of restitution affects the height of the bounce (it works vertically), while rotation of the ball has a horizontal influence. Topspin will cause the ball to bounce lower for the same approach angle, compared with backspin.
26. A ball with backspin will initially rise and therefore increase the length of the hit (boundary layer under the ball is reduced in speed causing an increase in pressure).
27. a. Laminar

Appendix E

Glossary of key terms

Angular momentum: Is the product (multiplication) of the moment of inertia of the object/body combined with its angular velocity (rotational velocity).

Bernoulli's principle: States that an increase in the speed of fluid occurs simultaneously with a decrease in pressure.

Coefficient of restitution (COR): Or bounciness of an object is a value representing the ratio of the velocity after an impact compared with the velocity before the impact.

First class lever: The axis of rotation (the fulcrum) is between the force and the load.

Force arm: The perpendicular distance between the force and the pivot point or axis of rotation.

Form drag: Is the pressure differential between the front and back of the body – it is most influenced by the frontal surface area.

Frictional drag: Is the drag created by the surface of the immersed body in a fluid (eg. air or water).

Imperfect elastic collision: Objects with a COR < 1 (linear momentum is not fully conserved, some energy is lost).

Impulse (F·t): Is the product of force and time. That is, the amount of force that can be produced over a time interval. Impulse is equivalent to the change in momentum ($mv_2 - mv_1$) of the object.

Law of Conservation of (Linear) Momentum: When two bodies collide, the momentum into the collision remains the same as the momentum after the collision and therefore momentum is conserved.

Lever: A lever consists of: A pivot point or axis (point about which the two lever arms {force and resistance} operate); a weight/load/resistance to be moved; and the applied force required to move the weight/load/resistance.

Linear momentum: Is the product (multiplication) of mass (m) and velocity (v).

Magnus effect: Explains the change in flight path of a projectile and particularly relates to a ball that is spinning. The curving effect of spin on the flight of a ball is termed the Magnus effect.

Moment of force (N·m): The turning effect produced by application of force is equal to the applied force (N) x perpendicular distance (m) between the line of the force and the axis of rotation.

Moment of Inertia: Is a measure of an objects reluctance to move with angular motion. It is a reflection of the distribution of the object's mass about the point that is used to rotate the object.

Perfectly elastic collision: Objects with a COR of 1 (linear momentum fully conserved).

Perfectly inelastic collision: Linear momentum is zero after the collision.

Resistance arm: The perpendicular distance between the weight/load/resistance and the axis of rotation.

Second class lever: The weight/load/resistance is located between the fulcrum and applied force.

Third class lever: The applied force (the muscle attachment), is somewhere between the axis of rotation and the weight/load/resistance.

Wave drag: Energy lost due to the creation of waves.



Functional Anatomy

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and Dr Kym Guelfi (Senior Lecturer)

BACKGROUND INFORMATION

The following dot-points provide a revision of the key concepts from Units 1 and 2.

The respiratory and cardiovascular systems: Supporting the aerobic energy system

- The respiratory system transports oxygen from our external surroundings into the lungs to the site of gas exchange (the alveoli).
- The amount of air we inspire (minute ventilation) is determined by the amount of air inspired with each breath (tidal volume) and the frequency of breaths each minute.
- At the alveoli, passive diffusion occurs where oxygen moves from the alveoli (high concentration) into the bloodstream (low concentration), while carbon dioxide moves from the blood (high concentration) into the alveoli (low concentration) to be expelled from the body upon expiration.
- The cardiovascular system transports oxygen to the level of the working muscle.
- The amount of blood pumped

around the body each minute (cardiac output) is determined by the volume of blood pumped with each beat of the heart (stroke volume) and the number of beats per minute (heart rate).

- Systolic blood pressure represents the highest pressure in the arteries resulting from the contraction of the heart, while diastolic blood pressure occurs when the heart relaxes.
- The majority of oxygen is transported in the blood in combination with haemoglobin in red blood cells.
- The majority of carbon dioxide is transported in the blood as bicarbonate after combining with water.
- The volume of oxygen consumption ($\dot{V}O_2$) represents the volume of oxygen actually used by the body. This is the product of the amount of blood being transported around the body (cardiac output) and the amount of oxygen extracted from this blood (the $a-vO_2$ difference).

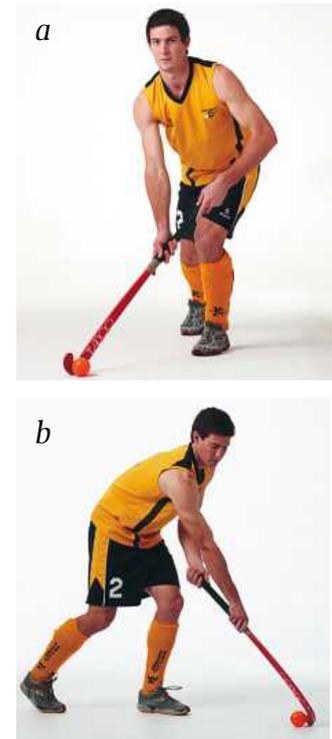


Figure 2.1: The right hand forearm supinated (a) and pronated (b)

The pivot joint

- When performing a crossover dribble in field hockey:
 - Bones: radius and ulna.
 - Joint type: pivot joint.
 - Muscles: pronators and supinators.
 - Action: pronation and supination.
- Pronation: occurs when you cross over the radius and ulna (palm down).
- Supination: occurs when the radius and ulna are parallel (palm up).
- Origin: the muscle attachment site (tendon) that is at the static end.
- Insertion: the muscle attachment site (tendon) that is closest to the end that moves.

The hinge joint

- When performing a biceps curl:
 - Bones: humerus, radius and ulna.
 - Joint type: hinge joint.
 - Muscles: biceps (agonist) and triceps (antagonist).
 - Action: flexion and extension.
- Flexion: the joint angle is decreased and limbs move closer together.
- Extension: the joint angle is increased and limbs move further apart.
- Agonist: the prime muscle, when restricted is responsible for movement.
- Antagonist: muscles that create the opposite movement to that created by the agonist.

- Concentric muscle contraction: muscle shortens when tension is developing.
- Eccentric muscle contraction: muscle lengthens when tension is developed.
- Isometric contraction: no change in length when tension is developed.

The gliding joint

- When swinging a softball bat, the trunk:
 - Bones: vertebrae.
 - Joint type: gliding joint.
 - Muscles: left-side abdominals (agonist), right-side abdominals (antagonist).
 - Action: Rotation.

Kicking a football: The knee – gliding joint and hinge joint

- When kicking a football:
 - Bones: femur, patella, tibia, and fibula.
 - Joint type: hinge and pivot joint.
 - Muscles: quadriceps (agonist) and hamstrings (antagonist).
 - Action: extension.
- The patella gives the knee joint a mechanical advantage.
- Because the hamstrings are contracting eccentrically at the end of the kicking phase they are subjected to large or fast forces that can lead to injury.

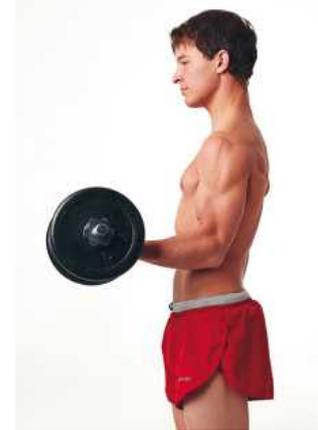


Figure 2.2: Biceps curl



Figure 2.3: Hitting a softball



Figure 2.4: Extension of the leg about the knee during a kick

The splits:

The hip – ball and socket joint

- When performing the splits laterally (Figure 2.5):
 - Bones: pelvis and femur.
 - Joint type: ball and socket joint.
 - Muscles: hip adductors (antagonist) and abductors (agonist).
 - Action: abduction.



Pitching in softball: *The shoulder – ball and socket joint*

- When pitching a softball (circumduction):
 - Bones: humerus, scapula, and clavicle.
 - Joint type: ball and socket joint.
 - Muscles:
 - ◇ At the initiation of the delivery stride, contraction of the shoulder muscles—pectoralis major and deltoid (agonist) and latissimus dorsi (antagonist).
 - Action: shoulder flexion.
 - ◇ As the arm begins to move upward and outward, contraction of the shoulder and back muscles—latissimus dorsi, (agonist) and pectoralis major (antagonist).
 - Action: shoulder extension.
 - ◇ At the ball delivery towards the batter, contraction of the shoulder muscles—pectoralis major and deltoid (agonist) and latissimus dorsi (antagonist).
 - Action: shoulder flexion.



Figure 2.6:
The softball pitch, action of the right humerus

Figure 2.5: Flexibility and relaxation of the adductor muscles permits this gymnast to complete the splits

The saddle joint

- When gripping a hockey stick, baseball bat, tennis racquet, golf club and so on:
 - Bones: thumb, carpals and metacarpal.
 - Joint type: saddle joint.
 - Action: flexion, extension, abduction, adduction and circumduction.
- When dribbling with a hockey stick:
 - Bones: thumb, carpals and metacarpals.
 - Joint type: saddle joint.
 - Muscles: wrist flexors and extensors.
 - Action: flexion and extension.



Figure 2.7: The right thumb of the hockey player is flexed and adducted (bottom hand) and his top hand (left) is abducted

The breaststroke frog kick

- In the first phase of kicking the legs in breaststroke (Figure 2.8):
 - Bones: tibia, fibula, and tarsals.
 - Joint type: hinge.
 - Muscles: gastrocnemius.
 - Action: plantar flexion.
- In the second phase of kicking the legs in breaststroke (Figure 2.9a & b):
 - Bones: femur and tibia.
 - Joint type: hinge.
 - Muscles: hamstrings.
 - Action: flexion at the knee.
- In the third phase of kicking the legs in breaststroke (Figure 2.10a & b):
 - Bones: tibia, fibula and tarsals.
 - Joint type: gliding joint and hinge joint.
 - Muscles: tibialis anterior.
 - Action: dorsi flexion and eversion.
- In the fourth phase of kicking the legs in breaststroke (Figure 2.11a & b–12a & b):
 - Bones: pelvis and femur.
 - Joint type: ball and socket:
 - Muscles: adductors.
 - Action: adduction.
 - Bones: femur and tibia.
 - Joint type: hinge joint:
 - Muscles: quadriceps.
 - Action: extension.
- The fifth phase involves the swimmer returning to first phase position (Figure 2.13).



Figure 2.8: Breaststroke streamlined position, plantar flexion of the foot



Figure 2.9: Flexion at the knee

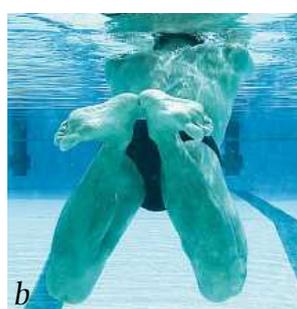
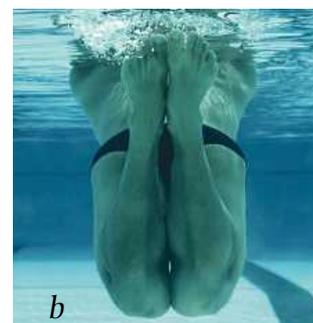


Figure 2.10: Dorsi flexion and eversion of the feet



Figure 2.11: The legs are adducting to complete the kick



Figure 2.12: The legs are extending and adducting through the main phase of the kick



Figure 2.13: Completing the breaststroke kick

Functional Anatomy: ATAR Units 3 and 4

A similar approach is followed for each section of the ATAR Units 3 and 4 curriculum. Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the ‘Content that follows’ and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A ‘Key point summary’ box is presented at the end of each section.

Revision questions (with answers) are included near the end of this chapter as Appendix C. A ‘Glossary of key terms’ appears on the final pages of this chapter (Appendix E).

At the end of the Chapter titled Exercise Physiology is a ‘Personalised project’, which requires students to apply knowledge and understanding from ‘Biomechanics, Functional Anatomy and Exercise Physiology’ (Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision.

Skeletal Muscle Structure

Text outcomes: *Skeletal muscle structure (Unit 3)*

- Explain the structure of skeletal muscle i.e. epimysium, fascicle, perimysium, muscle fibre, myofibril.

Content that follows: *Skeletal muscle (Unit 3)*

- *Skeletal muscle structure*
 - epimysium, fascicle, perimysium, muscle fibre, and myofibril

Skeletal muscle

Skeletal muscles are muscles that are connected to bones (skeleton) via tendons and permit movement when contracted (Figure 2.14). It is important to realise that muscles only pull, they do not push. The contraction of skeletal muscle is voluntary, which allows us to manipulate objects, move around the room and balance on one leg. That is, you must first ‘think’ about what you want to do, then the brain sends a message to the muscles to either contract or relax to allow the movement to occur.

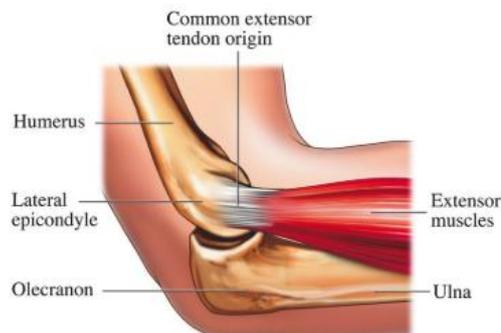


Figure 2.14: Skeletal muscle, attached to bone via tendons

Skeletal muscle is made up of long **muscle fibres** all bundled together, similar in appearance to a large group of electrical cables. When you cook a piece of meat it may be possible to separate out groups of muscle

fibres in a particular muscle belly (for example, chicken breast) (Figure 2.15a). In meat from larger animals (for example, steak) it may be possible to determine different groups of muscles that are each surrounded by thin layers of connective tissue (Figure 2.15b). It is these long muscle fibres where contraction occurs and movement is generated. A number of these bundles of muscle fibres contribute to creating the **muscle belly** (Figure 2.16).

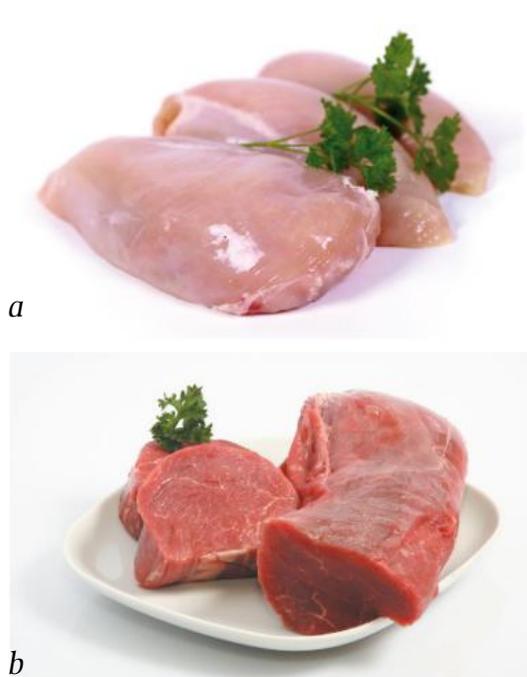


Figure 2.15: You can see the muscle structure when looking at chicken (a) and steak (b)

from other muscles. Inside the epimysium are bundles of muscle fibres. Each bundle is called a **fascicle**. The fascicles are surrounded by connective tissue known as **perimysium**.

The muscle fibres forming part of the fascicles are comprised of **myofibrils**. That is, bundles of myofibrils form muscle fibres. It is at the level of the myofibrils where contraction occurs.

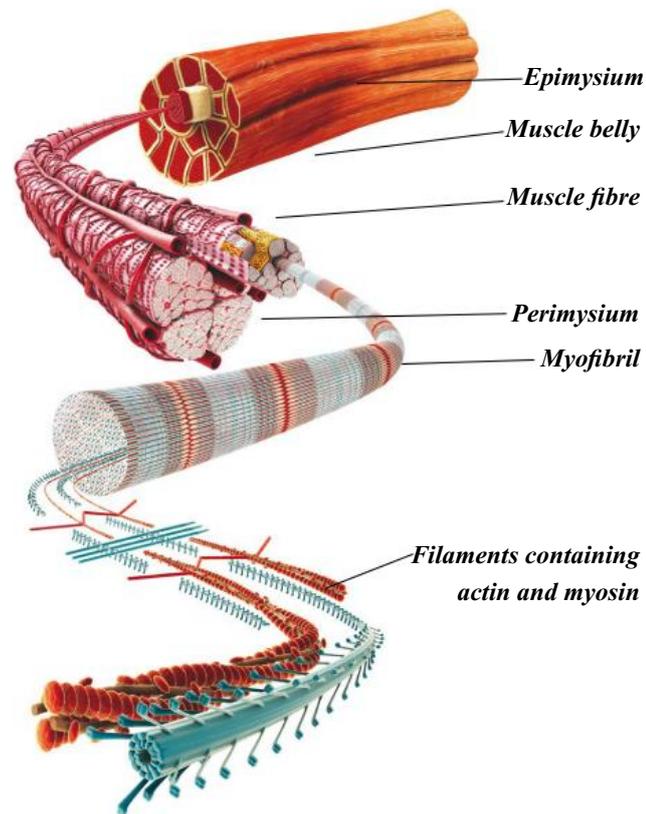


Figure 2.16: The structure of a skeletal muscle

Figure 2.16 provides a detailed view of skeletal muscle structure. Each muscle is encased by a thin layer of connective tissue known as the **epimysium**. This connective tissue holds the muscle belly together and separates it

The structure of the muscles can be seen as similar to filling shopping bags (Figure 2.17). Each bag represents the outer layer – epimysium of a muscle and separates your shopping (muscles) and holds it all together.

Inside the shopping bag we have a number of groceries (fascicle – bundles of muscle fibres) each with their own external packaging – or perimysium which keeps each item (or bundle of muscle fibres) separated.

Each grocery item (fascicle) is comprised of a number smaller components. That is, within the individual packaging (perimysium) we find the strands of spaghetti, slices of bread or a dozen eggs (fibre).



Figure 2.17: Shopping bags representing the structure of a muscle

Key point summary:

- Skeletal muscle is comprised of the following components.
- Myofibril: A single strand of muscle comprising actin and myosin (myofilaments) – the level of muscle contraction.
- Muscle fibre: A strand of muscle that forms part of the fascicles comprising a collection of myofibrils.
- Fascicle: A bundle of muscle fibres.
- Perimysium: The connective tissue that surrounds the fascicle or bundle of muscle fibres.
- Epimysium: The connective tissue that surrounds the whole muscle.
- Muscles are connected to bones via tendons.

Revision questions:

Test yourself on revision questions 1–3 located at the end of this chapter.

Skeletal Muscle Contraction

Text outcomes:

Skeletal muscle contraction (Unit 3)

- Explain how skeletal muscle contracts in relation to sliding filament theory i.e. the role of myosin, actin and the sarcomere.

Content that follows: *Muscle contraction (Unit 3)*

- *Muscle contraction*
- *The contractile unit of skeletal muscle*
 - *Sarcomere, actin, myosin, Z line, H zone, and I band*
- *The sliding filament theory: Contraction and relaxation*

Muscle contraction

Muscle contraction creates movement of limbs and assists in maintaining posture and ensuring joint stability. When you contract a muscle the origin and insertion points of the muscle come closer together (Figure 2.18a). The muscle shortens and feels firm to the touch as tension is developed in the muscle belly. The other thing you will observe is the muscle belly appears to get bigger (Figure 2.18b). So how does this occur?

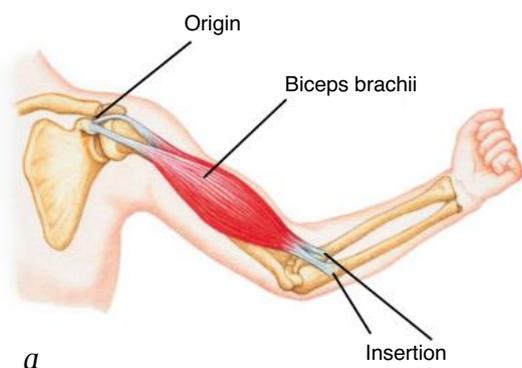


Figure 2.18:
The muscles attachment sites come closer together (a) and the muscle changes shape when contracted (b)



The contractile unit of skeletal muscle

As mentioned above, contraction of skeletal muscle occurs at the level of the myofibrils. Each myofibril is comprised of numerous sarcomeres that run parallel to the muscle belly. Each *sarcomere* is comprised of a combination of *actin* and *myosin* proteins (Figure 2.16 and Figure 2.20). Within the sarcomere the actin and myosin overlap each other.

The actin filaments are thin. They are attached to the membrane that divides each sarcomere. This membrane is called a *Z line*. When at rest, the actin filaments extend out toward each other, but have a gap between them. This gap between the ends of opposing actin filaments is called the *H zone*.

The myosin filaments are relatively thick. When viewed under a microscope they give skeletal muscles its striated appearance. The myosin filaments run parallel to the actin and sit between each actin filament, in the middle



Figure 2.19: Myosin cross-bridges sweep or oscillate like the oars in this boat

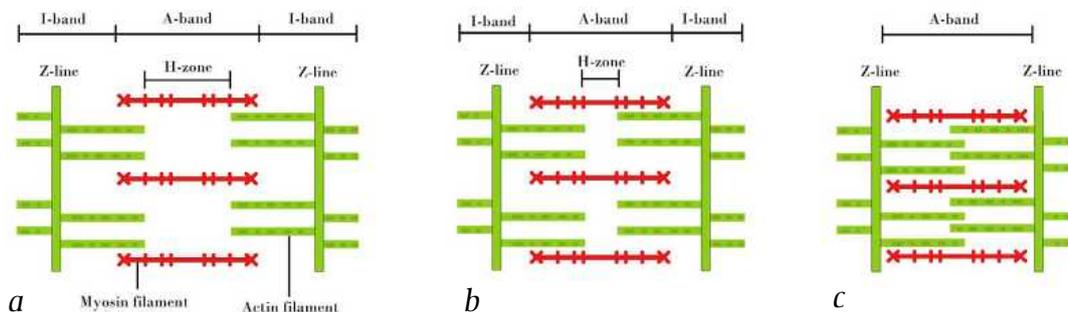


Figure 2.20: The actin and myosin of a sarcomere, separated when relaxed (a). When contracted the actin and myosin slide across each other (c)

of the sarcomere. Unlike the actin the myosin do not attach to the Z line. The gap between the end of a myosin and the Z line is called an **I band**. Myosin filaments have small cross-bridges that stick out from the side, similar in appearance to the oars on a rowing boat with eight people used for racing. Just like the oars, the cross-bridges are able to sweep or oscillate back and forward (Figure 2.19).

The sliding filament theory

The **sliding filament theory** describes how skeletal muscle contracts. For a concentric muscle contraction to occur there needs to be a command delivered by a motor nerve (neuron). Upon being stimulated, the myosin cross-bridges reach out and ‘grab on’ to the actin filaments. At this point the myosin cross-bridges begin to oscillate – just like oars do when rowing a boat. The actin filaments are pulled inward (Figure 2.20b). Because the actin filaments are attached to the Z line, they reduce the length of the sarcomere. The I band, the gap between the end of the myosin and the Z line, gets smaller and may even disappear. The gap between the ends of opposing actin get closer together, and consequently the H zone gets

smaller and may even disappear as the actin meet in the middle (Figure 2.20c).

As each of the sarcomeres contract, the length of the sarcomere and thus the length of the muscle reduces. Each sarcomere may shorten by 20–50% of its resting length. Millions of sarcomeres may be shortening at the same time thus causing the muscle to shorten with great force.

As a result more proteins, actin and myosin, are squashed into a smaller area. We recognise this as an increased cross sectional area of the muscle belly.

When the muscle relaxes the links between the actin and myosin are released and the proteins slide past each other back to the original positions.

The sliding of filaments is like the action of climbing a ladder

Whilst we have used a rowing boat for eight people to represent muscle contraction, an alternative is to compare the sliding filament theory to a builder climbing a ladder (Figure 2.21).

The ladder would represent actin and a builder the myosin. When the builder is away from the ladder no cross-bridges are formed and the builder can not ascend the ladder (no contraction occurs) unless he can fly! As the builder makes contact with the hands and then feet – cross-bridges are formed and the workman can commence climbing the ladder, just as the two protein filaments begin

moving past each other in a muscle contraction. If the builder stops half way up the ladder to fix a nail to the wall, connection is still maintained, but he neither moves up nor down the ladder – similar to an isometric contraction. During an isometric contraction the actin and myosin do not move past each other. The sarcomere does not change length, hence the muscle belly remains the same length and no movement occurs. However, it is important to note that the proteins, actin and myosin, still maintain a tight hold on each other.

When the workman reaches the top of the ladder he is unable to go any higher and similar to reaching the end point of a contraction. Finally, the quickest way back down a ladder is to slide along the rails (Figure 2.21b). At this time cross-bridges are maintained and the actin and myosin can return to their original positions as quickly as possible.



Figure 2.21: The sliding filament theory can be likened to climbing a ladder (a) and sliding back down (b)

Practical activity: Evidencing sarcomeres during a muscle contraction

- Relax your arm by your side then roll up your sleeve such that you can see your biceps. Look at the size of your bicep. Now pick up this text book and flex your arm to 90° by contracting the bicep muscle. Observe the change in shape and size of the bicep muscle.
- We hope it got bigger (rounder).
- Did it become more compact?
- Look closely, as you hold the book at 90° with an isometric contraction. Can you see any ‘fluttering’ of the fibres under the skin (this being the myosin and actin myofilaments at work)?

Equipment:

- Textbook.

Key point summary:

- The contractile component of a skeletal muscle is the sarcomere.
- Actin and myosin are the proteins which form the sarcomere.
- The sliding filament theory explains muscle contraction at the level of the actin and myosin and can be summarised as:

Key point summary (continued):

- stimulus delivered by a motor nerve
- myosin cross-bridges attach to actin and begin to oscillate
- actin filaments are pulled in – I band and H zone get smaller and may disappear
- Z lines are pulled closer together – sarcomere gets smaller
- with many millions of sarcomeres getting smaller – the muscle contracts with an increased cross sectional area of the muscle belly.

Revision questions:

Test yourself on revision questions 4–10 located at the end of this chapter.

Developing Muscle Force

Text outcomes:
Developing muscle force (Unit 3):

- *Understand the relationship between the velocity and duration of muscle contraction to the amount of force exerted by the contraction i.e. force-velocity & force-length.*

Content that follows:
Force-velocity and force-length relationships (Unit 3)

- *Muscle force and velocity relationship*
- *Muscle length and velocity relationship*

Figure 2.22: Pulling a truck requires many muscle fibres to contract at the same time

Force-velocity relationship

It takes time, although only about 0.01 seconds, for a muscle contraction to occur. The signal is sent from our brains to the muscle which tells the actin and myosin to slide past each other. If we want our contraction to occur rapidly, such as during running, it may not allow sufficient time for the sarcomere to contract fully. This means not as much force would be developed. If you need to move a heavy object such as pushing (or pulling) a truck (Figure 2.22) your movements are much slower, this gives time for all the sarcomeres to contract and therefore be able to produce much greater forces.



The greatest amount of force can be developed during an isometric contraction (Figure 2.23 and Figure 2.24). That is, there is no movement in the muscle and as indicated above all the actin and myosin proteins are held firmly together. At this point the greatest amounts of cross-bridges are engaged.

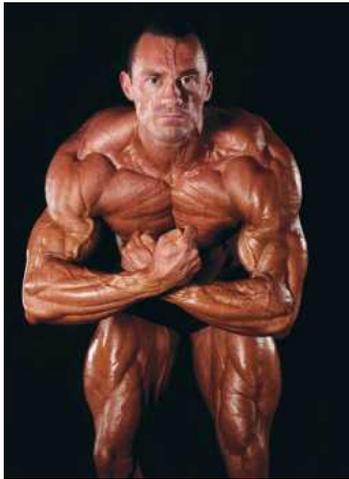


Figure 2.23: An isometric contraction. The position is maintained such that there is no change in muscle length

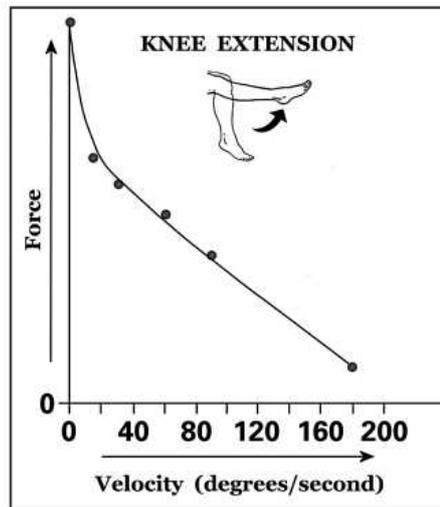


Figure 2.24: Force-velocity relationship

When there is no resistance to the movement or no force exerted, the greatest velocity of that movement is achievable. If you were to throw a table tennis ball you could move your arm much faster than if you were trying to throw a shot put (Figure 2.25).



a



b

Figure 2.25: The velocity of arm movement when throwing the light table tennis ball (*a*) and heavy shot (*b*) will be different

Power is a combination of strength and speed. To achieve maximum power, the velocity and the resistance should be approximately one third of maximum values. For example, if you were to ride your bike (Figure 2.26) in the easiest gear you are able to spin your legs very fast, maybe up to 200 revolutions per minute. At this cadence the muscles in your legs are contracting so rapidly they do not have time to contract fully and thus the force they produce is minimal. This would have a negative impact on

the power production and thus the bike speed would be low.

If you change gears to one that is harder to push, that is there is more resistance, you are no longer able to spin your legs at the same cadence. Your legs may slow down to 30 revolutions per minute. In this case, greater amounts of muscle force are produced but as the velocity of contraction is low, power output is reduced and bike speed is low.

Neither of these cadences produces the optimum horizontal velocity while cycling on the road. For most cyclists, choosing a gear that maintains a cadence of between 75 and 90 revolutions per minute (30-40% of maximum) offers the most efficient combination of resistance and velocity of leg turn over. Therefore the greatest horizontal velocity can be produced.



Figure 2.26: Cyclists can vary their velocity by changing gears to find the optimum muscular contraction speed

Force-length relationship

The length of a muscle and the angle at the joint has an impact on the force that can be generated. The optimum muscle length and joint angle is different for each part of the body. However, the optimal position is somewhere

near the middle of a joints range, allowing maximum attachment of the myosin cross-bridges with the actin. For example, the bicep muscle will generate maximum tension during a concentric contraction when it is positioned at about 120° (Figure 2.27). However, the quadriceps muscles generate maximum tension at approximately 90° on knee flexion.

When the bicep muscle is shortened to about 30° , it is unlikely to be able to develop any tension (Figure 2.27). This can be seen by examining the sarcomere, that is, the myosin and actin have reached their limit of moving past each other.

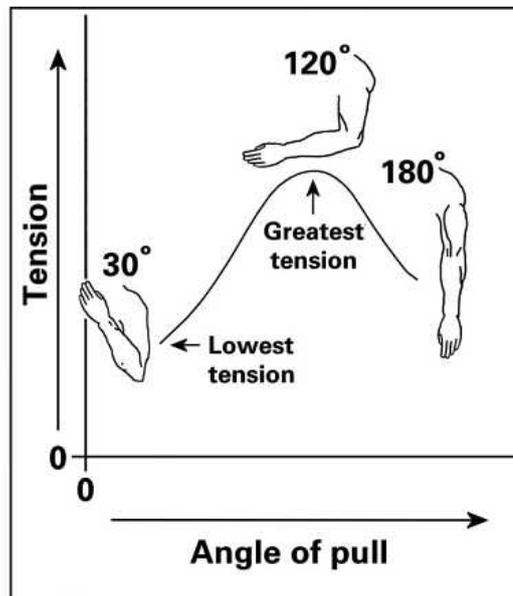


Figure 2.27: An arm positioned at approximately 120° is able to generate maximum tension

The longer muscles, such as the hamstring muscles, have the ability to contract over a greater distance and thus can create a greater range of motion at a joint. However, a shorter wider muscle (for example, the deltoid), one

that has a greater cross sectional area has the ability to produce greater amounts of force (Figure 2.28).

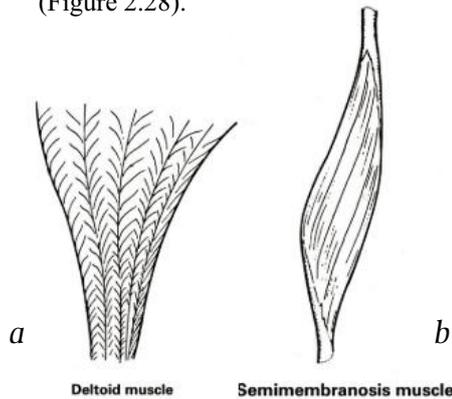


Figure 2.28: Muscle range of motion and strength varies depending on the structure. For example, the deltoid (a) is a short muscle, while the hamstring (b) is a long muscle

Key point summary:

- The greatest amount of force can be developed during an isometric contraction, when there is no movement in the muscle.
- When movement is required, the maximum force can be generated by performing movements at approximately one third of maximum velocity.
- The greatest amount of force can be generated when most cross-bridges are engaged, this being somewhere near the middle of a joints range of motion.
- Longer muscles have the potential to move joints through a greater range of motion.
- Shorter muscles have the potential to generate greater force.

Revision questions:

Test yourself on revision questions 11–14 located at the end of this chapter.

Neuromuscular Structure and Function

Text outcomes:

Neuromuscular structure and function (Unit 4)

- *Understand the function of nerve, impulse, spinal cord, motor unit (dendrite, cell body, and axon).*

Content that follows: *Nerves and muscle function (Unit 4)*

- *The nervous system*
- *Components of a motor unit: Motor neuron, dendrite, cell body, neural chain*

The nervous system

The nervous system comprises two main parts, the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS is comprised of the brain and spinal cord where as the PNS includes all the nerve branches that our outside the spinal cord.

Information must be sent from the brain down the spinal cord then to the target muscle for muscle contraction, and thus movement to occur (Figure 2.29). This information is sent via

an electrical impulse with the nerves acting as a conductor. These nerves act in the same manner as an electrical cable such as the power cord for a toaster. Thus, it is not advisable to put your fingers in a power point!

The spinal cord is part of the CNS. It acts as a highway for neural traffic. Impulses travel up and down the spinal cord delivering information to the peripheral nervous system (PNS) to produce movement or send sensory information back to the brain. When neural messages travel to the muscle from the CNS, they do so along **motor neurons** and when they send impulses back from receptors to the brain, they do so along **sensory neurons**.

Components of a motor unit

A **motor neuron** is a nerve whose end point is a muscle. A motor neuron or nerve is made up of three main parts; the dendrite, cell body and axon (Figure 2.30). The **dendrite** is like a TV antennae, it receives the signal or information from the CNS. It feeds this information to the **cell body**. A cell body directs the activities of the neuron, so when it receives the signal it then transmits the information along the length of the **axon**. The axon is responsible for transmitting messages away from the cell body. The message is generally relayed through a series of these neurons (**neural chain**) to eventually finish at the target site where muscle activation occurs. The motor neuron and the muscle fibres that it innervates are collectively called a **motor unit**.

The axons of motor units are **myelinated** which means they have an insulated covering (myelin sheath) over much of the length of the axon. This myelination increases the speed of the information transfer to about 100 M.S^{-1} . When the information reaches the end of the axon of a motor neuron the nerve impulse will lead to creation of movement via either contraction or relaxation of the muscle fibres.

Class task:

Time to create motion

How long would it take to send information from the brain to the big toe in someone who is 2 m tall? If the distance from brain to toe $\sim 2 \text{ m}$; and, the nerve conduction velocity is $\sim 100 \text{ M.S}^{-1}$, then the time taken would be $\sim 0.02 \text{ s}$.

So, how long would it take to send information from your brain to your hands?

The **motor unit** refers to the muscle fibres which are influenced by each nerve (Figure 2.31). The axons of the neurons can branch to one or many thousands of muscle fibres. In large muscles, such as the quadriceps in the thigh, a motor unit may comprise 1000s of muscle fibres where big, powerful movements are required. When precision is needed, such as movements of the eye, a motor unit may be 1–3 muscle fibres.

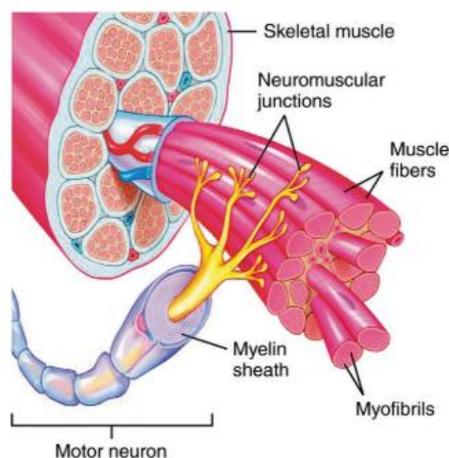


Figure 2.31: The motor neuron can innervate one or many thousands of muscle fibres



Figure 2.29: Basic neural pathway from the brain down the spinal cord, then to a muscle to derive movement

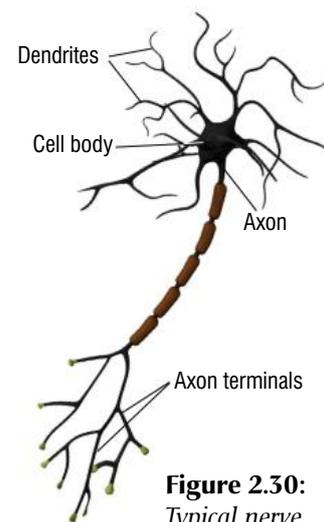


Figure 2.30: Typical nerve

Neuromuscular function can be likened to sharing information with your friends. If you wanted to get the attention of one friend to ask them over for dinner you are more likely to ring them and speak to them. That way the response is targeted and more accurate.

If you wanted to let all your friends know that you are going to the beach and if they wanted to join you they could, you may use a more broad communication tool like Facebook or Twitter. You may not know which of your friends will meet you, but you have been able to inform them all of your intentions in the most efficient manner.

Key point summary:

- Motor neurons transmit neural impulses away from the CNS.
- Sensory neurons send impulses back from receptors to the brain.
- A motor neuron is a nerve whose end point is a muscle.
- A motor neuron or nerve is made up of a dendrite, cell body and axon.
- A dendrite receives the signal or information from the CNS and feeds it to the cell body.
- A cell body directs the activities of the motor neuron. It receives the signal from the dendrite, before transmitting the information along the length of the axon.
- An axon is responsible for transmitting messages away from the cell body.
- Axons are surrounded by myelin sheath to improve conductivity.

- A neural chain is a series of motor neurons or nerves that are linked together.
- The motor unit is comprised of a motor neuron and the target muscle fibres it innervates.

Revision questions:

Test yourself on revision questions 15–17 located at the end of this chapter.

Developing Muscle Tension

Text outcomes: *Developing muscle tension (Unit 4)*

- *Describe the relationship between muscle contraction and nerve function.*

Content that follows: *Developing muscle tension (Unit 4)*

- *The all-or-none principle*
- *Neuromuscular response to strength training*

The ‘all-or-none principle’ of motor neuron stimulation

If you are in a dark room you turn on the light so that you can see. If you wanted to read a book at a desk you may turn on a lamp so that the light is directed at the pages you are reading

(Figure 2.32a). If the room is large you may turn on two or three lights at the same time. When you go to the football at night with one flick of the switch hundreds of lights can come on at once. These lights will be directed on the playing arena but some of the light will spill into the crowd (Figure 2.32b).

The relationship between muscle contraction and nerve function is similar to the above examples regarding turning on lights in dark spaces. If we want to light up more area we turn on more lights, if we want to make a muscle contraction more forceful we stimulate more motor units and therefore contract more muscle fibres at the same time. If we want to be more direct with our light we will turn on a lamp, similarly if we want to be more precise with movement we will only contract a small number of muscle fibres.

The *all-or-none principle* of a motor unit states that if an electric stimulus reaches a threshold level, then all of the muscle fibres associated with that unit will contract to their maximum level and all at the same time. So how do you increase the tension or force generated in that particular muscle? There are two possibilities. Just as the desk lamp and stadium lighting examples suggest, to generate greater tension, we need to recruit more motor units from the targeted muscle group. The second possibility is to increase the rate of firing of the neural impulses to the existing fibres. What actually happens, is we employ both possibilities to work together to generate more muscle tension.

Neuromuscular response to strength training

Great improvements in muscular strength can occur in the first two to eight weeks of training without any changes in muscle size. This is because the improvements first occur at the

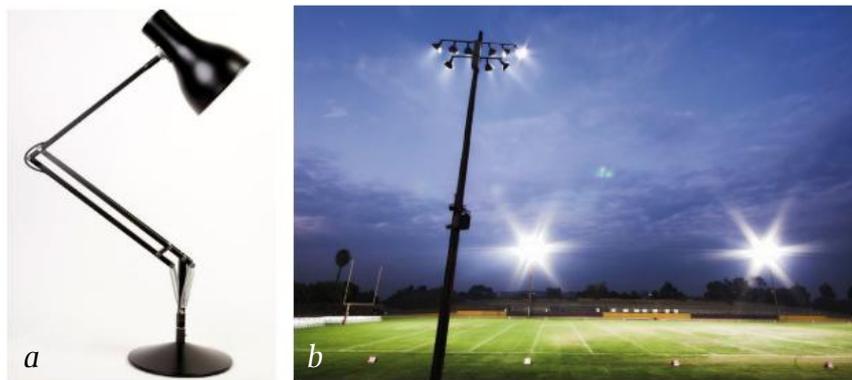


Figure 2.32: A desk lamp is more precise with light direction (a) compared to stadium lighting (b)

neuromuscular level, that is, the skill level of the movement improves. There are four main responses to strength training without changes in muscle bulk: improved technique, increased firing rate of motor units, more motor units are recruited and the firing pattern of the motor units is better coordinated.

With further training muscle hypertrophy can occur. This is where the muscle belly gets thicker. This is due to the increasing number of sarcomeres due to more actin and myosin.

Practical activity: *Throwing a ball for maximum distance – A test of nerves!*

Stand at the end of the oval and throw a tennis ball as far as possible (no run up). Repeat the activity with your non-preferred hand. Can the strongest person in your class throw a tennis ball further than anyone else with both left and right hand? How much does technique and muscle recruitment patterns play a role in throwing a ball?

Why can you throw further with your preferred hand?

Equipment:

- Tennis ball.
- Open space.

Key point summary:

- The all-or-none principle of a motor unit states that, when stimulated, all of the muscle fibres associated with that unit will contract to their maximum level and all at the same time.
- The more muscle fibres that are stimulated to contract, the greater the resultant force.
- An increase in the firing rate of neural impulses, results in the development of a greater muscle tension.
- During the first 2–8 weeks of strength training, the resultant improvements in muscle strength are mainly due to improved neural function.

Revision questions:

Test yourself on revision questions 18–20 located at the end of this chapter.

Muscle Fibre Types

Text outcomes:

Muscle fibre types (Unit 4)

- *Identify fast and slow twitch fibres and their relationship to physical performance types (sprint, endurance) i.e. characteristics of fibres, Type I, Type IIa, Type IIb.*

Content that follows:

Muscle fibre types (Unit 4)

- *Muscle fibre types*
 - *Slow-twitch (Type I)*
 - *Fast-twitch (Type IIa and Type IIb)*
- *Predicting athletic success using muscle fibre types*

Slow-twitch and fast-twitch muscle fibre types

Skeletal muscle is comprised of the contractile component which is made up of muscle fibres. These fibres can be either slow or fast twitch. **Slow-twitch muscle fibres (Type I)** are found in muscles related to posture. They are more fatigue resistant and as a result, athletes involved in endurance events typically have a higher percentage of slow-twitch muscle fibres (Figure 2.33a). In line with the endurance nature of these fibres, for contraction to occur they require aerobic energy.

Fast-twitch fibres (Type II) can be classified into Type IIa or Type IIb. **Type IIb** are those

linked to muscles involved in quicker, more explosive movements and may contract up to 10 times faster than Type 1 fibres. *Type IIa* fibres are intermediate in relation to contraction speed. Sprinters have a higher percentage of fast-twitch muscle fibres (Figure 2.33b) compared to the normal population which gives them a greater advantage in their sport. Muscles of the eye are made up primarily of fast-twitch muscle fibres. The muscle energy for contraction in fast-twitch muscle fibres comes from the faster metabolic anaerobic pathway.

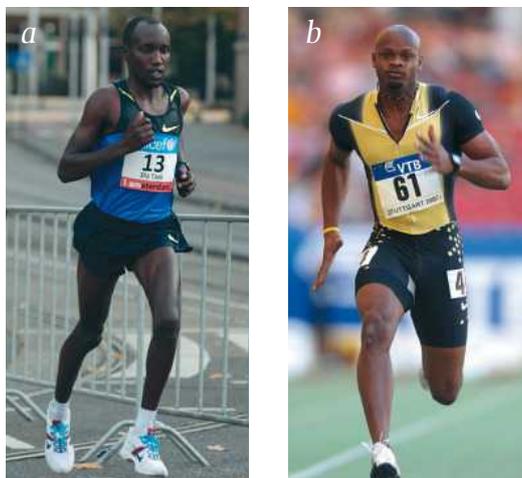


Figure 2.33: Slow-twitch muscle fibres are more prevalent in endurance runners (a), whereas sprinters have more fast-twitch fibres (b)

The structural and functional qualities of the different muscle fibres is summarised in Table 2.1.

Using muscle fibre types to determine athletic success

The composition of fibre type of muscles can be a good predictor of athletic success. The specific percentage of each fibre type can be established at birth and remains virtually unchanged during life. The composition is determined by the genetic offering of your parents. If you consider the relative endurance or speed preference of your parents, your athletic qualities are probably similar.

If we were to determine the amount of fast and slow twitch fibres in the vastus lateralis muscle (part of the quadriceps muscle group) of a marathon runner we may find 20% fast-twitch and 80% slow-twitch fibres. In the same muscle of a successful 100 m sprinter 80% could be fast-twitch fibres and 20% slow-twitch fibres.

To gain an accurate determination of fibre typing a muscle biopsy (Figure 2.34) is performed. A needle about the size of a pen is inserted in to the muscle belly and a rotating blade cuts out a small piece of muscle. The muscle is then stained and the number of Type I and Type II muscle fibres are counted (Figure 2.35). Slow-twitch fibres (Type I) generally stain dark and fast-twitch fibres (Type II) remain unstained.

Table 2.1: Qualities of different muscles fibre types

	<i>Type I fibres</i>	<i>Type IIa fibres</i>	<i>Type IIb fibres</i>
Speed of contraction	Slow	Fast – intermediate	Fast – explosive
Endurance qualities	High	Low	Very low
Predominant energy system used	Aerobic	Anaerobic	Anaerobic
Size	Small	Large	Large
Colour	Red	White	White



Figure 2.34: Muscle biopsy

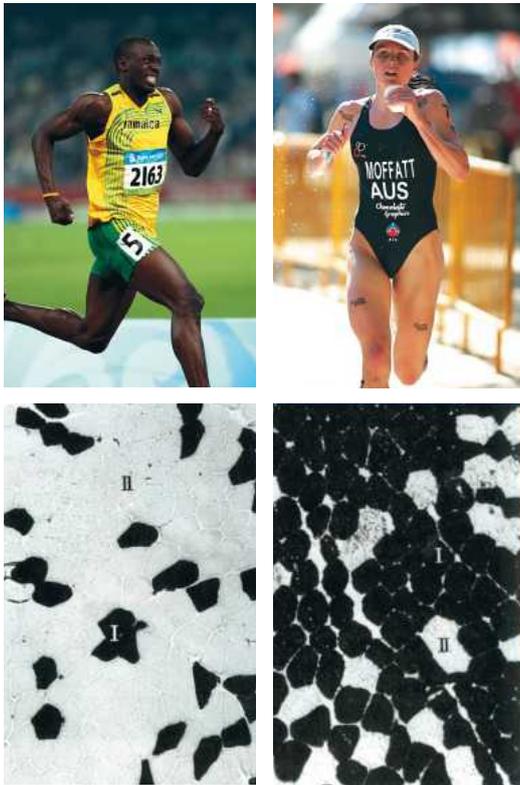


Figure 2.35: Type I and II muscle fibres. Type I fibres stain dark and type II fibres remain unstained

As this technique is very invasive, time consuming and expensive, a number of simpler activities can be used to predict muscle fibre composition. The standing broad jump or

the vertical jump (Figure 2.36) may be used to determine muscle power. Higher levels of power would indicate greater amounts of fast twitch muscle fibres in the legs.

The muscle fibres may also be known as white or red based on their visual appearance. Fast twitch fibres are typically white in colour as they have less blood supply, because they do not require oxygen to produce energy compared to the redder, slow twitch muscle fibres which have an extensive blood supply. Compare the colour of meat from a chicken to a cow. The chicken flesh is much whiter than the red steak of a cow. Chickens make many more rapid movements than the cow which maintains a consistent posture for prolonged periods. The chicken is comprised of greater amounts of fast twitch muscle fibres compared to the slow twitch muscle fibres of the cow (Figure 2.37a and b).



Figure 2.36: A vertical jump can be used to determine muscle power of the lower limbs and thus a predictor for muscle fibre typing

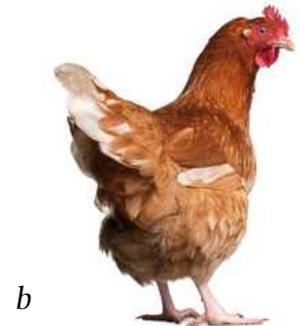


Figure 2.37: A cow (a) and chicken (b) have different fibre types distinguished by their meat colour

The muscle fibre type of each muscle in the body varies depending on its function. For example comparing the two calf muscles, the proportion of slow twitch muscle fibres is greater in the soleus muscle, whereas there are more fast-twitch muscle fibres in the gastrocnemius. The soleus is a postural muscle which is used in balance compared to the gastrocnemius which is a more powerful muscle used in jumping and running.

Practical activity: Evaluating leg muscle power and muscle fibre composition

Lie on the ground and have your partner use chalk to mark the length of your body (heels to top of your head). Stand with both feet at the mark of your heels and perform a standing broad jump towards your marked head. Measure the distance and calculate the percentage that you jumped when compared with the length of your body.

Compare your distance jumped in Table 2.2, below.

Equipment:

- Measuring tape.
- Chalk.
- Table 2.2.

Table 2.2 Ratings for the standing broad jump

Rating	Male	Female	Muscle fibre type
Very good	Height +	$\frac{3}{4}$ height +	More fast twitch
Good	$\frac{3}{4}$ height	$\frac{2}{3}$ height	More fast twitch
Average	$\frac{1}{2}$ height	$\frac{1}{2}$ height	Equal fast & slow
Low	$< \frac{1}{2}$ height	$< \frac{1}{2}$ height	More slow twitch

Key point summary:

- Muscle fibres can be classified as Type I, Type IIa or Type IIb.
- Type I are slow-twitch fibres or red fibres and are more prevalent in endurance-based athletes.
 - Type I fibres are more prevalent in postural muscles.
- Type II are fast-twitch fibres or white fibres and are important in speed and power sports.
 - Type IIa fast-twitch fibres are intermediate for speed of contraction.
 - Type IIb fast-twitch fibres are fastest for speed of contraction and linked to explosive movements.

Revision questions:

Test yourself on revision questions 21–25 located at the end of this chapter.

Appendix C (I)

Revision questions

1. Place in order, from the largest to smallest component, the following terms related to skeletal muscle structure: Muscle fibre, myofibril, muscle belly, myofibrils, fascicle.
2. Epimysium is a thin connective tissue that surrounds a...?
3. A thin connective tissue that surrounds a fascicle is called...?
4. What is the name given to the contractile component of a skeletal muscle?
 - a. Myosin
 - b. Actin
 - c. Sarcomere
 - d. Myofibril
5. What is the name given to the thin membrane that divides each individual sarcomere?
6. Which of the two myofilaments has cross-bridges?
7. Which of the two myofilaments does not attach to a Z line?
8. Using your understanding of the sliding filament theory, upon receiving a neural stimulus to contract a muscle, what happens first?
9. Using your understanding of the sliding filament theory, explain how the H zone may become smaller and might even disappear.
10. Using your understanding of the sliding filament theory, explain how the I band may become smaller or might even disappear.
11. With respect to the velocity of movement and the force that can be generated by a muscle, what is the optimum velocity to achieve maximum force?
12. If you are required to generate a muscle contraction to achieve maximum force, but in doing this action you are required to shorten the muscle, such as the quadriceps when riding a bike, at what velocity would this maximum force be achieved?
 - a. At approximately one third of maximum velocity
 - b. At maximum velocity
 - c. The exercise intensity where lactic acid cannot be removed and accumulates
 - d. At approximately 60% of maximum velocity
13. Using your understanding of the muscle force-length relationship, explain why the performance of a one-repetition maximum bicep curl (most mass that can be lifted in one single effort) is actually a reflection of one of the weakest points in the bicep curl action.
14. The deltoid is a relatively short and wide muscle, therefore is it better suited to developing force or range of motion?
15. A motor nerve has three main parts. List each of these parts with a brief description of its function.
16. A sensory nerve functions to
 - a. send impulses to the muscles.
 - b. inform the cell body of what to do.
 - c. stimulate muscle contraction.
 - d. send impulses back to the brain.
17. True or False: A motor unit that functions in the eye is likely to innervate 800–1000 muscle fibres.
18. Briefly explain the ‘all-or-none principle’ of neural stimulation.

19. Explain the two neural processes that assist us to generate a stronger muscle contraction in the one muscle group.
20. There are five specific improvements that occur with strength training. List these.
21. Slow twitch muscle fibres are also
 - a. white fibres.
 - b. type II fibres.
 - c. relatively slow to fatigue.
 - d. predominately function anaerobically.
22. Which muscle fibre is better suited to the specific function of assisting posture?
23. Identify the fibre type that is best suited to explosive actions.
24. Why are type I fibres referred to as red fibres?
25. Using your understanding of fibre types, explain how sprint athletes are born and not made.

Appendix C (II)

Revision answers

1. Muscle belly, fascicle, muscle fibre, myofibrils, myofilament.
2. Muscle belly.
3. Perimysium.
4. a. Sarcomere
5. Z line.
6. Myosin.
7. Myosin.
8. The myosin cross-bridges reach out and grab-on to the actin and begin to oscillate.
9. The H zone is the gap between the two opposing ends of the actin filaments. The H zone can disappear when the actin filaments are pulled inward and overlap each other during muscle contraction.
10. The I band is the area from a Z line to the end of the myosin filaments. The actin filaments are attached to Z lines and when the actin are pulled inward, the gap between the Z line and the end of the myosin becomes smaller. During full contraction the Z lines may butt-up against the myosin filaments.
11. An isometric contraction, where zero velocity is recorded allowing the greatest amount of cross-bridges to be engaged.
12. a. At approximately one third of maximum velocity
13. At the starting point of the bicep curl the arm is extended and the elbow is at 180° of extension. At this point, less cross-bridges are attached to the actin, unlike the position at 120° of elbow flexion. That is, the starting point of the bicep curl is a point where relatively less tension or force can be developed. If we could start in the middle phase of the curl, 120° of flexion, we could actually generate more tension and lift a heavier dumbbell.
14. Force.
15. i. Dendrite – receives signals from the CNS.
ii. Cell body – directs the activities of the neuron.
iii. Axon – transmits messages away from the cell body; either to another neuron in a chain or directly to the site where muscle activation occurs.
16. d. Send impulses back to the brain.
17. False – Because the eye requires fine motor control and movement. Each motor unit is more likely to innervate very few fibres, for example, three fibres per motor unit.
18. Once a threshold has been reached, all of the fibres associated with a motor unit will contract at the same time with maximum force.
19. i. We can generate a greater muscle tension by stimulating more motor units and therefore more fibres contract.
ii. We can generate a greater muscle tension by increasing the rate of neural impulses to the existing fibres.
20. i. Improved technique.
ii. Increased firing rate of motor units.
iii. Increased number of motor units recruited.
iv. The firing pattern of motor units is better coordinated.
v. Muscle hypertrophy – an increase

- in the number of sarcomeres leading to an increase in the cross-sectional area or bulk of the muscles.
21. c. Relatively slow to fatigue.
 22. Slow-twitch fibres (Type I) as they are relatively fatigue resistant.
 23. Fast-twitch Type IIb fibres.
 24. Because type I fibres are used for aerobic muscle function, they receive a higher supply of blood, due to higher levels of capillarisation, associated with the need for oxygen during aerobic metabolism.
 25. Elite sprint athletes have relatively high percentages or predominance of type II fibres (fast-twitch). You are born with and do not change your percentage of muscle fibre types. That is, they are determined by your genetic heritage (your parents) and do not change, even with training. Therefore the limits placed on your allocation of specific fibre types at birth, limits your ability to generate high levels of force in exceptionally short periods of time – as in sprinting.

Appendix E

Glossary of key terms

Actin: A thin protein myofilament that attaches to a Z line.

All-or-none principle: When a motor unit is stimulated, all of the muscle fibres associated with that unit will contract to their maximum level and all at the same time.

Axon: Long part of the nerve extending from the nerve body where information is transmitted to target cells.

Cell body: Directs the activities of the neuron.

Dendrite: The antennae like structure of a nerve which receives information from other nerve cells.

Epimysium: Connective tissue surrounding each muscle.

Fascicle: A bundle of muscle fibres.

Fast-twitch muscle fibres (Type II fibres): Muscle fibres with anaerobic characteristics (that is, they are well-suited to producing ATP via anaerobic pathways).

Motor unit: A neuron and the muscle fibres that it activates.

Muscle fibre: Forms part of the fascicles and are comprised of myofibrils.

Myofibril: Comprised of actin and myosin, the level of muscle contraction.

Myosin: A thick protein myofilament that has cross-bridges.

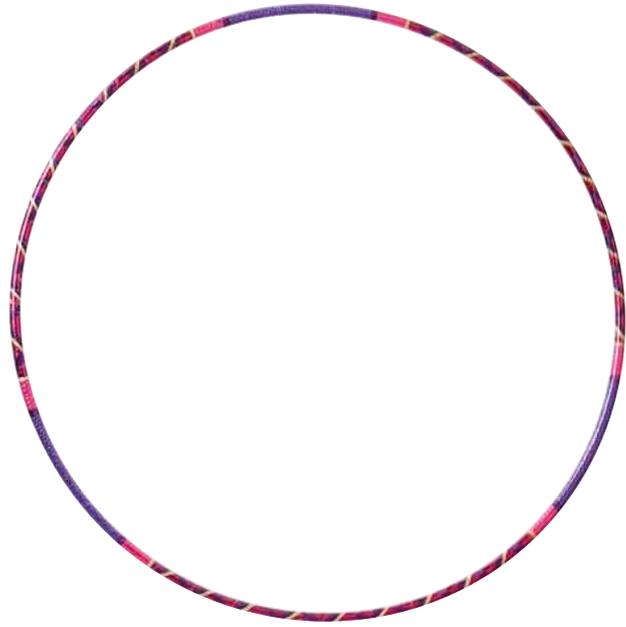
Neural chain: A series of motor neurons or nerves that are linked together.

Perimysium: The connective tissue that surround the fascicles.

Sarcomere: The contractile component of a muscle fibre. It is comprised of actin and myosin.

Sensory neuron: Nerve that sends impulses back from receptors to the brain.

Slow-twitch muscle fibres (Type I fibres): Muscle fibres with aerobic characteristics (that is, they rely predominantly on the aerobic energy system to produce ATP for contraction).



Exercise Physiology

Dr Kym Guelfi (Senior Lecturer), Dr Peter Whipp (Associate Professor)
and Dr Peter Peeling (Senior Lecturer)

BACKGROUND INFORMATION

The following dot-points provide a revision of the key concepts from Units 1 and 2.

Energy for physical activity

- ATP is the basic unit of energy that fuels all of the activities that we participate in throughout the day.
- Energy is released from ATP when the high-energy bond linking the outermost phosphate group to the rest of the molecule is broken to liberate ADP and Pi.
- A limited amount of ATP is stored in the body.
- ATP must be continuously replenished so that our stores never run out. This is achieved by rejoining ADP and Pi using chemical energy derived from the food we eat.
- The food (and drink) we consume provides energy for the repletion of ATP stores in the body.
- The food (and drink) we consume contains three macronutrients: carbohydrate, fat and protein.

- The amount of each macronutrient required in the diet varies, depending on the physical activity level of the individual.

Energy systems

- There are three ways in which ATP can be replenished:
 - ATP-CP system.
 - Lactic acid system (anaerobic glycolysis).
 - Aerobic system (requires oxygen).

Energy systems: ATP-CP system

- The ATP-CP system replenishes ATP using energy from the breakdown of creatine phosphate (CP) to creatine and Pi.
- The ATP-CP system does not use oxygen (an anaerobic pathway).
- The ATP-CP system allows for the most immediate replenishment of ATP.

- We only store enough CP to power about eight seconds of intense activity.
- CP stores are replenished during recovery from exercise when adequate oxygen becomes available.

Energy systems: Lactic acid system

- The lactic acid system (anaerobic glycolysis) involves the partial breakdown of carbohydrate to lactic acid, which releases energy to make ATP.
- The lactic acid system does not require oxygen (an anaerobic pathway).
- The lactic acid system is the dominant source of ATP production during high-intensity activities lasting thirty to sixty seconds.
- Lactic acid accumulates in the muscle when exercising at an intensity level higher than the lactate threshold, eventually resulting in fatigue.
- Lactic acid is removed during recovery from exercise as adequate oxygen becomes available.

Energy systems: Aerobic system

- The production of ATP via the aerobic energy system requires the presence of oxygen.
- Both carbohydrate and fat can be used as fuels in the aerobic energy system.
- The specific series of chemical reactions involved in the breakdown of fat and carbohydrate via the aerobic energy system differ.

- Aerobic metabolism of carbohydrate produces ATP at a faster rate than fat.
- The aerobic system is capable of producing the largest amount of ATP.
- The aerobic system is the dominant source of ATP production at rest and during moderate intensity or prolonged exercise.

Energy systems: Comparing the systems

- The ATP-CP system provides the most rapid source of ATP, but is limited in the amount of ATP that can be produced.
- The lactic acid system (anaerobic glycolysis) also provides a rapid source of ATP production, but is not as fast as the ATP-CP system.
- The lactic acid system (anaerobic glycolysis) can provide a larger amount of ATP than the ATP-CP system, but is ultimately limited by the production of lactic acid.
- The aerobic system can supply an unlimited total amount of ATP, but the rate of production is relatively slow.
- At rest, aerobic metabolism of fat is the predominant energy source for ATP synthesis.
- The three energy systems all operate at once, with the intensity and duration of the activity determining the percentage contribution of each different system.

- When commencing exercise, it takes time for oxygen consumption to increase, resulting in an oxygen deficit that must be repaid post-exercise.

- Oxygen consumption may remain elevated for hours after exercise.

The immediate responses to exercise

- The body responds to the commencement of exercise by increasing all the processes involved in transporting oxygen to the working muscle.
- These include:
 - Increased minute ventilation as a result of an increase in both the tidal volume and the number of breaths per minute.
 - Increased cardiac output due to an increase in both heart rate and stroke volume.
 - Increased oxygen exchange at the tissues ($a-vO_2$ diff).
- Systolic blood pressure increases in direct proportion to exercise intensity, while diastolic blood pressure remains relatively stable.
- Blood is rapidly redistributed to the working muscles with the onset of exercise.
- Oxygen consumption ($\dot{V}O_2$) increases in direct proportion to exercise intensity, until a maximum is reached.
- The lactate threshold is the exercise intensity at which lactic acid begins to accumulate in the blood.

The long-term adaptations to training

- Regular exercise training results in cardiorespiratory adaptations that improve exercise performance including:
 - More efficient respiration.
 - Higher maximal minute ventilation as a result of increased breathing frequency and maximal tidal volume.
 - Increased oxygen exchange at the lungs.
 - Increased maximal cardiac output due to greater maximal stroke volume.
 - Increased total blood volume and haemoglobin (to a lesser extent).
 - Improved oxygen exchange at the tissues ($a-vO_2$ diff) due to increased capillarisation.
 - Quicker attainment of steady state oxygen consumption (and therefore a smaller oxygen deficit).
 - Increased maximal oxygen consumption ($\dot{V}O_{2\text{ max}}$).
- Regular exercise training results in muscular adaptations that improve exercise performance including:
 - Hypertrophy of selective muscle fibres (type I or II depending on the type of training).

- Regular exercise training results in metabolic adaptations that improve exercise performance including:
 - Increased fuel storage within the muscle.
 - Increased number and size of mitochondria for the aerobic energy system.
 - Increased levels of the enzymes involved in the production of ATP.

The components of fitness

- The health-related components of fitness include cardiorespiratory fitness, muscular fitness and body composition.
- Cardiorespiratory endurance (or aerobic fitness) relates to the ability of the respiratory and circulatory systems to supply oxygen to the working muscle during exercise.
- Muscular fitness relates to optimising the strength, endurance and flexibility characteristics of our muscles.
- Body composition relates to the proportion of fat and lean muscle mass in the body.
- The performance or skill-related components of fitness include agility, balance, coordination, reaction time, speed and power.
- Different sports (and positions within a given sport) have differing demands on each component of fitness.

The principles of training

- The way in which the body responds to exercise training depends on the type of training undertaken (specificity of training).
- Progressive overload must be applied to achieve training adaptations.
- Progressive overload can be applied by increasing the intensity, duration or frequency of exercise.
- Adaptations to training are not permanent and can be lost with detraining (principle of reversibility).

Training methods

- Continuous training involves exercising in a continuous fashion for a prolonged period of time.
- Cross-training involves an alternative mode of exercise to the one that an athlete is training for.
- Fartlek training is a method of continuous training involving variations in pace between periods of harder work and periods of easier work for relief.
- Interval training involves repeated bouts of work, alternated with periods of recovery. Intervals can be aerobic or anaerobic in nature.
- Resistance training stimulates the body to adapt to coping with heavier loads.
- By changing the load (%1RM), number of sets, repetitions and the speed of motion, we can change the focus from enhancing muscular strength, power or endurance.

- Flexibility may be improved using static stretching, ballistic stretching or PNF stretching.
- Plyometrics is a form of resistance training that uses the weight of the body to apply resistance in dynamic activities such as jumping.

Exercise Physiology: ATAR Units 3 and 4

A similar approach is followed for each section of the ATAR Units 3 and 4 curriculum. Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the ‘Content that follows’ and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A ‘Key point summary’ box is presented at the end of each section.

Two practical investigations are included as Appendix B1 (Unit 3 content: Evaluate the implications of preparing for and performing exercise in hot/humid conditions) and Appendix B2 (Unit 4 content: Evaluate the impact of post-exercise recovery strategies). A format for report writing can be located at the end of this chapter (Appendix A) to assist students with their preparation of a practical investigation. Marking matrices are also included in Appendices B1 and B2. Answers are provided for teachers only.

Revision questions (with answers) are included near the end of this chapter as Appendix C. Following the revision questions is a ‘Personalised project’, which requires students to apply knowledge and understanding from ‘Biomechanics, Functional Anatomy and Exercise Physiology’

(Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision. A ‘Glossary of key terms’ appears on the final pages of this chapter (Appendix E).

Introduction

Having studied the body’s immediate responses to exercise and long-term adaptations to regular exercise training in Units 1 and 2, the current Units 3 and 4 chapters explore ways in which athletic performance can be further enhanced with appropriate nutritional strategies, ergogenic aids, and purposeful manipulation of the training program. More specifically, this chapter explores:

- the specific nutritional requirements during a range of physical activities
- the implications for preparing and performing in different environmental conditions
- a range of specific performance enhancers (namely protein powders, anabolic steroids and stimulants)
- a range of real-life training programs to assist the reader to consolidate course knowledge and application to sport-specific energy system requirements and training principles.

Nutritional Considerations for Exercise

Text outcomes: *Nutritional physiology (Unit 3)*

- *Describe the relationship between energy demands and nutritional requirements during physical activity.*

Content that follows: Nutritional considerations (Unit 3)

- *Balanced diet*
- *Carbohydrate (including Glycaemic index)*
- *Fat*
- *Protein*
- *Fluid replacement*

- limit intake of food and drinks containing added sugars (e.g. soft drinks, lollies).
- limit alcohol intake. (Dietary Guidelines for Australian Adults 2013)

These guidelines are summarised in Figure 3.1 (The Australian Guide to Healthy Eating). This represents the types and proportions of different foods we should aim to consume each day for good health and well-being.

Balanced diet

A **balanced diet** is important not only for everyday health, but also for optimal athletic performance. A good pre-event meal alone will not be much help if daily nutrition is poor. It is also important to note that just because an athlete is fit, they may not necessarily be ‘healthy’. A balanced diet includes healthy amounts and proportions of the three macronutrients – **carbohydrate**, **fat** (lipid) and **protein** – as well as a variety of **minerals** and **vitamins**. To obtain a healthy balance of these nutrients, a wide variety of nutritious foods should be consumed every day including:

- vegetables, legumes and fruits
- cereals (including breads, rice, pasta and noodles), preferably wholegrain
- lean meat, fish, poultry and/or alternatives
- milks, yoghurts, cheeses and/or alternatives (reduced fat varieties where possible).

In addition, a balanced diet includes drinking plenty of water, while taking care to:

- limit intake of foods high in saturated fat (e.g. cakes, biscuits, fried foods)
- limit intake of foods containing added salt

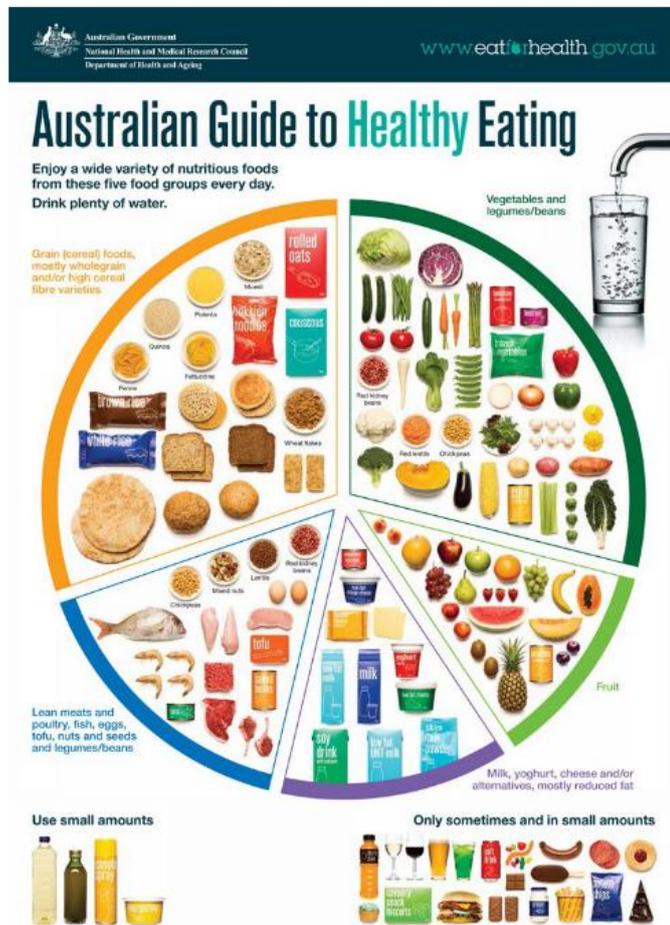


Figure 3.1: The Australian Guide to Healthy Eating

Key point summary:

- A balanced diet includes carbohydrate, fat and protein as well as a wide variety of minerals and vitamins.

Carbohydrate

Carbohydrate accounts for approximately 55% of overall energy intake in a typical Australian diet. The carbohydrate that we eat can be broadly divided into two main categories. First, we have the **simple sugars**, which are small molecules and are found in foods such as honey, table sugar and fruit juice. The **complex carbohydrates** are larger molecules found mainly in plant-derived foods, such as potatoes, bread, cereal, rice and pasta (Figure 3.2).

The role of carbohydrate in the diet

Regardless of the type of carbohydrate eaten, they are all digested to their simplest unit, which is a single small molecule called **glucose**. Once in the form of glucose, the carbohydrates from our diet have two main fates. First, some of the glucose obtained from the digestion of carbohydrate is released into the bloodstream to circulate around, providing fuel for the brain or remaining a readily available source of energy for adenosine

triphosphate (ATP) repletion when the body might need to spring into action. However, the speed at which glucose is released into the bloodstream after eating carbohydrates varies. This characteristic is termed the **glycaemic index** (GI). Carbohydrates that result in a rapid release of glucose into the bloodstream after eating are referred to as high GI foods. In contrast, ingested carbohydrates that result in a slow, sustained release of glucose into the bloodstream are termed low GI foods (Figure 3.3). Examples of both high and low GI foods are shown in Table 3.1.



Figure 3.2: Common sources of carbohydrate in the diet

Table 3.1: Examples of high and low glycaemic Index foods

	Food	Glycaemic Index
High Glycaemic Index Foods (GI > 70)	Watermelon	72
	Jellybeans	76
	Coco Pops™ cereal	77
	Honey	87
Low Glycaemic Index Foods (GI < 55)	Banana	50
	Apples	40
	Egg Pasta	46
	All-Bran™ cereal	30

The second possible fate of glucose obtained from the digestion of dietary carbohydrate is conversion into the storage form of carbohydrate in the body, called **glycogen**. Glycogen results from the combination of many glucose molecules together to form one larger molecule. The resulting glycogen is stored in two main locations of the body: a small amount is stored directly in the muscle to be available in times of rapid demand, but the majority

of glycogen is stored in the liver. Of note, the amount of glycogen that can be stored in the body is limited (a maximum of 600–800 g after a high carbohydrate diet). Therefore, the amount of energy that can be provided from this macronutrient is restricted to some extent. Because carbohydrate is such an important fuel for physical activity, the carbohydrate intake of an endurance athlete may account for up to 70% of total energy intake (Figure 3.4).

Key point summary:

- Carbohydrate accounts for approximately 55% of total energy intake.
- Carbohydrates include simple sugars (such as honey, table sugar and fruit juice) and complex carbohydrates (such as potatoes, bread, cereal, rice and pasta).
- Carbohydrates are digested to a single small molecule called glucose.
- Glucose obtained from dietary carbohydrate is either:
 - released into the bloodstream for circulation
 - converted into glycogen and stored in the muscle and in the liver.
- The glycaemic index (GI) is a measure of the speed at which glucose is released into the bloodstream after eating carbohydrates.
- High GI foods result in a rapid release of glucose into the bloodstream.
- Low GI foods result in a slow, sustained release of glucose into the bloodstream.
- The amount of glycogen that can be stored in the body is limited to 600–800 g.
- The carbohydrate intake of an endurance athlete may account for up to 70% of total energy intake.

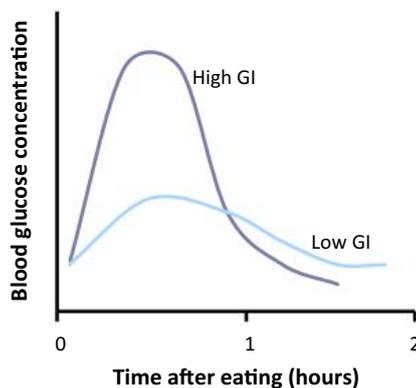


Figure 3.3: The release of glucose into the bloodstream following the ingestion of carbohydrate with a high or low glycaemic index

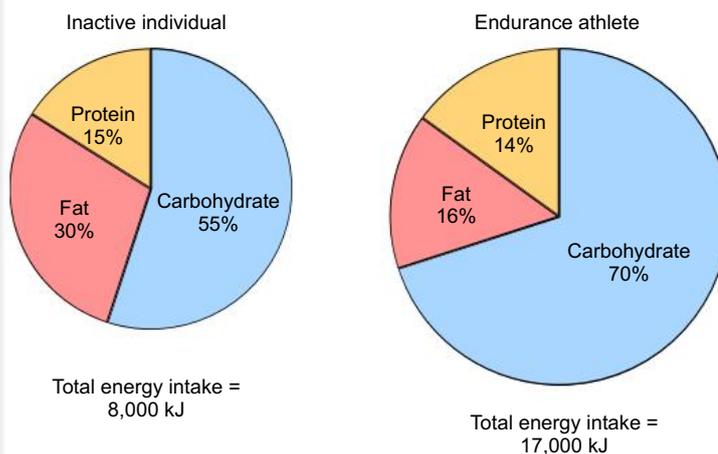


Figure 3.4: Endurance athletes consume a greater amount of total energy, as well as an increased proportion of carbohydrate compared with inactive individuals

Fat

Fats (or lipids) represent approximately 30% of the dietary intake of most individuals. It is recommended that dietary fat intake does not exceed this amount since excess fat consumption is associated with being overweight, as well as diseases of the heart and blood vessels. In the same way that all of the carbohydrate that we eat is digested to the simple glucose molecule, the fats we consume are broken down in the digestive system to **free fatty acids**. Broadly, there are two main types of fatty acids depending on their chemical structure: **saturated** and **unsaturated fatty acids**. High levels of saturated fat in the diet can increase the risk of heart disease. Foods that are high in saturated fatty acids include most dairy products, such as full cream milk, cheese and fatty meats. In contrast, avocados, fish, nuts and olive oil are examples of foods high in unsaturated fatty acids. These are often considered ‘healthy’ fats since they reduce the risk of heart disease when consumed in moderation (Figure 3.5).

The role of fat in the diet

Once dietary fats have been digested to free fatty acids, some will be released into the bloodstream to circulate around, while others will be stored as **triglycerides** (a molecule resulting from the combination of three fatty acids) in adipose (fat) tissue. Unlike carbohydrate, fat stored as triglycerides in the body provides a plentiful source of energy. In fact, the amount of fat we store in the body could provide us with enough energy to survive for weeks without food.

Key point summary:

- Fat accounts for approximately 30% of total energy intake.
- The fats we consume are broken down in the digestive system to free fatty acids.
- Saturated fatty acids (found in full cream milk, cheese and fatty meats) are considered unhealthy, while unsaturated fatty acids (avocados, fish, nuts and olive oil) can be beneficial for health if consumed in moderation.
- Free fatty acids obtained from dietary fat are either:
 - released into the bloodstream for circulation
 - stored as triglycerides (a molecule resulting from the combination of three fatty acids) in adipose (fat) tissue.
- Fat stored as triglycerides in the body provides a plentiful source of energy.



Figure 3.5: Common sources of fat in the diet

Protein

Protein is consumed in the diet from a variety of sources, including eggs, meat and fish (Figure 3.6). The recommended amount of protein is approximately 15% of dietary intake, or 0.8 g per kilogram of body mass for most active men and women. Therefore, a 70 kg man would require about 56 g of protein each day. This is equivalent to the amount of protein contained in a large piece of steak. However, strength and endurance athletes

may need up to 1.6 g per kilogram of body mass, and a body builder may consume up to 30% of their overall energy intake from protein sources. Despite the higher protein demands of some individuals, it is generally possible to consume adequate amounts from natural food sources, without the need for special supplementation from protein powders or bars.

The role of protein in the diet

Like both carbohydrate and fat, protein consumed in the diet is digested into its simplest unit called the ***amino acid***. Once in this form, amino acids can be broken down to provide energy for ATP repletion; however, this contribution is minor compared to that of carbohydrate and fat. Instead, the primary role of ingested protein is to maintain the body's structures. In particular, protein plays a vital role in the growth and repair of muscle tissue.

Key point summary:

- A protein intake of approximately 15% of total energy, or 0.8 g per kilogram of body mass is adequate for most active men and women.
- Strength and endurance athletes may require a protein intake of up to 1.6 g per kilogram of body mass.
- Protein consumed in the diet is digested into amino acids.
- The primary role of protein is to maintain the body's structures, growth and repair of muscle tissue.



Figure 3.6:
Common sources of protein in the diet

Revision questions:

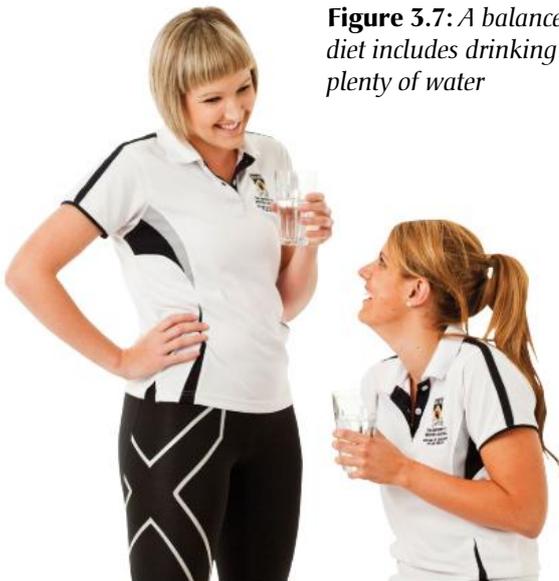
Test yourself on revision questions 1–8 located at the end of this chapter.

Fluid intake

A balanced diet includes drinking plenty of water to ensure optimal health and performance (Figure 3.7). This is because water is a vital component of the body and we lose approximately 2 L of fluid from the body each day. In fact, our body consists of 60–70% water. This is not surprising when you consider that blood is mostly water, and that our vital organs including the lungs, brain and muscles contain a lot of water. In addition, all of the chemical reactions that go on inside the body, including the production of ATP, occur in a watery environment. The importance of water to the body is further demonstrated by the fact that if we were stranded on a deserted island, we could survive for weeks without food, but only for days without water.

Each day we lose water from the body via natural processes such as breathing, going to the toilet and sweating. To replace these losses, it is generally recommended to consume approximately 2 L of water per day, although the exact amount needed will vary between individuals. For this reason, a good guide may be to drink to match thirst and ensure that your urine is a pale yellow colour (rather than dark and concentrated). Daily water requirements are greater for those individuals living in a tropical (humid) or hot environment since more fluid is lost from the body via sweat under these conditions. In addition, fluid requirements are greatly increased for athletes involved in strenuous training or competition. Although water can be obtained from a variety of drinks such as tea, coffee, soft drinks and cordial, the best drink to make up for the majority of fluid lost throughout the day is plain water. However, the recommendations for fluid intake during and after exercise are different, and this will be discussed in further detail later in this chapter.

Figure 3.7: *A balanced diet includes drinking plenty of water*



Key point summary:

- The body loses about 2 L of fluid per day from general living.
- Plain water is adequate to replace fluid lost due to normal daily activities.
- Daily fluid requirements are impacted by exercise and the environmental conditions.

Revision questions:

Test yourself on revision questions 9 and 10 located at the end of this chapter.

Nutritional requirements for physical activity

It is typically recommended that the general population should obtain approximately 55% of energy intake from carbohydrates, less than 30% from fat, and around 15% from protein. However, the optimal nutrition for an athlete may vary depending on their chosen sport. As previously mentioned, individuals involved in vigorous endurance training may require a carbohydrate intake of up to 70% of daily energy consumption. Alternatively, body builders may consume up to 30% of energy from protein sources.

In addition to variations in the proportions of each macronutrient in the diet, the total amount of energy (kilojoules; kJ) consumed varies considerably between athletes. While a sedentary person may consume 6000 kJ per day, an endurance athlete may ingest 15,000–25,000 kJ per day. Likewise, a female gymnast

may consume approximately 7000 kJ each day (Jonnalagadda et al., 1998), while an AFL player will consume almost double this amount (~13,250 kJ; Schokman et al., 1999). Even more astonishing is the fact that Tour de France riders may consume up to 37,000 kJ per day during the mountain stages of the race. This amount of energy (kJ) is the equivalent of eating 6 full loaves of bread (or about 120 slices) in one day (Figure 3.8).



Figure 3.8: Daily energy (kJ) intake of a Tour de France rider

Key point summary:

- The optimal percentage of carbohydrate, fat and protein in the diet is dependent upon the specific sport of interest.
- The total amount of energy (kJ) consumed is highly variable depending upon the specific sport of interest.

Revision questions:

Test yourself on revision question 11 located at the end of this chapter.

Nutritional Considerations by Phase of Activity

As mentioned previously, a balanced diet is important for both everyday health and elite performance. In addition, the specific foods and drinks consumed before, during and after competition can influence athletic performance. The following discussion outlines nutritional strategies for each phase of activity (pre-competition, during exercise and post-exercise recovery) to optimise athletic performance.

Content that follows: *Phases of activity (Unit 3)*

- *Pre-competition nutrition*
- *Nutrition during exercise*
- *Recovery and post-exercise nutrition*

Pre-competition nutrition

The primary goal of the pre-competition meal should be to ensure that there is enough carbohydrate and fluid stores for the commencement of exercise. This is particularly important before prolonged endurance activities in which performance may be limited by the depletion of carbohydrate stores, or when exercising in a hot or humid environment.

Carbohydrate loading

Carbohydrate loading (or glycogen loading) is a routinely used method to improve endurance performance by enhancing the amount of carbohydrate stored in the muscle. It involves consuming high amounts of dietary carbohydrate in the days leading up to competition, in combination with reduced training load. The reduction in training load prior to competition is called a *taper*. The result of increased carbohydrate intake and reduced training load is higher than normal (almost double) levels of glycogen stored in the muscle ready for use on the day of competition. This is important given that depletion of carbohydrate stores during exercise is a limiting factor for endurance performance. As we know from Units 1 and 2, the aerobic breakdown of carbohydrate supplies ATP at a much faster rate than the aerobic metabolism of fat. Therefore, carbohydrate provides the majority of ATP when exercising at a high intensity. By carbohydrate loading, an athlete will be able to work for longer at a higher intensity before the limited carbohydrate stores become depleted (Figure 3.9). However, it is important to note that this will only be of benefit for events longer than one hour in duration such as a marathon or Olympic distance triathlon. For team sports, carbohydrate loading may be useful in situations where games extend beyond one hour. However, it is often difficult for these athletes to carbohydrate load effectively anyway since they cannot properly ‘taper’ within the context of a weekly training schedule. In sprint or power events, carbohydrate loading may in fact be detrimental to performance. This is because water is stored along with glycogen, meaning pre-competition weight gain of about 2 kg

is not uncommon following a period of carbohydrate loading.

There are a number of specific protocols available to ‘load’ the body with carbohydrate. Typically athletes will decrease their overall volume of training in the week leading up to competition, while increasing carbohydrate intake in the final three days of this period to 10–12 g per kilogram of body mass, accounting for up to 70% of total energy intake. An alternative, more rapid method of carbohydrate loading has been developed in the School of Sport Science, Exercise and Health at The University of Western Australia. This method involves just one short bout (3 min) of very high-intensity exercise followed by one day of high glycaemic carbohydrate intake (~10 g/kg). The result is an almost doubling of muscle

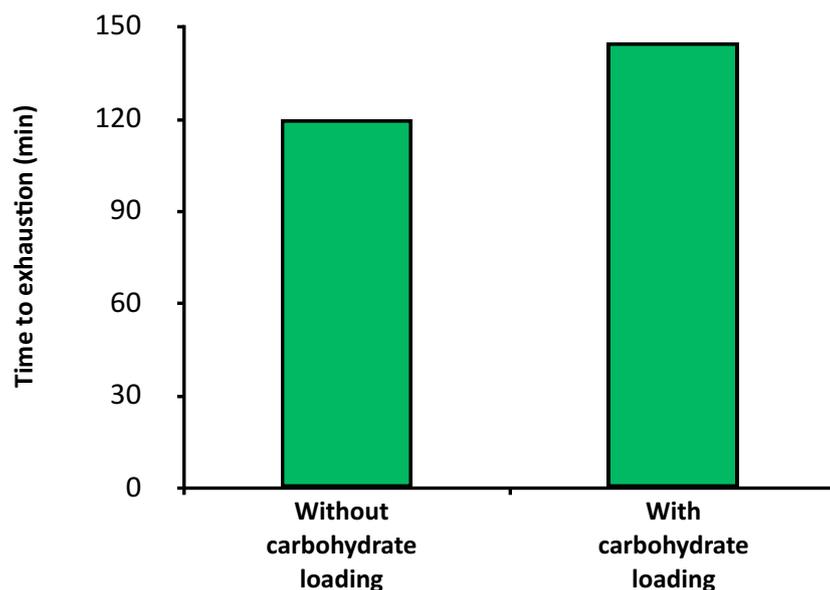


Figure 3.9: Time to exhaustion with and without carbohydrate loading

Table 3.2: Sample carbohydrate loading diet for a 70 kg man

Meal	Food	Carbohydrate (g)
Breakfast	8 weetbix with low-fat milk and honey	118 g
	2 slices of toast with strawberry jam	40 g
	1 banana	27 g
	2 cups of orange juice	60 g
Lunch	2 rounds of sandwiches with choice of filling	80 g
	1 muffin with honey	60 g
	1 apple	25 g
	1 Sports drink	35 g
Dinner	Large serving of spaghetti bolognese (3 cups of pasta)	150 g
	3 slices of garlic bread	35 g
	1 can of lemonade	38 g
	1 serve of vanilla ice cream	30 g
Snacks	1 x muesli bar	23 g
	1 x tub yoghurt	30 g
	1 x glass of cordial	20 g
	TOTAL	770 g (11 g/kg)

carbohydrate stores within 24 hours (Fairchild et al., 2002).

Although carbohydrate loading may not sound like a complicated procedure, it is actually quite difficult to eat 10–12 g per kilogram of body mass of carbohydrate. To demonstrate this point, the average 70 kg person would aim to consume 840 g of carbohydrate per day during the loading phase (70 kg x 12 g carbohydrate). This would equate to eating more than 3 loaves of white bread each day! For this reason, ‘compact’ sources of carbohydrate may be better than eating ‘bulky’ foods like bread, pasta and potatoes alone. Some commercially available carbohydrate drinks and supplements have been designed for this purpose. Table 3.2 represents a typical diet

for one day of carbohydrate loading for a 70 kg person.

Carbohydrate Loading:

Is a potential advantage because it:

- leads to higher than normal (almost double) levels of glycogen stored in the muscle
- allows endurance athletes to work for longer at a higher intensity.

Is a potential disadvantage because it:

- increases pre-competition weight.

The pre-competition meal

We know from Units 1 and 2 that performance in endurance activities greater than one hour in duration, such as an Olympic distance triathlon (approximately two hours) or a cycling road race (approximately 4–6 hours), may be limited by the depletion of carbohydrate stores. This is because we can only store a limited amount of carbohydrate in the body, and as these stores start to become low during prolonged exercise, the body must rely more on fat for the aerobic production of ATP. However, the rate of producing ATP from fat is slower than carbohydrate, resulting in a decline in performance. For this reason, the pre-competition meal is vital for ensuring adequate carbohydrate stores prior to the start of exercise. This is especially important for early morning competitions, since the body's carbohydrate stores are somewhat depleted overnight while sleeping. Based on this, the pre-competition meal should consist mainly of carbohydrate to replenish the body's stores. Meals that are high in fat and protein are not recommended since they take longer to digest and will not be the main source of energy during exercise.

Examples of high carbohydrate, low-fat pre-event meals include cereal with low-fat milk and fruit, crumpets with jam/honey, or pasta with a tomato-based sauce. This sort of meal involving solid foods should be consumed 3–4 hours prior to competition. However, the size of the meal may vary depending on the sport. For example, a cyclist may tolerate a larger meal better than a runner since cycling involves less physical disruption (bouncing around) of the

gastrointestinal tract. For some individuals, a liquid meal may be preferred to a solid meal, especially if pre-competition nerves cause gastrointestinal upset or the athlete is prone to runner's diarrhoea. Liquid meal supplements are available for this purpose (for example, Sustagen Sport: Figure 3.10), or a home-made fruit smoothie offers a similar alternative.

NUTRITION INFORMATION				
SERVINGS PER PACKAGE: 1 SERVING SIZE: 60g				
	AVE QUANTITY PER SERVING	%RDI*	AVE QUANTITY PER 100g	AVE QUANTITY PER SERVE WITH 165ml RED FAT MILK
ENERGY kJ (Cal)	940(225)	10.8%	1570(375)	1270(304)
PROTEIN	14.7g	29.4%	24.5g	20.9g
FAT TOTAL	Less than 1g	0.5%	1.1g	2.6g
-SATURATED	Less than 1g	0.9%	Less than 1g	1.7g
CARBOHYDRATE	39.2g	12.6%	65.3g	48.2g
-SUGARS	34.4g	38.2%	57.3g	42.9g
SODIUM	150mg	6.5%	250mg	226mg
VITAMIN A	187µg	25%	312µg	210µg
VITAMIN D	1.25µg	12.5%	2.1µg	2.5µg
VITAMIN E	4.0µg	40%	6.67µg	4.04µg
VITAMIN C	16.0mg	40%	26.7mg	17.7mg
THIAMINE	385µg	35%	642µg	417µg
RIBOFLAVIN	595µg	35%	992µg	915µg
NIACIN	3.54mg	35%	9.75mg	7.0mg
VITAMIN B6	400µg	25%	667µg	500µg
VITAMIN B12	0.7µg	35%	1.17µg	1.34µg
FOLIC ACID	70.2µg	35%	117µg	79.8µg
CALCIUM	400mg	50%	667mg	620mg
PHOSPHORUS	445mg	44.5%	741mg	619mg
IRON	6.0mg	50%	10.0mg	6.0mg
MAGNESIUM	80.4mg	25%	134mg	101mg
ZINC	3.0mg	25%	5.0mg	3.66mg
IODINE	37.5µg	25%	62.5µg	48.7µg
POTASSIUM	741mg		1235mg	1020mg
GLUTEN	0mg		0mg	0mg

PERCENTAGE DAILY INTAKES ARE BASED ON AN AVERAGE ADULT DIET OF 8700kJ.
YOUR DAILY INTAKES MAY BE HIGHER OR LOWER DEPENDING ON YOUR ENERGY NEEDS.

FORMULATED SUPPLEMENTARY SPORTS FOOD. CAN ASSIST WHERE DIETARY INTAKES OF NUTRIENTS AND ENERGY MAY NOT BE ADEQUATE. THE FOOD IS NOT A SOLE SOURCE OF NUTRITION AND SHOULD BE CONSUMED IN CONJUNCTION WITH A NUTRITIOUS DIET. THE FOOD SHOULD BE USED IN CONJUNCTION WITH AN APPROPRIATE PHYSICAL TRAINING OR EXERCISE PROGRAM. NOT SUITABLE FOR CHILDREN UNDER 15 YEARS OF AGE OR PREGNANT WOMEN: SHOULD ONLY BE USED UNDER MEDICAL OR DIETETIC SUPERVISION. RECOMMENDED CONSUMPTION 2 SERVES DAILY.



Figure 3.10: A liquid pre-event meal

The pre-competition snack

In addition to a high-carbohydrate, low-fat meal ingested 3–4 hours before competition, it may be beneficial for the endurance athlete to consume another small **carbohydrate snack** in the 30–60 minutes prior to the event to ‘top up’ carbohydrate stores. The type of carbohydrate consumed at this time should be low or medium GI (for example, fruit like strawberries, apples and oranges). The reason for this is that high GI carbohydrates (like jelly beans) result in a rapid release of glucose into the bloodstream. This causes a sudden rise in a hormone called insulin, which acts to reduce blood glucose levels back to normal. Starting exercise when insulin levels are high may cause a large drop in blood glucose levels (below normal levels) which may be negative for performance. This phenomenon is often referred to as **rebound hypoglycaemia** (Figure 3.11). While some recent research suggests that the ingestion of a high GI carbohydrate snack prior to exercise probably doesn’t have a huge effect on performance, it is still recommended to avoid high GI carbohydrate snacks in the period immediately prior to your event just in case. Also, a liquid form of carbohydrate (for example, fruit juice or a sports drink) may be better tolerated than a solid snack at this time, especially if the stomach is upset by pre-competition nerves. However, it is important to remember that this extra carbohydrate will only be helpful for events in which the depletion of carbohydrate stores may limit performance. Taking on extra carbohydrate prior to an event that relies predominantly on the ATP-CP system such as the long jump or a 50 m freestyle race will give no added benefit.

Pre-competition fluid intake

Another important aspect of pre-competition

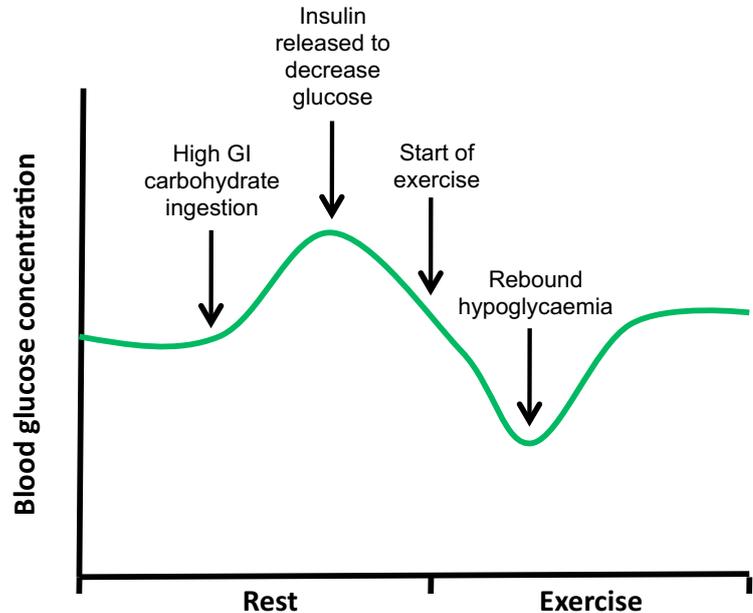


Figure 3.11: *Rebound hypoglycaemia*

nutrition is ensuring adequate fluid intake. Optimising body fluid levels before exercise can reduce the risk of dehydration. Pre-exercise water intake will vary considerably between individuals, so it is difficult to give a standardised recommendation. As mentioned previously, a good guide may be to drink to match thirst and ensure that your urine is a pale yellow colour (rather than dark and concentrated). As a rough guideline, athletes may consume 350–500 mL at least four hours prior to competition to allow time to optimise hydration status and excrete excess fluid as urine (Sawka et al., 2007). If the urine produced is dark and concentrated in colour, or no urine is produced at all, the athlete should drink another 200–350 mL two hours prior to the event. This allows time for urine production to return to normal before the race or competition.

More fluid may be required for performance in hot and/or humid environmental conditions. However, this must be balanced with the risk of needing to go to the toilet during exercise. Furthermore, pre-event hyperhydration may be detrimental to performance in certain sprint and power events. For example, a high jumper does not want to have excess fluid gushing around the stomach while taking the run-up approach to the bar.



Figure 3.12: Pre-competition hydration is crucial to performance

Key point summary:

- The pre-competition meal should focus on providing adequate carbohydrate and fluid for the commencement of exercise.
- Pre-competition carbohydrate consumption is particularly important for endurance events lasting more than one hour in duration.
- The pre-competition meal should be:
 - high in carbohydrate (low in fat and protein)
 - consumed 3–4 hours prior to the event.
- A pre-competition snack (low–medium GI carbohydrate) ingested 30–60 min prior to exercise will ‘top up’ carbohydrate stores.
- Pre-competition fluid intake is important to ensure adequate hydration prior to the commencement of exercise.

Nutrition during exercise

Carbohydrate intake during exercise

The goal of nutritional strategies during exercise should be to minimise the depletion of carbohydrate stores and to replace fluid lost via sweat. As we know, performance in events lasting longer than 1 hour in duration (such as an Olympic distance triathlon, cycling road race, marathon or many team sport games) may be affected by carbohydrate

depletion. Therefore, carbohydrate feeding during exercise will assist in maintaining high intensity endurance performance for longer (Figure 3.13) by keeping blood glucose levels up (an alternative fuel source), which in turn will spare some muscle glycogen. Under these conditions, the athlete should aim to consume 30–60 g of carbohydrate for each hour of activity. Overconsumption will not enhance performance further, but likely lead to discomfort and cramping in the stomach.

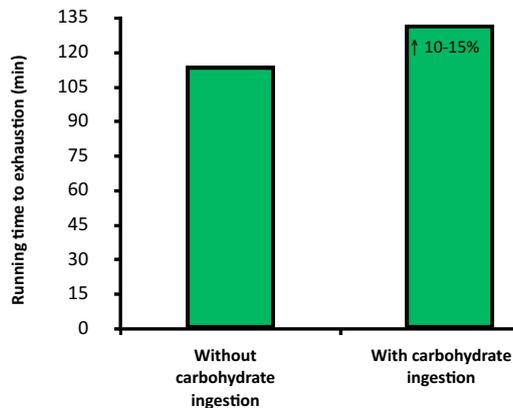


Figure 3.13: Time to exhaustion with and without carbohydrate ingestion during exercise

It is generally best to consume carbohydrate in a liquid form during exercise, since solid food is typically not well tolerated. Specially formulated liquid gels have been designed for this purpose. These are small satchels containing approximately 30 g of liquid carbohydrate (Figure 3.14). However, some solid food may be tolerated in sports such as cycling where there is less physical disruption (bouncing around) of the gastrointestinal tract (Figure 3.15). Under these conditions, choose solid foods that are easy to access/open and chew. Moderate to



Figure 3.15: Carbohydrate intake during competition



Figure 3.14: Liquid carbohydrate gels

high GI carbohydrates are preferable to low GI carbohydrates to ensure the rapid release of glucose into the bloodstream for use.

Fluid intake during exercise

Consuming fluid during prolonged exercise will decrease the risk of dehydration. The precise amount of fluid needed will vary depending on the environmental conditions, the individual athlete's sweat rate and the duration of exercise. A rough estimate to start with is to drink 400–800 mL per hour of exercise. For events of shorter duration, it may be better to break this down to 100–200 mL per 15 min. This is either in combination with, or without carbohydrate, depending on the duration of the event.

For events that are less than one hour in duration, there is little benefit in consuming extra carbohydrate, so drinking plain water to replace fluid loss is fine. However, voluntary drinking during exercise (drinking to thirst) tends to only replace about half of the fluid loss via sweating. For this reason, one potential

benefit of consuming a drink containing carbohydrate (for example, sport drinks or commercially available ‘sports water’) during short events in hot or humid conditions is that the sweet flavour may encourage increased fluid consumption.

For more prolonged events, combining fluids with carbohydrate is definitely beneficial. Some athletes may dilute a liquid carbohydrate gel in water. Alternatively, specialised sports drinks like Gatorade and Powerade have been developed for the combined purpose of carbohydrate feeding during exercise, as well as fluid replacement (Figure 3.17). These types of drinks are specially formulated to provide about 35 g of carbohydrate per 600 mL. Another special feature of these drinks is that the carbohydrate content in solution is provided at a concentration of 6–8%. This has been shown to be the optimal concentration for carbohydrate to travel through the stomach and intestines to be absorbed into the bloodstream for use. A higher concentration of carbohydrate can impair fluid replacement and delay the availability of ingested carbohydrate in the bloodstream. Fruit juice, soft drinks and some commercially available energy drinks are examples of fluids containing carbohydrate at a much higher concentration than sports drinks.

It is important to be aware that the recommended rate of fluid consumption during exercise may not equate to the amount of fluid loss from sweating during exercise; however, even drinking the recommended amount of fluid during exercise is not an easy task, particularly in running events. To improve the drinkability of fluids during exercise it is suggested to keep fluids cool. It is worthy of note, most commercially available sports drinks like Gatorade and Powerade contain electrolytes (sodium and potassium) in addition to

carbohydrate. Electrolytes increase the desire to drink, as well as enhance fluid and carbohydrate uptake in the intestines. Furthermore, it is important for athletes to trial their nutritional strategies during training, rather than waiting for competition. This will assist in determining what strategies work best for each individual athlete.

Figure 3.16: Fluid intake during exercise



NUTRITION INFORMATION			
	PER SERVING	%DVT	PER 100ML
SERVINGS PER PACKAGE	1		8
AVERAGE QUANTITY	786 kJ (188 CAL)		131 kJ (31 CAL)
ENERGY	0 g	0	0 g
PROTEIN	0 g	0	0 g
FAT, TOTAL	0 g	0	0 g
SATURATED	45 g	15	7.5 g
CARBOHYDRATES	35 g	39	5.8 g
SUCROSE	9.6 g		1.6 g
MALTODEXTRIN	0 g	0	0 g
DIETARY FIBRE	1.67 mg (2.2 mmol)	7	28 mg (1.2 mmol)
SODIUM	85 mg (2.4 mmol)		14.1 mg (0.4 mmol)
POTASSIUM			

100% DAILY INTAKE PER SERVING IS BASED ON AN AVERAGE ADULT DIET OF 8700 KJ. YOUR DAILY INTAKE MAY BE HIGHER OR LOWER DEPENDING ON YOUR ENERGY NEEDS
www.makeeverydropmatter.com.au
TO REACH YOUR GOAL: CONTAINS: WATER, SUCROSE, POTASSIUM PHOSPHATE, ...

Figure 3.17: A commercially available sport drink

UWA research snapshot: *The effect of a carbohydrate mouth rinse on performance*

Recent research suggests that simply swirling a carbohydrate drink in the mouth like a mouth wash may assist in performance for events lasting less than 1 hour in duration (Carter et al., 2004). The reasons for this are not yet known; however, it has been suggested that the detection of carbohydrate by receptors in the mouth may stimulate areas in the brain leading to increased central drive and motivation (and therefore performance). Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia are currently investigating whether rinsing the mouth with a carbohydrate solution can benefit maximal sprint performance. The findings of this research will have important implications for athletes involved in sprint and power events.

Key point summary:

- Carbohydrate feeding during exercise (30–60 g per hour) will assist performance in exercise events > 1 hour in duration.
- Drinking during exercise (400–800 mL per hour) will decrease the risk of dehydration during prolonged events.
- For short duration events, aim to drink 100–200 mL per 15 minutes.
- Drinking plain water is adequate for exercise < 1 hour in duration.
- For exercise > 1 hour, combining carbohydrate with fluid is beneficial.
- A carbohydrate concentration of 6–8% in solution is optimal for absorption in the gastrointestinal tract.
- Cold and flavoured fluids encourage increased consumption.
- Electrolytes increase the desire to drink and fluid absorption in the gastrointestinal tract.
- Consuming the recommended amount of fluid during exercise may still not equate to the amount of fluid lost from sweat during exercise in hot conditions.

Recovery and post-exercise nutrition

Carbohydrate intake during recovery

The goal of post-exercise nutrition is to replenish fuel stores (predominantly carbohydrate) and replace fluid loss from sweat. In terms of replenishing the fuel stores used during exercise, the immediate consumption of

high glycaemic index carbohydrates has been shown to facilitate a faster rate of glycogen repletion post-exercise. Examples of high GI foods include fruit juice, soft drink, or lollies (Figure 3.18), while a more substantial snack might include a white bread roll with banana and honey. Fast replenishment of glycogen stores is of particular importance for those

athletes that may have to compete again within a limited timeframe like a team sport athlete or tennis player in a tournament situation. There is also evidence to suggest that multiple small feedings may be better than one single large post-exercise meal.

Fluid intake during recovery

Voluntary fluid intake during exercise typically cannot keep pace with sweat loss. In fact, studies suggest that when an athlete is left to drink at their own pace, they will only consume about half of the fluid needed to replace sweat lost through exercise. During recovery, it is possible to make sure that adequate fluid has been consumed to replace the sweat lost through exercise by measuring nude body mass pre and post exercise. The reason why body mass must be measured nude is that clothing will hold sweat after exercise. By measuring nude body mass, the difference in mass pre- to post-exercise reflects the amount of body water lost through sweat. For example, a difference in pre to post-exercise nude body mass of 1 kg reflects a need for approximately 1 L of fluid intake. Table 3.3 shows the average amount of fluid lost in various sports. During recovery, athletes should aim to ingest a little extra fluid on top of that lost during exercise to account for further fluid loss through urine and sweating



Figure 3.18: Replenishing carbohydrate stores after exercise

in the hours following exercise. As a general guide, consuming an extra 50% of the body fluid lost should account for this (for example, consume 1.5 L of fluid if 1 kg of body mass is lost though exercise). Fluids containing caffeine or alcohol are not recommended at this time since they cause increased urine losses (they are diuretics). Consuming fluids containing electrolytes post-exercise, such as sports drinks, may speed rehydration since they reduce the amount of urine produced post-exercise, as well as stimulate thirst.

Table 3.3: Average sweat rate, voluntary fluid consumption and body fluid loss in various sports

Sport	Sweat rate (L/hr)	Voluntary fluid consumption (L/hr)	Body fluid loss (L/hr)
Netball (Broad et al., 1996)	0.98	0.52	-0.46
Swimming (Cox et al., 2002)	0.37	0.38	+0.01
Soccer (Shirreffs et al., 2005)	1.46	0.65	-0.81
Tennis (Bergeron et al., 1995)	1.6	1.1	-0.5

Practical activity: Assessing dehydration during exercise

At the start of a moderate/intense Physical Education class, select a couple of well hydrated students to weigh themselves (without shoes or socks and wearing minimal clothing). To ensure adequate hydration to start with, they should have consumed at least 500 mL of water in the 2 hours prior to class. During exercise, ensure that no water is consumed and at the end of class towel off any perspiration and reweigh them (without shoes or socks and wearing minimal clothing). Compare their body mass pre and post-exercise. Any decrease in body mass represents water loss through sweat. Based on this, calculate how much water the student should consume to rehydrate appropriately.

Equipment:

- Area for physical activity.
- Towel.
- Weighing scales.

Nutritional strategies for optimal performance

Table 3.4 provides a summary of the nutritional strategies employed by an individual undertaking a Half Ironman Triathlon. This event involves a 1.9 km swim, followed by a 90 km ride, and then a 21 km run (Figure 3.19). The athlete is aiming to complete the race in approximately 4.5 hours. Table 3.5 provides a summary of a sample nutrition strategy for an Aussie Rules player.



Figure 3.19:
Nutrition during
an Ironman
triathlon

TIME	FOOD	CHO (g)
Pre-race meal (3 hours prior)	6 Weetbix with hot water and honey	80 g
	600 mL Powerade	35 g
	300 mL water	-
Pre-race snack (60 min prior)	1 x vanilla powerbar	40 g
	300 mL Powerade	17 g
	100 mL water	-
Swim (28–30 min)	-	-
Swim-cycle transition	-	-
Cycle (2.5 hours)	2 x 600 mL Powerade	70 g
	600 mL water	-
	3 x Carboshotz	90 g
	1 x vanilla powerbar	40 g
Cycle-run transition	1 x Carboshotz	30 g
Run (1.5 hours)	500 mL water	-
	1 x Carboshotz	30 g
	300 mL Powerade	17 g
Post-race (within 1 hour)	600 mL Powerade	35 g
	500 mL water	-
	2 x banana sandwich	120 g

Table 3.3:
Sample nutrition
strategy for the
Busselton Half
Ironman Triathlon
(prepared by Dr
Peter Peeling,
School of Sport
Science, Exercise
and Health.
The University
of Western
Australia.)

***Note:** Total carbohydrate intake during the race period is 277 g which equates to 62 g per hour.

Table 3.5: Sample nutrition strategy for an AFL player

TIME	FOOD	CHO (g)
Pre-game meal (3–4 hrs before)	Spaghetti with napolitana sauce 600 mL sports drink	70 g 35 g
Pre-game snack (1–2 hrs before)	Banana and honey sandwich	60 g
During game	900 mL x sports drinks	50 g
Half-time	600 mL x sports drink Muesli bar or banana	35 g 27 g
Post-game (within 30 min)	Sports drink / sustagen sport Lollies	50 g 35 g

**Figure 3.20:** A footballer during the half-time break

- When fluid replacement is based on voluntary thirst, athletes typically drink only 50% of what is needed to replace sweat loss through exercise.
- During recovery, athletes should aim to consume 1.5 times the nett fluid lost during exercise.
- Post-exercise consumption of drinks containing electrolytes may speed rehydration by reducing urine production and stimulating thirst.

Key point summary:

- Post-exercise nutrition should focus on replacing fuel stores (predominately carbohydrate) and body fluid losses.
- High GI carbohydrates consumed immediately post-exercise will accelerate glycogen replenishment.

Revision questions:

Test yourself on revision questions 12–21 located at the end of this chapter.

Environmental Influences on Performance

Text outcomes:

Environmental physiology (Unit 3)

- *Evaluate the implications of preparing for and performing in varying environmental conditions.*

Content that follows:

Environmental conditions (Unit 3)

- *Regulation of body temperature*
- *Exercise in the heat*
- *Exercise in humidity*
- *Exercise in the cold*
- *Exercise at altitude*

Regulation of body temperature

In order to understand the implications of preparing for and performing exercise in the heat or cold, we must first understand how the body regulates its temperature. You may be surprised to learn that the human body tightly regulates its internal (core) temperature to approximately 37°C regardless of the temperature of the surrounding environment. For instance, the core temperature of a person living in Perth will be similar to that of an Eskimo living in the Arctic. The reason for this tight regulation of core temperature is that all of the chemical reactions that go on inside the body (including the production of ATP for

muscular work) occur most optimally (fastest) at this temperature. If core body temperature deviates too far from this optimal range (37°C \pm 3°C), the results can impact on athletic performance and even be life-threatening. For this reason, the body tightly regulates its temperature by balancing the production of heat from chemical reactions occurring within the body, with the four main mechanisms of heat exchange to the environment; **radiation**, **conduction**, **convection** and **evaporation**. This balance is represented in Figure 3.21.

The transfer of heat by these four mechanism is always from warmer objects to cooler objects. In addition, the actual amount of heat transferred is relative to the temperature gradient (the temperature difference) between the two objects. These characteristics of heat exchange are demonstrated below in the description of each main mechanism.

- **Radiation** – the transfer of heat via electromagnetic waves. This is the way in which we are warmed by the sun. Since the sun is much warmer than us, we gain heat via radiation. This helps explain why we feel warmer when we stand in the sun, rather than in the shade. In contrast, we lose heat to objects in our surrounding environment that are cooler than us. For example, an ice skater would lose some heat to the walls and floor in a skating arena.
- **Conduction** – the transfer of heat through direct contact. We encounter heat transfer via conduction each time our body comes into contact with an external object. For example, an athlete wearing an ice vest would lose some heat from the body to the vest. In contrast, when running on a hot bitumen road, there is heat transfer

from the road to our shoes and feet.

- Convection** – the transfer of heat by the motion of a moving substance (typically air or water). This explains why a breeze feels cool. In fact, the amount of heat loss via convection depends upon the speed and temperature of the surrounding air or water flow. For this reason, you can still feel cool when going for a brisk walk on a warm sunny day if there is a significant breeze. This also explains why it feels cooler to cycle outside as you pass through the air, as opposed to cycling on a stationary bike in the one spot.
- Evaporation** – the transfer of heat resulting from the evaporation of sweat on the skin. Evaporation is the process whereby a liquid (like sweat) changes to a vapour or a gas. This is the main mechanism of heat loss from the body during exercise. When sweat evaporates, it has a cooling effect on the surface of the skin. This is why your skin may feel cool to touch after a sweaty run. If the skin is cool, then there will be heat transfer with the warm blood directly below the skin surface. The cooled blood then continues to travel back to the core of the body, assisting in maintaining a stable internal temperature. For this reason, during exercise, blood is diverted to the skin as well as to the working muscles. Of importance, sweat alone does not achieve heat loss. The sweat must evaporate to cause cooling. Therefore, towelling off your sweat or changing out of a sweaty shirt into a dry one may be counterproductive in terms of cooling the body (Figure 3.22).

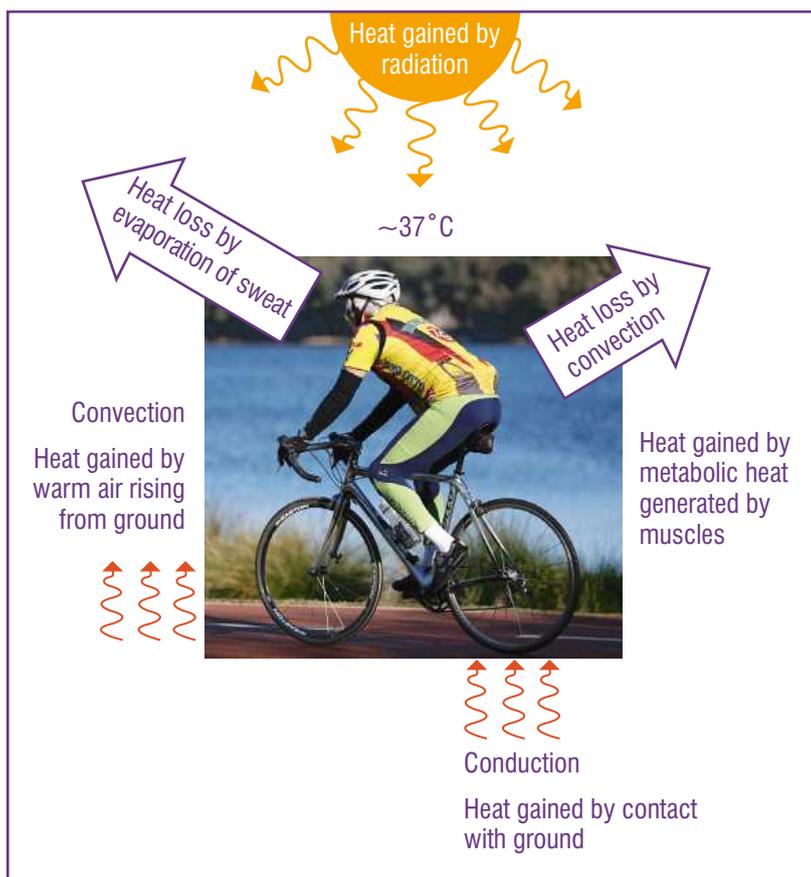


Figure 3.21: Factors contributing to heat gain and heat loss to maintain a stable core temperature



Figure 3.22: Towelling off sweat is counterproductive for body cooling

Key point summary:

- The body's core temperature is maintained close to 37°C.
- If core temperature deviates too far from 37°C ($\pm 3^\circ\text{C}$), performance can be impaired and the results can be life-threatening.
- The body uses four mechanisms to regulate core temperature:
 - Radiation – transfer of heat by electromagnetic waves
 - Conduction – transfer of heat through direct contact
 - Convection – transfer of heat by the motion of moving substances (typically air or water)
 - Evaporation – transfer of heat resulting from the evaporation of water (sweat) on the skin surface.

Exercising in the heat

During exercise, the rapid increase in chemical reactions required to produce the ATP needed for muscular work causes a major increase in heat production by the body. This heat must be dissipated from the body in order to prevent a rise in core body temperature to a dangerous level. If core temperature does rise to this critical threshold (approximately 40°C), continued performance becomes limited.

When the external surroundings are cool, the body can transfer (lose) heat via radiation, convection, conduction and evaporation. However, when exercising in the heat (when the external surroundings are warm), conduction, convection and radiation are not very effective for heat loss. In fact, there is the possibility of actually gaining further heat from the

environment under these conditions. The reason for this is that each of these mechanisms of heat transfer involves the passage of heat along a temperature gradient from warmer to cooler objects. In addition, the actual amount of heat transfer depends upon the amount of temperature difference. Therefore, if the outside temperature is warm, there is only a small gradient for heat transfer from the body to the environment. If the ambient temperature is higher than core temperature, the body will actually gain heat. Under these conditions, evaporation is the only mechanism by which heat can be dissipated from the body (Figure 3.23).



Figure 3.23: *Evaporation of sweat is the only mechanism of heat loss during exercise in the heat*

Practical activity: The effect of convection on thermoregulation

Select some students to complete 20 min of moderate intensity exercise (such as skipping rope, treadmill jogging or stationary cycling); either i) with or ii) without a fan placed in front of them. Monitor heart rate, perceived exertion and perceived thermal stress at 5 min intervals throughout the exercise and compare between conditions. Discuss the physiological reasons why any differences between conditions might exist.

Equipment:

- Equipment or area for activity.
- Fan.
- Heart rate monitor (or measure pulse manually).
- Stopwatch.
- Rating of perceived exertion and thermal stress scales (See appendix 3.A and 3.B).

Sweat loss during exercise

Although evaporation can be an effective mechanism of heat loss when exercising in the heat, it places a demand on the body's fluid reserves. A team sport player may lose around 2 L of fluid per hour during intense exercise in the heat. Just try to picture a 2 L carton full of sweat – this is a lot! In fact, an elite marathon runner may lose up to 6 L of sweat in a race, even if taking on fluids at drinks stops along the way. Ultimately this amount of fluid loss causes dehydration which will impair both performance and continued heat loss. This is because significant loss of fluid from the body will reduce blood plasma volume, which in turn impairs the body's ability to continue to deliver blood to both the working muscles *and* the skin for cooling via sweat evaporation. This is called the **double heat load**. With reduced plasma volume, there is a decline in the stroke volume of the heart; however, in order to maintain cardiac output, the heart rate increases to compensate. This phenomenon is termed **cardiac drift** (Figure 3.24).

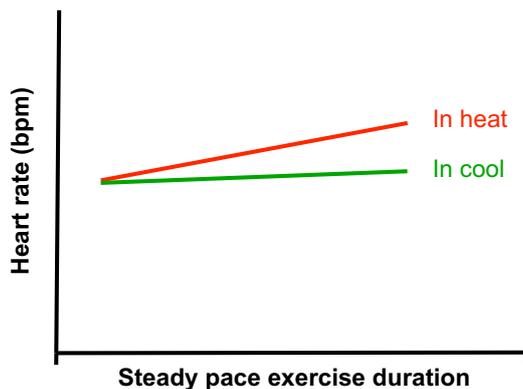


Figure 3.24: *Cardiac drift*

The increase in heart rate resulting from cardiac drift can only compensate for the reduction in stroke volume to a certain extent. With

significantly reduced plasma volume, the body prioritises blood supply to the working muscles, rather than the skin. This means less blood flow to the skin, limiting further cooling by evaporation and therefore continued performance. A loss of fluid equal to 1–2% of body mass during exercise can significantly impair both athletic performance and mental function. Of interest, competing in an Ironman triathlon in temperate conditions (approximately 21°C) may result in an approximate loss of 3.5% of body mass (Speedy et al., 2001). In extreme cases, significant fluid loss may result in heat illnesses such as heat exhaustion or heat stroke which is a life-threatening emergency (Figure 3.25).



Figure 3.25: *An athlete suffering from heat exhaustion*

UWA research snapshot:
Physiological effects of exercise in the heat

In an experiment conducted at the School of Sports Science, Exercise and Health at The University of Western Australia, a local triathlete completed a 40 min treadmill run in a climate chamber set to replicate a typical Perth summer day (37°C and 36% relative humidity). Before, during and after the run, physiological measures were taken to monitor his responses to exercising in the heat. These included:

- Monitoring heart rate using a heart rate monitor
- Monitoring core body temperature via ingestion of a radiotelemetry pill
- Monitoring skin temperature using skin temperature probes
- Monitoring oxygen consumption using a computerised gas analysis system
- Monitoring blood lactate levels via capillary blood sampling
- Measuring nude body mass pre and post exercise to determine nett fluid loss.

The results of the run are shown in the table below. Note that the run was abandoned after only 37 min due to the severe environmental conditions.

Time	Body mass	Heart rate	Core temperature	Skin temperature	Oxygen consumption	Blood lactate
Pre-exercise	75.7 kg	52 bpm	37.23°C	31.17°C	-	1.3 mM
20 min of exercise	-	177 bpm	39.11°C	37.26°C	4.12 L/min	4.0 mM
37 min of exercise	-	182 bpm	39.53°C	37.45°C	4.17 L/min	4.3 mM
Post-exercise	73.65 kg	-	-	-	-	-
Body mass loss 2.35 kg						

Based on these results, calculate what percentage of total body mass was lost as a result of running in the heat. In addition, determine how much water this athlete should drink during recovery to replace the body fluid that was lost during exercise.



Figure 3.26: Running in a climate chamber

Pre-event hydration strategies for exercising in the heat

It is crucial to consume fluids before, during and after exercise in the heat. In particular, it is vital to commence exercise in a state of hydration. If the athlete is already dehydrated at the start of exercise, it is virtually impossible to reverse the situation once exercise has begun. As mentioned in the section on pre-event nutrition, the amount of water intake required to achieve adequate hydration will vary considerably between individuals, so it is difficult to give a standardised recommendation. A good guide is to drink to match thirst and ensure that urine is a pale yellow colour (rather than dark and concentrated). As a rough guideline:

- Athletes may consume 350–500 mL at least four hours prior to competition to allow time to optimise hydration status and excrete excess fluid as urine (Sawka et al., 2007).
- If the urine produced is dark and concentrated in colour, or no urine is produced at all, the athlete should drink another 200–350 mL two hours prior to the event.

This allows time for urine production to return to normal before the race or competition. For events in which a large amount of fluid loss is expected it may be useful to start exercise in a state of **hyperhydration** (excess hydration). This may assist in maintaining an adequate plasma volume and allow sweating to continue at an optimal rate for longer. However, this should be trialled in training to determine the optimal amount of fluid for each individual, as taking on too much water prior to an event may cause discomfort and there may be a risk of needing to go to the toilet during exercise. Furthermore, pre-event hyperhydration may be negative for performance in certain sprint and power events.

Key point summary:

- When exercising in the heat, evaporation is the main mechanism by which heat can be lost from the body.
- When exercising in the heat, a significant amount of body fluid (water) is lost via sweat.
- Fluid loss during exercise in the heat results in reduced blood plasma volume and therefore:
 - a double heat load (decreased blood flow to both the working muscles *and* the skin)
 - a reduced stroke volume leading to an increased heart rate to compensate (cardiac drift).
- A loss of fluid equal to 1–2% of body mass during exercise will significantly impair both athletic performance and mental function.

For example, a 100 m sprinter does not want to have excess fluid gushing around the stomach and most certainly doesn't want to be busting for the toilet on the starting line!

Hydration strategies during exercise in the heat

Regular fluid intake is vital during exercise in the heat. The precise amount of fluid needed will vary depending on the heat, humidity, individual athlete's sweat rate and the duration of exercise.

- A rough estimate to start with is to drink 400–800 mL per hour of exercise.

However, this amount can be refined depending on how much fluid is expected to be lost during the event. This can be determined in training or a practise race by measuring nude body mass pre- and post-exercise. The reason why body mass must be measured nude is that clothing will hold sweat after exercise. By measuring nude body mass, the difference in mass pre- to post-exercise reflects the amount of body water lost through sweat. For example, a difference in pre- to post-exercise nude body mass of 1 kg reflects a loss of approximately 1 L of fluid. Studies have shown the amount of



Figure 3.27: Fluid intake is vital during exercise in the heat

fluid loss to vary significantly between sports and with differing environmental conditions. For instance, a tennis player in a summer competition may have an average sweat rate of 1.6 L per hour (Bergeron et al., 1995). In many prolonged events like the marathon, the fluid loss from the body may be greater than that which can be comfortably consumed, meaning that fluid intake will not keep pace with fluid loss, and ultimately performance will be compromised.

In events lasting longer than 1 hour in duration, fluid should be taken in combination with carbohydrate as detailed in the nutrition section of this chapter. In contrast, for events lasting less than 1 hour in duration, fluid intake in the form of plain water is fine. However, voluntary drinking during exercise tends to only replace about half of the fluid loss via sweating. For this reason, one potential benefit of consuming a fluid containing carbohydrate (like a sports drink or commercially available 'sports water') during exercise of less than one hour in duration in the heat is that the sweet taste may encourage increased voluntary fluid consumption. Also, many sports drinks are specially formulated to provide carbohydrate at a precise concentration of 6–8% in solution. A higher concentration of carbohydrate can impair fluid uptake in the intestines and therefore impair rehydration. Fruit juice, soft drinks and other commercially available energy drinks are examples of fluids containing carbohydrate at a higher concentration. Another way in which voluntary intake of fluids may be enhanced is to keep the fluids cool. In addition, most commercially available sports drinks like Gatorade and Powerade contain electrolytes (sodium and potassium) in addition to carbohydrate. Electrolytes increase the drive to drink, as well as enhance fluid and carbohydrate uptake in the intestines. It is important for athletes to trial their nutritional

strategies during training, rather than waiting for competition. This will assist in determining what strategies work best for each individual athlete. Finally, beware of consuming caffeinated drinks (like Coca Cola) or some energy drinks which contain guarana (which is chemically similar to caffeine) as these act as diuretics which increase urine production which may increase the risk of dehydration if taken in large doses.

Other strategies for coping with exercise in the heat

Another way in which an athlete may prepare for competition in the heat is to **pre-cool** the body. Pre-cooling can be achieved using a range of techniques including wearing cooling jackets, cold water immersion or the ingestion of ice (Figure 3.28). Each of these methods lowers core body temperature prior to the commencement of exercise thereby allowing for a greater increase in temperature before the critical threshold is reached (Figure 3.29).

UWA research snapshot: Beneficial effects of crushed ice ingestion on cycling performance (Ihsan et al., 2010)

Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia recently showed that ingestion of crushed ice 30 min prior to a 40 km cycling time-trial improved performance in a hot and humid environment (30°C; 75% relative humidity) compared to ingestion of an equivalent amount of tap water (6.8 g/kg of body mass). It was found that core temperature remained cooler for the initial part of the time trial, and performance was 6.5% faster after the ingestion of ice compared to tap water.

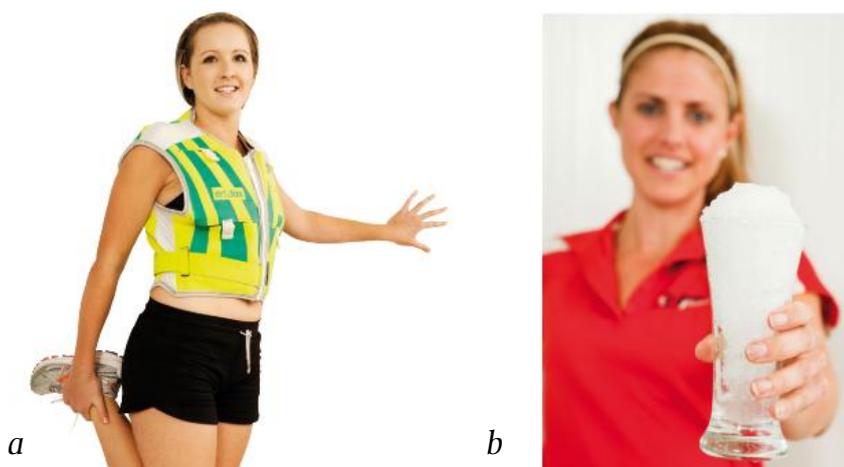


Figure 3.28: Methods of pre-cooling include a) wearing a cooling jacket and b) the ingestion of ice

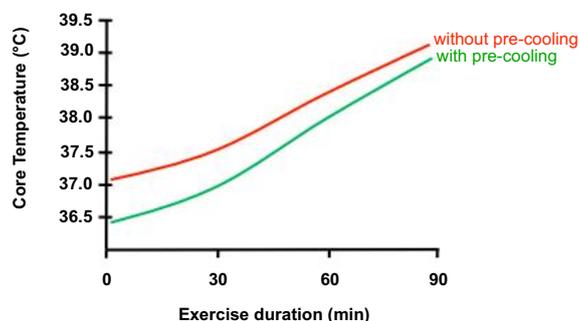


Figure 3.29: The increase in core temperature during exercise with and without pre-cooling

Other strategies for competing in the heat include wearing thin, light coloured clothing made from natural fibres (like cotton rather than polyester). In fact, the less clothing the better, as it allows for increased skin exposure and therefore area available for sweat evaporation. Of note, those individuals with a low ratio of skin surface area to body mass (wrestlers, rugby players) may tolerate the heat less well than thin, linear individuals with a larger skin surface to body mass ratio (Figure 3.30).



Figure 3.30: Athletes with a high ratio of skin surface area to body mass (b) may tolerate the heat better

Heat acclimatisation

Although exercise in the heat can significantly impair performance, our ability to tolerate the heat can be enhanced through **heat acclimatisation**. Acclimatisation to the heat involves a period of exercise training (typically 5–10 days) in a similar environment to that which is expected for competition. This produces physiological adaptations to help the athlete cope better with the heat including:

- a faster onset of sweating
- a greater rate of sweating, and
- an increase in plasma volume.

Elite athletes may acclimatise by travelling to a hot location. For example, the Australian Hockey team spent time training in Darwin (a hot, humid environment) before the Beijing Olympics in 2008. In Darwin, the average daily temperature is 30°C in June, compared to 19°C at the same time of year in Perth (Australian Bureau of Meteorology). Alternatively, some athletes may have access to a climate chamber which is a specialised room in which the temperature and humidity can be adjusted to reflect the conditions expected for competition (Figure 3.31). For athletes without access to such equipment, one strategy that may be employed is to train in the warmer parts of the day, although care must be taken in the first few days of acclimatisation to prevent heat illness.



Figure 3.31: Training in the climate chamber

Key point summary:

- Adequate hydration is crucial prior to commencing exercise in the heat.
- Hyperhydration is the consumption of excess fluid in preparation for loss of fluid in upcoming exercise.
- Drinking during exercise (400–800 mL per hour) will decrease the risk of dehydration.
- Drinking plain water is adequate for exercise < 1 hour in duration.
- For exercise > 1 hour, combining carbohydrate with fluid is beneficial. A carbohydrate concentration of 6–8% in solution is optimal for absorption in the gastrointestinal tract.
- Cold and flavoured fluids encourage increased consumption.

- Electrolytes increase the desire to drink and fluid absorption in the gastrointestinal tract.
- Consuming the recommended amount of fluid during exercise may still not equate to the amount of fluid loss from sweat during exercise in hot conditions.
- Pre-cooling the body (using cooling jackets, cold water immersion, or crushed ice ingestion) lowers core temperature prior to exercise allowing for a greater increase before the critical threshold is reached.
- Thin, light coloured cotton clothing should be worn when exercising in the heat.
- Individuals with a large skin surface area to body mass ratio may tolerate heat better.
- Heat acclimatisation (5–10 days of exercise training in the heat) results in increased plasma volume, an earlier onset of sweating and increased rate of sweating.

the body, which is of no use for cooling and simply represents a waste of precious body water (Figure 3.32). Consequently, fluid intake is vital when exercising in a hot and humid environment.



Figure 3.32: *Sweat dripping from the body is not effective for body cooling*

Exercising in a humid environment

Humidity represents the proportion of water in ambient air. For instance, the humidity of a typical day in Perth is 50%, meaning that the ambient air is carrying 50% of its water capacity. This has relevance for the effectiveness of evaporation as a mechanism of heat loss from the body. If the relative humidity is high (such that the ambient air is already carrying a high proportion of water), then there is nowhere for the sweat on the skin to evaporate to. Under these conditions sweat will drip from

To demonstrate the effect of exercising in a hot, humid climate, see Table 3.6 for a comparison of the physiological responses to a 10 km run in Perth compared to Darwin. The higher ambient humidity in Darwin limits the evaporation of sweat on the skin surface, thereby resulting in the higher skin temperature. The higher skin temperature means there will be less cooling of the blood circulating below the skin surface. This in turn means there is a smaller gradient for transfer of heat between the warmer body core and the skin, resulting in a greater rise in core temperature, and a 6% decline in performance.

	Perth	Darwin
Ambient temperature	22°C	32°C
Relative humidity	43%	73%
Performance time	41 min 09 sec	43 min 53 sec
Pre-run core temperature	37.0°C	37.1°C
Post-run core temperature	39.0°C	40.3°C
Pre-run skin temperature	32.3°C	33.9°C
Post-run skin temperature	27.9°C	35.7°C
Exercise heart rate	190 bpm	198 bpm
Pre-run body mass	73.2 kg	73.2 kg
Post-run body mass	72.7 kg	71.5 kg
Estimated fluid loss (L)	0.5 L	1.7 L
Estimated fluid loss (% body mass)	0.6%	2.3%

Table 3.6: *Physiological responses to a 10 km run in hot and humid conditions*

Strategies to cope with exercise in a humid environment

The strategies for coping with exercise in a humid environment are similar to those described earlier when preparing for competition in the heat. For instance, in our previous example, the Australian Men's Hockey team travel to Darwin (where the average humidity can be 80% at certain times of the year) to acclimatise for upcoming tournaments scheduled in hot and humid conditions. Such a period of acclimatisation assists in increasing both blood plasma volume and the rate of sweating. However, given that there is limited evaporation of sweat in high humidity, acclimatisation can only assist to a certain extent. Therefore, fluid intake strategies prior to and during exercise in a hot/humid environment will be of great importance for preventing dehydration and an impairment in performance.

Key point summary:

- During exercise in humid conditions, evaporative heat loss is restricted by the highly saturated ambient air.
- Fluid intake prior to and during exercise is crucial for optimising performance in humid conditions.

Practical investigation

Evaluate the implications of preparing for and performing exercise in hot/humid conditions

See Appendix B1 for a practical investigation, along with questions and report-writing format recommendations.

Revision questions:

Test yourself on revision questions 22–32 located at the end of this chapter.

Exercising in the cold

When exposed to a cold environment, the body is forced to conserve heat (prevent heat loss to the environment) in order to maintain a stable core body temperature. This is achieved by a number of mechanisms including:

- **Peripheral vasoconstriction** – constriction of the blood vessels just below the skin surface to shunt blood away from the skin, towards the core instead. This minimises heat loss from the blood to the cold external environment. With less blood under the skin surface, the skin remains cool and there is a smaller gradient over which the body's precious heat can be lost via radiation to the cooler objects in the surrounding environment.
- **Shivering** – uncontrolled muscular contractions to elevate heat production.
- **Piloerection** – when the hairs on the body stand on end. This is what many people call 'goose bumps'. The erect hairs trap a warm layer of air close to the skin to help keep the skin surface warm.

Strategies to cope with exercise in the cold

Unfortunately, we don't adapt to the cold as well as we adapt to the heat with acclimatisation. However, it still may be of use to train in the cold if that is what is expected for competition in order to prepare from a psychological perspective. In addition, there is some evidence to suggest that it may improve

local blood flow and dexterity in the cold. Of particular importance when exercising in a cold environment is the use of appropriate protective clothing. If clothing is not adequate, cold injury may result, with early warning signs including numbness and tingling in the extremities, progressing to frostbite and potentially irreversible damage causing the need for amputation. However, it is important to be aware that as you commence exercise, the body will begin to produce more heat as a result of the increased rate of chemical reactions for muscular work. Therefore, it may be useful to wear multiple layers of clothing which can be removed as the athlete's body 'warms up' to an appropriate level (Figure 3.33). Of note, those athlete's with a greater level of subcutaneous fat (just below the skin surface) may experience some insulation from the cold. This sort of body composition may be beneficial in certain sports such as open water swimming. For added insulation these athletes may rub animal fat on their skin to protect against heat loss. Wetsuits serve a similar purpose (Figure 3.34).



Figure 3.33: The body produces heat during exercise



Figure 3.34: An open water swimmer attempting to keep warm

As mentioned previously, you can still feel cold on a warm sunny day if there is a significant breeze. Alternatively, sitting in the sun on a still winter day can feel quite warm. This phenomenon is referred to as **wind-chill**. Wind increases heat loss by constantly replacing the layer of warm air around the skin with fresh cool air. The same occurs when you exercise in the wind. Under these conditions appropriate clothing should be worn to protect the athlete from the wind.

Key point summary:

- When exposed to a cold environment, the body conserves heat by:
 - vasoconstricting peripheral blood vessels to shunt blood flow away from the skin surface
 - shivering
 - making the body hairs stand on end (piloerection) to trap and warm air at the skin surface.

- Wearing multiple layers of clothing is useful when exercising in the cold to allow the athlete to remove appropriate layers as they ‘warm up’ from the heat produced by muscular work.
- Insulation from body fat, animal fats rubbed on the skin and wetsuits help minimise heat loss from the body in cold conditions.
- Wind magnifies heat loss by constantly replacing the layer of warm air around the skin with fresh cool air (wind-chill).

Revision questions:

Test yourself on revision questions 33 and 34 located at the end of this chapter.

Exercising at altitude

At altitude, the air is thinner due to lower barometric pressure. Although the actual percentage of oxygen in the air does not change, because the air is thinner, there is less absolute oxygen available, resulting in **hypoxia** (lack of adequate oxygen).

The lower oxygen availability in the air, means lower oxygen availability in inspired air, and therefore the amount of oxygen transported in the blood to the working muscles. Since we know that oxygen is crucial for the aerobic production of ATP, the hypoxia resulting from altitude impairs performance in any type of activity that relies on this energy system. In particular, the maximal rate of oxygen consumption ($\dot{V}O_2\text{max}$) is significantly reduced at altitude (Figure 3.36). In fact, acclimatised men attempting to climb Mount Everest may



Figure 3.35: *The air is thinner at altitude*

have their $\dot{V}O_2$ max reduced from 40 mL/kg/min at sea level to 15 mL/kg/min near the 8,848 m summit (West et al., 1983). The reduction in $\dot{V}O_2$ max at altitude is also evident from the results of the 1968 Olympics held in Mexico City (altitude 2,300 m) in which poor performances were observed in the middle and long distance running events (Table 3.7).

You may also remember from Units 1 and 2 that oxygen is important during recovery from exercise that relies predominantly on the anaerobic energy systems (ATP-CP system and lactic acid system). This is because oxygen is used to produce ATP to provide energy for the replenishment of CP and the removal of lactic acid during recovery. For this reason, performance in any activities involving repeated anaerobic bouts with limited recovery in between may also be impaired at altitude. In contrast, performance in a one-off sprint or power event such as the long jump is not impaired at altitude due to these activities being powered predominantly by anaerobic sources of ATP (they do not require oxygen). In fact,

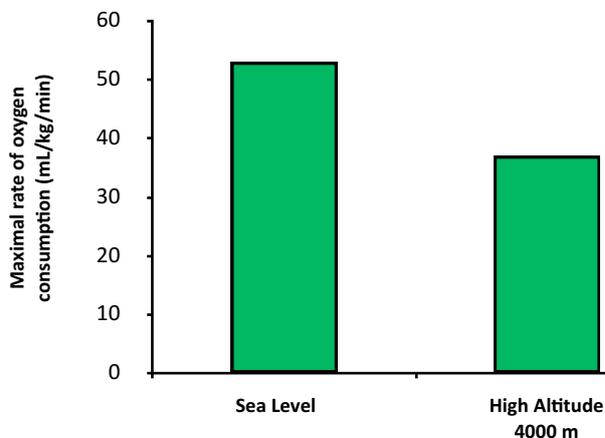


Fig 3.36: *Effect of altitude on $\dot{V}O_2$ max*

performing these activities at altitude may be enhanced by the lower air resistance providing less drag/resistance to travel through the air. For this reason, at the same Olympic Games in Mexico where poor performances were recorded in the middle and long distance running events, world records were broken in all the men's track races that were 400 m or shorter, as well as the long, high and triple jump (Table 3.7). In fact, the long jump record was broken by an incredible 55 cm and was not broken again for another 23 years (Figure 3.37)!

Adaptations to altitude

Upon arrival at altitude, the body attempts to compensate for reduced oxygen availability immediately with:

- increased pulmonary ventilation (hyperventilation) to try to get more air (and therefore oxygen) into the lungs
- decreased plasma volume (to make haemoglobin more concentrated in the blood)
- increased heart rate and cardiac output at rest and during submaximal exercise.

Event	Gold Medal performance in 1968	World Record in 1968
100 m Men	9.95 sec	New world record
100 m Women	11.0 sec	New world record
1500 m Men	3 min 34.9 sec	3 min 33.1 sec
10,000 m Men	29 min 27.4 sec	27 min 39.4 sec
Marathon Men	2 hr 20 min 27 sec	2 hr 12 min 0 sec
Long jump Men	8.90 m	New world record set
Long Jump Women	6.82 m	New world record set
Javelin Men	90.10 m	91.98 m
Javelin Women	60.36 m	62.40 m

Table 3.7: Gold Medal performances at the 1968 Olympic Games (source www.athletix.org)

Together, these responses act to counter the reduced oxygen availability to deliver adequate oxygen to the working muscles.

As well as these immediate adaptations to altitude, there are longer-term physiological adaptations that result from a prolonged stay at altitude (weeks to months). These include:

- increased red blood cells and haemoglobin concentration (to increase oxygen carrying capacity of the blood)
- increased capillarisation
- increased mitochondria
- increased enzymes of the aerobic energy system.

Strategies to cope with competing at altitude

In order to prepare for competition at altitude, athletes often spend a period of time acclimatising to improve their ability to cope with hypoxia. The duration of acclimatisation required will vary with the specific elevation (that is, the higher the altitude, the longer the period of acclimatisation required). Also, acclimatisation at one altitude only ensures partial acclimatisation to further increases in altitude. For this reason, climbers

attempting to reach the summit of Mount Everest may spend months at camps along the way up to ensure adequate acclimatisation (Figure 3.38). Of importance for athletes; however, is that a prolonged stay at altitude may also have some negative consequences including a loss of body mass (both fat and lean muscle mass), mainly as a result of a loss of appetite.



Figure 3.38: Climber ascending Mount Everest



Figure 3.37: Picture of Bob Beamon's long jump world record

Altitude training

You may have realised that the longer-term adaptations to altitude that were listed earlier are similar to those adaptations obtained from a period of aerobic exercise training (learnt in Units 1 and 2; including increased capillarisation, mitochondria and aerobic enzymes). In addition, we know that increased red blood cells and haemoglobin provide increased oxygen carrying capacity of the blood that will be beneficial for aerobic performance. This raises the question of whether it may be useful for athletes to train at altitude for the purpose of improving their aerobic performance at sea-level. Unfortunately this does not seem to be the case, probably because athletes cannot train as hard at altitude as what they could at sea level, resulting in some degree of detraining after an extended stay above sea level. Therefore, training at altitude probably only benefits subsequent competition at altitude. For enhanced sea level performance it appears better to train at sea level, although one method of obtaining the physiological benefits of altitude while maintaining the quality (intensity) of training is to **live high train low**. That is, live at altitude to obtain the long term physiological advantages such as increased red blood cells and haemoglobin, but return to sea level for training to ensure high intensity quality training sessions can be completed. Alternatively, athletes may have access to hypobaric chambers or altitude tents. Athlete's utilising these strategies will spend the night (8pm to 6am) in these chambers and breathe the 'altitude' air while sleeping (Figure 3.39), and then go about their normal daily activities including training throughout the day at sea level. Of note, some athletes may train in specially designed altitude houses located at sea level. This would be considered as **live low train high**.

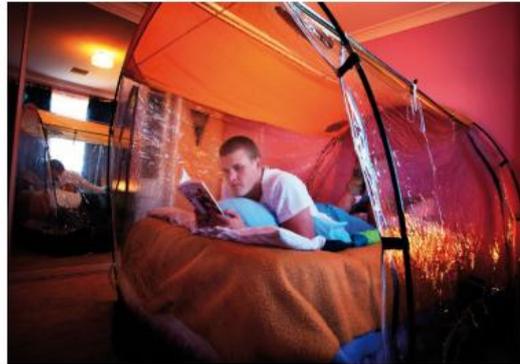


Figure 3.39: An athlete sleeping in an altitude tent

Key point summary:

- The air is thinner at altitude due to lower barometric pressure.
- The lower oxygen availability at altitude results in hypoxia (lack of adequate oxygen) and impaired $\dot{V}O_2$ max and aerobic performance.
- Performance in repeated sprint exercise is impaired at altitude due to the lower oxygen availability to replenish creatine phosphate stores and remove lactic acid.
- Performance in one-off sprint or power events may be enhanced at altitude due to lower air resistance and drag.
- Acute adaptations upon arrival at altitude include:
 - increased pulmonary ventilation
 - decreased plasma volume
 - increased heart rate and cardiac output at rest and during submaximal exercise.

- Long-term adaptations to a prolonged stay at altitude include:
 - increased red blood cells and haemoglobin concentration
 - increased capillarisation
 - increased mitochondria
 - increased aerobic enzymes.
- Acclimatisation to altitude improves the ability to cope with hypoxia.
- A prolonged stay at altitude may result in a loss of body mass and reduced training capacity (eventually leading to detraining).
- Sea level performance may be enhanced by living at altitude, but returning to sea level for training to ensure high intensity quality training sessions (live high, train low).
- Hypobaric chambers or altitude tents allow athletes to sleep in conditions similar to altitude, but still train at sea level during the day.

Revision questions:

Test yourself on revision questions 35–39 located at the end of this chapter.

Performance Enhancers

Text outcomes: *Performance enhancers (Unit 3)*

- Explain the physiological changes brought about by the use of performance enhancers.

Content that follows: *Performance enhancers (Unit 3)*

- Protein supplementation
- Caffeine
- Anabolic steroids

Elite athletes are always looking for an edge. Many are willing to try anything that might

help them run that split second faster or jump 1 cm further. Although such small improvements might not sound like much, a few milliseconds may mean the difference between an Olympics gold medal and fifth place in an event like the 100 m sprint. For this reason, a range of **performance enhancers**, or **ergogenic aids**, are applied in sport to gain any possible advantage. Some methods of enhancing performance are widely accepted, while others are prohibited or controversial. In general, those ergogenic aids that are prohibited in sport are those that result in potential harmful consequences or have detrimental side effects. Although in many cases this may not be enough to deter an athlete from using them. Track and field athlete Marion Jones won five medals at the 2000 Sydney Olympic Games (Figure 3.40). She was later stripped of her medals when it was found that she had been taking steroids. She still believes she would



Figure 3.40: Marion Jones

have won even without taking the drugs; however, nobody will ever know for sure.

Some substances are prohibited both in and out of competition, including:

- anabolic steroids
- certain hormones and growth factors such as erythropoietin (EPO; which stimulates the production of red blood cells) and growth hormone (which stimulates muscle growth)
- diuretics and masking agents (which may prevent the detection of other performance enhancers in a blood or urine test).

Substances such as alcohol and beta-blockers are banned in competition for particular sports only. For example, alcohol is banned in archery, while beta-blockers are prohibited in events such as bobsleigh, golf, gymnastics and shooting. This is because these substances may assist in decreasing shaking (improve steadiness). More specifically, beta-blockers reduce the heart rate which allows elite archers and shooters more time to take their shot (they are trained to shoot between heart beats to reduce vibration). Of note, alcohol can be a disadvantage in many sports since it increases dehydration and impairs decision-making ability.

Despite the wide range of performance enhancers used in sport, in Units 3 and 4 we will specifically focus on protein supplements, caffeine and anabolic steroids. These are discussed in further detail throughout this section.

Protein supplementation

Many athletes, particularly weightlifters and bodybuilders, consume extra protein or amino acids in the form of powders (Figure 3.41). The rationale behind this is that increased protein

in the diet will translate to increased muscle bulk and perhaps help repair muscle damage. In fact, some athlete's view these substances as a natural alternative to steroids. However, there appears to be little benefit in consuming these products for those individuals that already have adequate protein intake from a balanced diet. It is also important to note that excess protein intake alone will not stimulate muscle growth and development. A resistance training program designed specifically for muscle hypertrophy is needed for the best results. Although regular protein supplementation does not stimulate muscle growth and development alone, there is evidence to suggest that the adaptations to resistance training may be enhanced by consuming a protein and high glycaemic carbohydrate snack immediately following weight lifting sessions due to enhanced production of naturally occurring anabolic hormones and protein building.

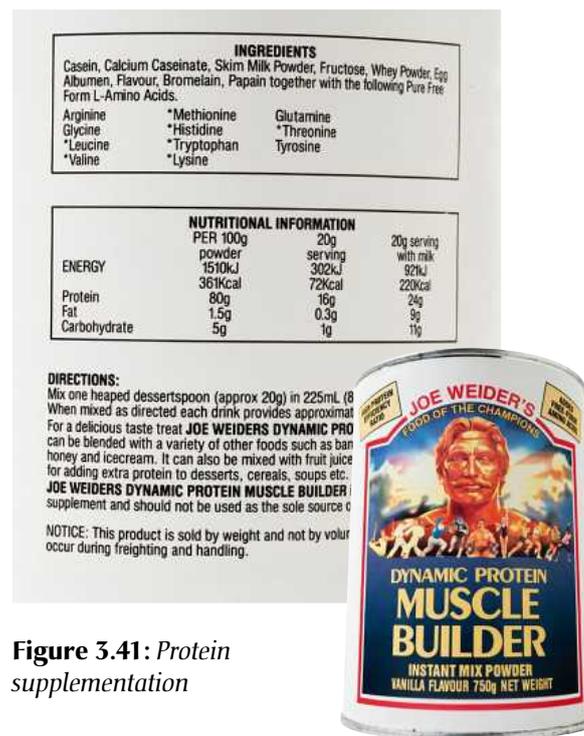


Figure 3.41: Protein supplementation

Protein Supplementation:**Is a potential advantage because it:**

- may enhance the adaptations to resistance training (increased muscle hypertrophy), particularly if protein intake from the normal diet is inadequate.

Is a potential disadvantage because:

- high protein levels in the diet may increase the risk of osteoporosis and colonic cancers, and impair kidney function in the long-term.

Caffeine

Caffeine is a widely available substance found in a variety of foods and drinks including chocolate, coffee, tea, many soft drinks and energy drinks. Following consumption, caffeine is quickly absorbed into the bloodstream causing a number of physiological effects in the body. In particular, caffeine is a stimulant, thereby increasing arousal which may be of benefit for improving reaction time, concentration and decision making ability. In addition, caffeine may reduce an athlete's perception of fatigue or effort. If exercise feels easier or less fatiguing, an athlete may work harder or go for longer before tiring. Caffeine also increases the availability of free fatty acids for ATP production, which in turn stimulates increased fat oxidation. This may assist in sparing some muscle glycogen and consequently enhance performance in endurance activities lasting more than one hour.

The above-mentioned benefits of caffeine may be obtained by consuming 3–6 mg per kg

of body mass approximately one hour prior to exercise. This is equivalent to consuming 6–10 cans of Coca Cola or 1.5 kg of chocolate for a 70 kg man. However, commercially available caffeine tablets are available for this purpose (Figure 3.42). Of note, the effect of caffeine on performance may be greater in individuals that do not regularly consume caffeine. So, for regular users, a washout period may be helpful whereby caffeine consumption is gradually decreased leading up to competition, with none taken at all in the couple of days before the pre-exercise dose. Ingesting high amounts of caffeine is not without consequences. Some individuals may feel symptoms including restlessness, muscle twitching, irritability and an elevated heart rate and blood pressure. While this may be good for some athletes, others may become overanxious. Caffeine is also a diuretic, which may be detrimental during exercise in the heat when dehydration may limit performance. Like other ergogenic aids, caffeine should be trialled in training before a major competition.



Figure 3.42: Caffeine supplementation

**UWA research snapshot:
Effect of caffeine ingestion
on repeated sprint running
performance (Carr et al., 2008)**

Team sport athletes are required to perform repeated maximal sprint efforts with limited recovery in between over the duration of a game. Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia recently tested whether the ingestion of caffeine (6 mg/kg) 60 minutes prior had beneficial effects on repeated sprint running performance. It was found that ingestion of caffeine improved repeated sprint running performance compared to when caffeine was not ingested. In addition, potential benefits were observed for the effect of caffeine on reaction time. Therefore, caffeine supplementation prior to exercise may be of benefit for team sport athletes.

Caffeine Supplementation:

Is a potential advantage because it:

- increases arousal which may improve reaction time, concentration and decision making ability
- may reduce an athlete's perception of fatigue or effort
- increases the availability of free fatty acids for ATP production, which may spare muscle glycogen, thereby enhancing prolonged endurance performance.

Is a potential disadvantage because it:

- may lead to restlessness, feeling overanxious, muscle twitching, irritability, an elevated heart rate and blood pressure
- is a diuretic and may increase the risk of dehydration.

Revision questions:

Test yourself on revision questions 40 and 41 located at the end of this chapter.

Anabolic steroids

There are a wide range of different *anabolic steroids* available which can be taken in oral form or injected directly into the muscle. These drugs are made in such a way that they simulate the anabolic actions of the male sex hormone testosterone. Although this hormone is found naturally in both men and women, levels are much higher in men as it is the primary hormone responsible for many of the secondary sex characteristics of the male body such as facial hair and a deep voice. However,

more importantly for athletic performance, this hormone plays a crucial role in muscular development. Therefore, anabolic steroids enhance performance in events involving muscular strength and power. In addition, they may benefit endurance performance by improving the rate of tissue repair, meaning athletes can train harder and longer with less recovery needed.

Figure 3.43: Anabolic steroids enhance muscular development



The use of anabolic steroids is legal for medical reasons. However, sale or possession of anabolic steroids for nonmedical reasons (like to enhance sports performance) is illegal. One important reason for prohibiting the use of anabolic steroids is the side-effects. Prolonged use may result in impaired natural production of testosterone by the body, infertility, acne, decreased testicular volume and increased levels of aggression and hostility. The latter is sometimes termed ‘roid rage’. In women, side-effects include a deepening voice, facial hair and menstrual irregularities. Other more serious consequences include increased risk of heart disease and liver dysfunction. It is believed that many athletes have died prematurely as a result of prolonged use of anabolic steroids.

Famous doping cases

– the fall of Ben Johnson

At the 1988 Seoul Olympics, the 100 m sprint was won by Canadian athlete Ben Johnson in a world record time of 9.79 sec. After the race, a urine sample revealed traces of an anabolic steroid. He was disqualified and the world record disallowed. It was later found that he had been using steroids since 1981. After serving a ban from the sport, he made a comeback in 1991 only to be caught again for excess testosterone in 1993 and given a lifetime ban.



Figure 3.44: Ben Johnson

Class task:

Discussing anabolic steroids

Discuss the following:

- What should happen to World Records of athletes who test positive for steroids years later?
- Should the use of anabolic steroids be legalised?
- The AFL has a three-strikes policy for the use of illicit drugs. This means that a player who tests positive to drugs will remain anonymous until three positive test results have been obtained within a four year period. What are the advantages and disadvantages of this policy? Consider the perspectives of the player, their family, the team, the club, the sponsors and the supporters.

Anabolic Steroid Use:

Is a potential advantage because it:

- facilitates muscle development, assisting performance in strength and power events
- improves the rate of tissue repair, meaning athletes can train harder and longer with less recovery needed.

Is a potential disadvantage because it:

- leads to increased levels of aggression and hostility, infertility, acne, decreased testicular volume, liver dysfunction, heart disease and possibly even death
- causes a deepened voice, facial hair and menstrual irregularities in women.

Revision questions:

Test yourself on revision questions 42 and 43 located at the end of this chapter.

Training Programs

Text outcomes: *Training to improve performance (Units 3 and 4)*

- *Critically evaluate training programs designed to improve performance.*

Content that follows: *Training programs (Unit 4)*

- *Periodisation*
- *Pre-season*
- *In-season*
- *Off-season*
- *Macrocycle*
- *Microcycle*

Periodisation

A successful training program involves thorough planning and is structured in a specific way to ensure that an athlete's best performances will be achieved at the right time of the season (for example an important competition like the Olympic Games). This is achieved through a process called **periodisation** whereby the training program is organised into different periods or blocks of time. The training program for an entire season or year is typically divided into three main phases. These include:

1. Preparatory Phase (pre-season)

2. Competition Phase (in-season)
3. Transition Phase (off-season).

For this reason, a great deal of thought must go into planning a training program, and a well written one will produce results. At the same time, the training program must be flexible to some extent to allow for adjustments based the individual athletes rate of progress.

Preparatory Phase (Pre-season)

The goal of the preparatory phase is exactly as the name suggests – it is to prepare for competition. This 'pre-season' training may be divided into two other phases; the **general preparatory phase**, followed by the **specific preparatory phase**. The purpose of the general preparatory phase is to establish a base-level of fitness and skills before moving onto the next phase of more specialised training. For this reason, the emphasis is typically on a high volume of moderate intensity physical activity. For example, a netballer may participate in longer runs at the start of the training year to develop their cardiorespiratory fitness. In the specific preparatory phase, training becomes more specific to the sport the athlete is training for. There is still a strong emphasis on the development of base levels of cardiorespiratory endurance; however, the intensity of training is increased (for example, adding in time trials or interval training), with an increasing focus on skill development and technique. Table 3.8 represents a typical week of training for an AFL player during the preparatory phase.

Table 3.8: National AFL competition pre-season training program for a midfielder player (prepared by Professor Brian Dawson, School of Sport Science, Exercise and Health, The University of Western Australia)

Activity	Type of training	Outcome
Sunday Beach Swim 500 m Body Surf 15 min (No organised training)	Cross-training Recovery	Aerobic energy system (easy recovery)
Monday (AM) Squad Training 60–90 min 40 min interval running 4 x 150m, go every 90s (80% max speed) 6 x 100m, go every 60s (85% max speed) 8 x 50m, go every 45s (90% max speed) Small sided handball game 5 vs 5 (4 x 4 min quarters) Beach swim 15 min	Interval training Interval (game) training Cross-training Recovery	Aerobic/Anaerobic energy system Conditioning Aerobic/Anaerobic energy system conditioning and skills/strategy Aerobic energy system (easy recovery)
Monday (PM) Gym 60 min 3 sets of 6–10 repetitions of 8-10 exercises Massage 20 min (Focus on leg muscles)	Resistance training Massage (Recovery)	Muscular strength and power Recovery
Tuesday (AM) Team Meeting 30 min Leadership/Team Values Discussion for team trademark Tuesday (PM) Squad Training 60 min Specific skills Goal kicking Close in handball Contested marking Tackling Cold water immersion 10°C for 10 min	Individual skill practice Recovery	Skill Recovery

Activity	Type of training	Outcome
<p>Wednesday (AM) Strategy/Tactics Meeting 30 min Discussion of game plan Focus for training session (to follow)</p> <p>Squad Training 90 min Game play, specific practice of elements of game plan</p> <p>Beach Swim 15 min</p> <p>Wednesday (PM) Team Meeting 30 min Video Review of Training session (just done) Discussion of game plan</p> <p>Gym 60 min 3 sets of 6–10 repetitions of 8–10 exercises</p> <p>Massage 20 min (Focus on leg muscles)</p>	<p>Strategy meeting</p> <p>Interval training with ball (skill)</p> <p>Cross-Training Recovery</p> <p>Resistance Training</p> <p>Massage (recovery)</p>	<p>Strategy/Tactics</p> <p>Aerobic/Anaerobic energy system conditioning and skills/strategy</p> <p>Aerobic energy system (easy recovery)</p> <p>Muscular strength and power</p> <p>Recovery</p>
<p>Thursday DAY OFF (Optional recovery/skills - no compulsory training)</p>		
<p>Friday (AM) Squad Training 60–90 min 30 min interval running 6 x 100m (50m shuttles), go every 60s (85% max speed) 6 x 50m (25m shuttles), go every 45s (90% max speed) 6 x 25m (12.5m shuttles), go every 30s (90% max speed) 6 x 15m, go every 10s (95% max speed)</p> <p>Small sided games 4 vs 4 (4 x 4 min quarters)</p> <p>Beach Swim 15 min</p>	<p>Interval Training</p> <p>Interval (game) training</p> <p>Cross-Training Recovery</p>	<p>Aerobic/Anaerobic energy system conditioning</p> <p>Aerobic/Anaerobic energy system conditioning and skills/strategy</p> <p>Aerobic energy system (easy recovery)</p>

Activity	Type of training	Outcome
Friday (PM) Gym (for selected players) 60 min 3 sets of 3–6 repetitions of 6–8 exercises	Resistance Training	Muscular strength and power
Saturday (AM) Squad Training 60 min Swim/Water Running (Pool Session) Cold water immersion 10°C for 10 min	Interval Training Cross-Training Recovery	Aerobic/Anaerobic energy system conditioning Recovery

Competition Phase (In-season)

The competition (in-season) phase of training may involve a single competition, or several competitions leading up to one larger event. The period of training in the immediate lead up to the competition is termed the *pre-competition phase*. Here, the goal of training is to approach peak condition. This involves highly specialised training, with an emphasis on the quality (intensity) of training, rather than quantity (total volume) of training. The coach may incorporate some practise competitions like early season races or ‘scratch matches’ for competitive experience, and adequate recovery is emphasised. At this stage in the training plan, all of the physical capacities and technical components required for optimal performance should be fully developed, so the athlete enters the *competition phase* ready to compete. During

the competition phase, the amount of work completed in training is simply enough for the maintenance of fitness levels (reduced volume, maintained intensity), rather than continued overload to try to stimulate further improvement. Instead, the focus may be on developing the psychological and tactical aspects of performance. In a well planned training program, this is the time of year in which peak performance will be achieved. Table 3.9 represents a typical week of training for an AFL player during the competition phase.

Table 3.9: National AFL competition in-season training program for a midfield player (prepared by Professor Brian Dawson, School of Sport Science, Exercise and Health, The University of Western Australia)

Activity	Type of training	Outcome
Sunday Walk–jog 15 min on grass Swim 500 m (easy) Cold water immersion 10°C for 10 min	Continuous training Cross-training Recovery	Aerobic energy system (easy recovery)

Activity	Type of training	Outcome
<p>Monday Gym 40 min Weights: 2–3 sets of 6–10 repetitions of 6–8 exercises</p> <p>Strategy meeting 50 min Team meeting (whole squad) 30 min. Review of previous game and early focus on next opponent. Line meeting (midfield players) 20 min. Review of midfield impact in previous game and early focus on next opponent.</p>	<p>Resistance training</p> <p>Strategy meeting</p>	<p>Muscular strength and power</p> <p>Strategy/skill</p>
<p>Tuesday Team meeting (whole squad) 20 min</p> <p>Squad training 45–60 min Skills/game play and conditioning involving 3–4 drills with footballs and tackle pressure in 1–2 drills</p> <p>Squad training 80 min Specific skills 30 min: General kicking, kicking for goal, marking</p> <p>Flexibility 30 min: 8–10 stretches held for 30–40 sec repeat twice on each major muscle group</p> <p>Massage 20 min: Focus on legs</p>	<p>Strategy meeting</p> <p>Interval training with ball (skill)</p> <p>Individual skill practice</p> <p>Static stretching</p> <p>Massage</p>	<p>Confirm things to work on & put into practice during training</p> <p>Anaerobic capacity (repeated moderate-hard efforts) and skills</p> <p>Recovery (light). Skill</p> <p>Flexibility</p> <p>Recovery</p>
<p>Wednesday No training. Some choose optional activities (boxing, cycling, swimming)</p>	<p>Cross-training</p>	<p>Aerobic energy system (easy recovery)</p>

Activity	Type of training	Outcome
<p>Thursday <i>Team meeting (whole squad) 20 min</i></p> <p><i>Squad training 45–60 min</i> Skills/game play and conditioning involving 2–3 drills with footballs and shadow pressure. Focus on clean, skilled ball movement</p> <p><i>Gym 40 min</i> Weights: 2–3 sets of 6–10 repetitions of 6–8 exercises</p> <p><i>Fly East for Game</i></p>	<p>Strategy meeting</p> <p>Interval training with ball (skill)</p> <p>Resistance training</p>	<p>Focus on opponent’s style of play</p> <p>Anaerobic capacity (repeated, moderate efforts) and skills</p> <p>Muscular strength and power</p>
<p>Friday <i>Squad training 30 min</i> 2–3 drills with emphasis on touch/skills and no pressure</p> <p><i>Strategy meeting 50 min</i> Team meeting (whole squad) 30 min. Focus on opposition and own game style Line meeting (midfield players) 20 min. Focus on match-ups</p>	<p>Interval training</p> <p>Strategy meeting</p>	<p>Aerobic (easy recovery)</p> <p>Strategy/skill</p>
<p>Saturday <i>Walk–jog 15 min</i></p> <p><i>Game (including warm-up and recovery) 4 hr</i> Total distance ~12.6 km, number of high intensity efforts (≥ 15 km/h) ~295, number of high intensity sprints (≥ 20 km/h) ~77.</p> <p><i>Fly West to home</i></p>	<p>Continuous training</p> <p>Competition</p>	<p>Aerobic (easy) Loosen-up and wake-up</p> <p>Aerobic and anaerobic capacity (repeated, very hard efforts) and skills</p>

Transition Phase (Off-season)

The *transition phase* is typically the period of time following the major competitive season (the off-season). During this time, athletes aim to maintain cardiorespiratory fitness, while recovering from the other demands of the competitive season. 'Active rest' is encouraged to prevent complete detraining. This involves

participation in physical activities other than that which the athlete normally trains for (cross-training). For example a track and field athlete may swim. Some athletes may use this time to deal with injuries and may even require surgery that couldn't take place during the competitive season. Table 3.10 summaries the phases of training for a soccer player.

Table 3.10: The phases of training for a soccer player

Training phase	Type of activity	Purpose
General preparatory phase	Moderate intensity & increased volume (e.g. long runs) Cross training	Develop fitness (especially cardiorespiratory endurance)
Specific preparatory phase	Increased intensity (e.g. intervals, time trials) Skills Repeated sprint ability	Further develop fitness Enhance and develop skills and technique
Pre-competition phase	Skills & tactics Small sided games Scratch matches	Gain competitive experience Fine tune technical aspects of game Hit top form
Competition phase	Training (reduced volume) Weekly Games	Maintain peak form Adequately recover
Transition phase	Swimming Cycling Social indoor soccer	Maintain base fitness while recovering from soccer season

Macrocycles and microcycles

Within each phase of training there are smaller periods of time referred to as *macrocycles* and *microcycles*. A *macrocycle* is typically a 4-6 week period in which there is a specific focus/aim of training. For example, during the specific preparation phase of training, a track sprinter may focus on strength development in one macrocycle, followed by explosive power in the next. On the other hand, *microcycles*

consist of smaller periods of training (typically a week). A number of microcycles combine to make up a macrocycle. Like macrocycles, microcycles also have specific goals, but they are smaller ones, designed to contribute towards the overall aim of the macrocycle. Within a microcycle you have training days and sessions. Table 3.11 shows how microcycles and macrocycles combine to make up larger training periods.

Table 3.11: Relationship between microcycles and macrocycles for a triathlete

Annual Plan																																							
June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	April	May																												
Phases of Training																																							
General Preparation			Specific Preparation			Pre-Competition		Competition			Transition																												
Macrocycles																																							
1	2	3	4	5	6	7	8	9	10	11	12																												
Microcycles																																							
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

Key point summary:

- Periodisation is the planned organisation of training into phases.
- The training plan is typically divided into three main phases: Preparation phase, competition phase, and transition phase.
- The preparation phase is further divided into:
 - a 'general preparation phase' to establish a base-level of fitness and skills
 - a 'specific preparation phase' in which training becomes more sport and competition specific.
- The competition phase includes:
 - a 'pre-competition phase' to approach peak condition
 - a 'competition phase' in which the athlete performs at their peak.
- The transition phase is focused on active recovery and avoiding detraining.
- Macrocycles are periods of time within the training plan (typically 1 month) in which there is a specific focus/goal for training.
- Microcycles are smaller periods of time within the training plan (typically a week) which combine to contribute towards the goal of the macrocycle.

Revision questions:

Test yourself on revision questions 44–49 located at the end of this chapter.

Specific energy system requirements

Content that follows: Training programs (Unit 4)

- *Specific energy system requirements*

The actual activities performed within each training session will be dependent upon which component of fitness and energy systems are trying to be developed in each microcycle within the macrocycle. We know from Units 1 and 2 that the **health-related components of fitness** include:

- **Cardiorespiratory endurance** – the ability of the respiratory and cardiovascular systems to supply oxygen to the working muscles during sustained exercise.
- **Muscular strength** – the ability to exert force in a single maximal effort.
- **Muscular endurance** – the ability to perform repeated submaximal contractions without undue fatigue.
- **Flexibility** – the range of motion about a joint.
- **Body composition** – the proportion of fat and lean mass in the body.

Each of these components of fitness is important for athletic performance, as well as overall health and wellbeing. In addition, performance in various sporting activities will be influenced by the **performance-related components of fitness** or **skill-related components of fitness**. These include:

- **Agility** – the ability to rapidly change direction. This is important for activities like sidestepping an opponent on the field, or in court sports such as netball where it is necessary to rapidly pivot or change direction.
- **Balance** – the ability to maintain stability while in motion. Balance is vital for activities like completing a tumbling series on the balance beam in gymnastics or when trying to stay on your feet while struggling with an opponent in a wrestling match.
- **Coordination** – the ability to integrate the senses and movement of body parts to perform tasks efficiently. This component of fitness is important for most sports. An example is the hockey player controlling the ball while dodging opponents and reading the play.
- **Reaction time** – the time taken from when a stimulus is presented to when the appropriate reaction is taken in response. For instance, the time taken to respond to a feint or dummy in rugby.
- **Speed** – the ability to perform a movement quickly. Speed is crucial in many events, such as the 100 m sprint, or team sports in which players are required to sprint for the ball.
- **Power** – the ability to perform a strong movement quickly (or the rate at which work can be performed). Examples of the use of muscular power in sport include taking a mark in football, or the start of a 100 m sprint or track cycling race.

We also know from Units 1 and 2 that there are three main pathways in the body by which ATP can be produced. These include the **ATP-CP system** (or phosphagen system), **lactic acid**

system (anaerobic glycolysis) and the *aerobic energy system*. These three systems of energy production operate together to produce ATP, with one particular system being the main

supplier of ATP at any one time, depending on the body's requirements. The characteristics of these three energy systems are summarised in Table 3.12.

Table 3.12: Characteristics of the three pathways of ATP production

	ATP-CP system	Lactic acid system	Aerobic system
Fuel source	CP	Carbohydrate	Carbohydrate & Fat (<i>& Protein</i>)
O₂ required	No	No	Yes
Speed of energy supply	Most rapid	Rapid	Slow
Limitation / cause of fatigue	Limited stores of CP	Lactic acid production	Unlimited
Duration	~8 sec	~30–60 sec	~1.5–3 hrs
Type of activity	Sprint / power activities	Sprint endurance activities	Long duration endurance
Examples	Long jump, sprint for ball in soccer	400 m sprint, 100 m freestyle race	Marathon, Olympic distance triathlon

As mentioned earlier, the specific activities performed within each training session are dependent upon the components of fitness and energy systems that the athlete is trying to develop within that cycle. Of course, this is also dependent upon the particular sport of interest, since each different sport has its own fitness demands. A 100 m sprinter will focus on improving their speed, muscular power and reaction time (Table 3.13), while an open water swimmer training for the Rottneest Swim may

be more concerned with their cardiorespiratory fitness and muscular endurance (Table 3.14). In contrast a team sport player must train multiple components of fitness and energy systems (Table 3.15).

Table 3.13: Typically weekly in-season training program for a 100 m sprinter

Time/Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	GYM 8 exercises 3 sets x 8 reps Focus: Maintain Strength Power Development	OFF	OFF	OFF	REST DAY	COMPETITION Maximal intensity performance	RECOVERY SESSION Beach 15 min Light Sand Jog 10 min Group Stretch Flags/short beach sprints 10 min in Ocean (Wade/Swim)
PM	TRACK SESSION 1 km jog w/up 10 min stretching 10 min drills 4 x 5 reps through (60 m, 80 m, 100 m, 120 m, 140 m) walk back recovery 1 km c/down	GRASS SESSION 1 km jog w/up 10 min stretching 10 min drills Plyometrics 2 x 3 x 20 m bounding 2 x 3 x 20 m hopping 2 x 6 reps 80 m 1 km c/down	GYM 8 exercises 3 sets x 8 reps Focus: Maintain Strength Power Development	TRACK SESSION 1 km jog w/up 10 min stretching 10 min drills 2 x 6 reps block starts 3 x 6 reps speed play (maximal 30 m sprint, coast 30 m, sprint 30 m)	REST DAY	OFF	OFF
*Note – Key energy system = ATP-CP system Key components of fitness = speed, muscular strength and power, reaction time							

Table 3.14: Typically weekly in-season training program for an open water swimmer

Time/Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	1500 m w/up Easy swim + drills 5 x 800 m Depart on 12' Target = 11' / rep 2 x 400 m c/dwn (swim/kick/pull/swim) TOTAL - 6.3 km	Gym 10 Exercises 4 Sets of 15 Reps Focus = Endurance	800 m w/up Easy swim + drills 1000 m + 800 m + 400 m Depart on 15', 12', 6' Target = 13'30, 11', 5'15 TWICE THRU 5 x 200 dps c/dwn TOTAL - 6.2 km	Gym 10 Exercises 4 Sets of 15 Reps Focus = Endurance	1200 w/up Easy swim + drills 4 x 500 descending 1-4 Rep 4 @ MAX EFFORT Departing on 7' 8 x 200 IM tempo Departing on 3' 400 (kick/swim) c/dwn TOTAL - 5.2 km	Race 5 km Open Water Ocean Swim MAX RACE EFFORT TOTAL - 5 km	REST DAY
PM	800 m w/up Easy swim + drills 400m+300m+200m+100m Depart on 5'45, 4'15, 3', 2' FOUR TIMES THRU 4 x 200 (100 kick/100 pull) TOTAL - 5.6 km	1500 m w/up Easy swim + drills 8 x 400 m Depart on 6' Target = 5'10/rep 1000 m Tempo c/dwn TOTAL - 5.7 km	1000 m w/up Easy swim + drills 30 x 100 m Depart on 1'30 Target = 1'15/rep 3 x 200 m c/dwn TOTAL - 4.6 km	1500 m w/up Easy swim + drills 3 x 1000 m Pull/Paddles Depart on 14' 10 x 100 Fartlek c/dwn Depart on 1'45 TOTAL - 5.5 km	OFF	OFF	REST DAY
*Note – Key energy system = aerobic energy system Key components of fitness = cardiorespiratory endurance, muscular endurance							

Table 3.15: Typically weekly in-season training program for a hockey player

Time/Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	OFF	OFF	GYM 15 min Aerobic Cycle (on ergo) 6 Exercises (2 Push, 2 Pull, 2 Legs) Focus: Maintain Strength Power Development	OFF	REST DAY	GAME Maximal Game Intensity	RECOVERY SESSION Beach 10 min Light Sand Jog 10 min Group Stretch 10 min in Ocean (Wade/Swim)
PM	PITCH SESSION 30 min Match Analysis 30 min W/up + Light Skills 15 min Penalty Corners 15 min Top-up Conditioning: 8 x Pitch Lap (Stride Length/Jog Width) Departing every 2 min	PITCH SESSION 20 min w/up + skills 5 x 3:30 4 v 3 (SSG) ½ Pitch (width) 2 min Recovery / Rep 5 min Recovery 4 x 2:00 ½ Pitch Press Attack vs Defense 1 min Recovery / Rep 10 min c/dwn + Stretch	X-TRAIN Optional 30 min Swim Session or LSD Jog	PITCH SESSION 20 min w/up + skills 8 x 1:30 3 v 3 (SSG) ½ Pitch (width) 1 min Recovery / Rep 20 min Penalty Corners 10 min c/dwn + Stretch	REST DAY	OFF	OFF

*Note – Key energy system = ATP-CP system, lactic acid system and aerobic energy system
Key components of fitness = cardiorespiratory endurance, agility, reaction time, speed, power muscular strength and endurance

Key point summary:

- The health-related components of fitness include:
 - cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition.
- The performance/skill-related components of fitness include:
 - agility, balance, coordination, reaction time, speed, and power.
- The three energy systems are:
 - the ATP-CP system, lactic acid system, and the aerobic energy system.
- Training activities need to reflect the fitness demands and the energy needs of the sport or activity.

Revision questions:

Test yourself on revision questions 50–53 located at the end of this chapter.

Content that follows: Training programs (Unit 3B)

- *Peaking*
- *Tapering*
- *Maintenance*
- *Recovery: Massage, compression garments, cold water immersion, warm water immersion, contrast water therapy, stretching*
- *Overtraining*

Peaking

The purpose of planning the organisation of a training program into phases or blocks of time is to achieve peak performance at a specific time in the training cycle (for example, at an important competition like the Olympic Games or a Grand Final). This concept is referred to as **peaking**. This is easier to achieve in sports in which the athlete is required to peak once or twice a year (like a high jumper for the National Championships or the Olympics), and is much harder in team sports where games occur each week. In this type of situation, performance must be balanced throughout the whole season in order to have a chance to make it to the Grand Final itself. In a well planned training program, the athlete will peak at the appropriate time during the competition phase of the training cycle (Figure 3.45).

Tapering

A heavy volume of training overloads the body, which can suppress physiological capacity and hence peak performance. For this reason, a **taper** in training is used to elicit

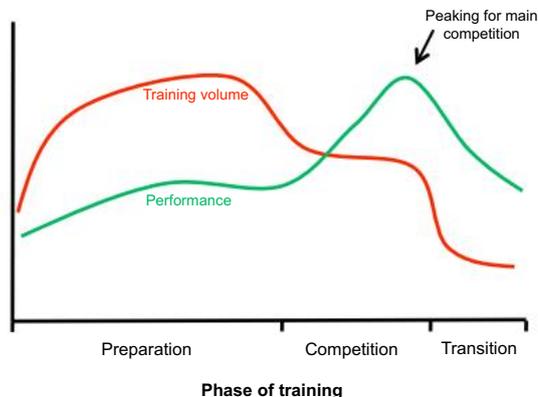


Figure 3.45: 'Peaking' of performance

peak performance at important competitions or events. Tapering involves a decrease in training load (overall training volume) while maintaining or possibly even increasing intensity. The reduction is generally between 1/3 to 1/2 of overall training volume. For example, a typical in-season session for a middle distance runner may be reduced from 3 sets of 6 repetitions of 600 m to 2 sets of 4 repetitions of 600 m at a faster pace leading up to an important race. This reduction in training load allows for a balance between maximising the fitness state and minimising levels of fatigue. Of interest, it appears that power athletes require a longer taper (10–21 days) compared to endurance athletes (7–10 days). This is related to the fact that speed and power are suppressed with intense periods of high volume training.

Although applying this concept to the training plan may be relatively easy for individual athletes like runners or swimmers with a set competition schedule involving a few important meets per year, it is much more difficult for the team sport athlete required to play each week. Under these conditions, it is not possible to taper

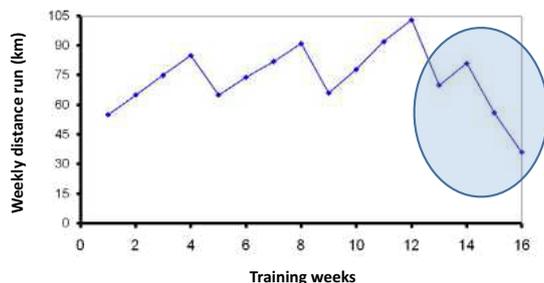


Figure 3.46: *Tapering for a distance runner prior to a major event*

before each game, otherwise a state of detraining would ultimately result. Instead, weekly training sessions may be planned to allow for a brief taper by scheduling heavy sessions mid-week and lighter sessions in the days immediately prior to the game.

Maintenance

As mentioned previously, the purpose of the preparatory phase of training is to develop all of the physical capacities and technical components required for optimal performance. As the athlete enters the competition phase of training they should be ready to compete. During this time, the amount of work completed in training is simply enough for the maintenance of fitness levels (reduced volume, maintained intensity), rather than continued overload to try to stimulate further improvement. This is evident when comparing the average training load of our AFL footballer in pre-season compared to in season (Tables 3.8 and 3.9).

Recovery

After each training session, the body attempts to recover, by replenishing fuel stores and repairing muscle damage. Despite the belief that ‘the more work, the better the performance’, this is not necessarily the case if adequate recovery is not provided. It is during recovery that the body adapts and overcompensates to get a training effect. If adequate recovery is not allowed between sessions,

the athlete will become progressively more tired and fatigued, ultimately resulting in decreased performance. Some athletes attempt to enhance recovery between training and competition by using a variety of modalities as described below (Figure 3.47). However, it is important to note that many of these recovery modalities have not been proven effective, despite widespread use in many sports.

- **Massage** – involves rubbing and kneading the muscles and connective tissue of the body. This is believed to enhance the removal of waste products (like lactate), and to decrease muscle soreness and swelling post-exercise.
- **Compression garments** – are specially designed items of elasticised clothing that are made to fit tight. When worn during recovery, compression garments may enhance the action of the venous muscular pump and reduce muscle soreness, although the evidence for this is limited.
- **Cold water immersion** – typically involves immersion of the body in cold water (< 15°C) for a period of 10–20 minutes after exercise to reduce blood flow, inflammation, muscle spasm and pain.
- **Warm water immersion** – may involve immersing the body in warm water (> 37°C) for a period of 10–20 minutes which increases body temperature and blood flow.
- **Contrast water therapy** – requires the athlete to alternate between heat and cold exposure. This is believed to reduce swelling and inflammation due to a ‘pumping action’ caused by the blood vessels as they relax and constrict as the athlete moves from the hot to the cold water.
- **Stretching** – is commonly performed by athletes for the purpose of reducing soreness, however, the scientific evidence to support this practise is not clear.



Figure 3.47: Commonly used recovery modalities include *a*) massage, *b*) compression garments, *c*) cold water immersion, *d*) stretching

Often athletes will try a combination of the above methods in order to optimise recovery. For example, some athletes may use ice massage or contrast hot and cold water immersion. However, much of the research in this area does not show clear benefits. Nonetheless, many athletes and coaches would argue that if it makes the athlete feel better, regardless of any performance benefit, then the use of these modalities is still worthwhile.

muscle soreness compared to contrast immersion and no immersion. In addition, cold water immersion caused a more rapid recovery of performance, with higher leg strength and repeated sprint ability 48 hours later. These results suggest that cold water immersion can assist recovery from exhaustive simulated team sport exercise.

Practical investigation

Evaluate the impact of post-exercise recovery strategies

See Appendix B2 for a practical investigation, along with questions and report-writing format recommendations.

UWA research snapshot: *Enhancing recovery from team sport exercise (Ingram et al., 2009)*

Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia recently investigated the effect of water immersion on recovery from exhaustive simulated team sport exercise. Male team sport athletes did either hot/cold contrast water immersion, cold-water immersion or no recovery treatment for 15 minutes immediately after exercise and again 24 hours later. It was found that cold water immersion reduced

Overtraining

While a well-designed training program results in peak performance at the appropriate time in the training cycle, an inadequate balance between training load and the time allowed for recovery may result in a state of *overtraining*. Symptoms of overtraining include a lack of energy, muscular aches, impaired performance, and maybe even a loss of enthusiasm for training and competition. Other effects of overtraining include increased risk of injury and illness (especially colds). The condition typically develops gradually and may go unnoticed for a considerable period of time as it is often confused with a ‘performance slump’. The risk of overtraining may be reduced by allowing 24–48 hours of recovery between ‘heavy sessions’ and ensuring adequate rest, sleep and nutrition. Some professional AFL teams attempt to monitor overtraining and recovery status by comparing weekly performance of single and repeated countermovement jumps. A reduction in performance may suggest inadequate recovery and allow for training load to be reduced appropriately (Cormack et al., 2008).

Injured athletes

Content that follows: *Training programs (Unit 4)*

- *Injured athletes*

The primary goal for the injured athlete is to limit the amount of detraining that results during the period in which they are unable to compete in their sport. A base level of fitness may be maintained in a number of ways. For example, the runner with a lower limb stress fracture may participate in water running, while a triathlete recovering from a knee or ankle operation may do one-legged cycling on a stationary cycle ergometer (Figure 3.48). Another issue of particular importance for the team sport athlete is the isolation that can result from no longer being able to train

with the rest of the team. For this reason, the injured athlete should be

included as much as possible in team activities. Return to competition requires the injured athlete to be ready both physically as well as psychologically.

The latter is quite important given that many injured athletes returning to competition feel anxious about the possibility of re-injury and a lack of competitive confidence.



Figure 3.48: An injured athlete

Key point summary:

- Peaking involves the achievement of optimal performance at the appropriate time in the training plan.
- Tapering involves the reduction of training volume in the days/weeks leading up to a competition to allow the body to recover from training overload, thereby maximising physiological capacity and performance.
- Fitness levels need to be maintained throughout the season with an appropriate training load that permits maximum performance.
- Adequate recovery between training sessions is needed to allow a physiological training effect (overcompensation).
- Recovery strategies commonly employed by athletes include:
 - massage, compression garments, cold water immersion, warm water immersion, contrast water therapy and stretching.
- An imbalance between training load and recovery will lead to overtraining which is characterised by:
 - a lack of energy, muscle aches, impaired performance, lack of enthusiasm, increased risk of injury and illness.
- The primary goal of the injured athlete is to limit the amount of detraining.

Revision questions:

Test yourself on revision questions 54–58 located at the end of this chapter.

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Appendix A: Writing the practical investigation report

Writing the report

If you are required to write a report as part of your practical investigation, you may choose to use the following format.

Title: Title of the practical investigation.

Aim: State what you hope to achieve in the experiments (~30–50 words).

Introduction: Define and discuss the sport science principles being investigated (~200 words).

Hypotheses: Identify the expected results or anticipated outcomes (*statements*).

Method: Identify the steps taken to complete the experiments (~100 words).

Results: Present the data and findings in the appropriate format (*for example, graphs, diagrams and tables*).

Response to the questions: Write the questions out and respond.

Discussion: Provide a detailed discussion of the results. Apply the sport science principles under investigation to other sporting contexts (~400 words).

Conclusion: Summarise the discoveries made. Make links to each hypothesis and include limitations of the experiment (~100 words).

Appendix B1

Practical Investigation and Report: Exercise Physiology

Evaluate the implications of preparing for and performing exercise in hot/humid conditions

Weighting: Unit 3

Type: Investigation

Content:

- Describe, evaluate and apply to selected activities and sports the physiological responses to exercise in hot/humid conditions.

Task outline

When completing the experiment outlined below you are to observe, record, describe and evaluate the physiological impact of performing 30 minutes of exercise in hot and humid environmental conditions.

Total marks = /30

Experiment: Task one

- Two groups of three participants will be required to undertake 30 minutes of exercise (step-ups) in two different rooms. Each room will be prepared for different environmental conditions.
- Pre-exercise measurements of participants
 - Accurately record each participants' body mass using bathroom scales. Body mass should be recorded after going to the toilet and while wearing

- minimal clothing (i.e. shorts, sports top, but no shoes or socks). After the weigh-in, all fluid consumption must be recorded (volume in mL) before the post-exercise weigh-in is completed.
- Record each participant's body temperature with an oral thermometer.
 - Pre-exercise room preparation: Room A (Condition A)
 - Place a heater/s in a relatively small room for 30 minutes prior to the class, to render the room relatively warm. Also, boil a kettle in the room regularly for 30 minutes prior to the lesson to render the air saturated and increase the humidity.
 - Measure and record the air temperature of the room just prior to commencing exercise. Ensure the room temperature is approximately 30–33°C, but not exceeding 35°C. If possible, also measure and record the humidity in the room.
 - Place three sets of steps (useable for step-ups) in the room.
 - Prepare 30 disposable cups each containing 250 mL of cold (refrigerated) water. Place the cups in the room on a pre-wet/pre-frozen towel.
 - Pre-exercise room preparation: Room B (Condition B)
 - Place a fan in this room (preferably air-conditioned), such that all three participants will have some direct airflow from the fan.
 - Measure and record the air temperature of the room just prior to commencing exercise. Ensure the room temperature is less than 20°C. If possible, also measure and record

the humidity in the room.

- Place three sets of steps (useable for step-ups) in the room.
- Prepare 30 disposable cups each containing 250 mL of cold (refrigerated) water. Place the cups in the room on a pre-wet/pre-frozen towel.

Thirty minutes of Exercise Condition A (Room A) and Condition B (Room B)

- Two sets of three participants are to undertake 30 minutes of step-ups in each room.
- Step-ups should be performed at an intensity of 20 step-cycles per minute. Up-up (1 second), stay-stay (1 second), down-down (1 second).
- Participants may choose to consume water at any time from the cups provided, but the volume of water consumed by each participant must be recorded. They are not permitted to spill or splash water onto themselves or their clothing.
- After 15 minutes and 29 minutes of exercise, ask each participant to report how they feel using the:
 - Rating for Perceived Exertion Scale
 - Thermal Sensation Scale

Post-exercise measurements of participants

Immediately upon completion of the 30 minutes of exercise, remove the participants from the exercise room, and:

- Measure and record each participant's body temperature with an oral thermometer.
- Re-weigh each participant after they have removed all clothing not worn in the pre-exercise weigh-in (including shoes and socks) and used a towel to

wipe-off all excess sweat from the skin and dry the hair as much as possible.

- Calculate the total volume of water consumed and convert to grams (1 mL = 1 g).
- Calculate the nett fluid loss (NFL) resulting from exercise:
- $\text{NFL} = \text{Pre-body mass (kg)} - (\text{Post-exercise body mass (kg)} - \text{volume of fluid consumed (kg)})$
- Convert NFL to millilitres (1 g = 1 mL).
- Option: Continue to record the post-exercise (1 hr) fluid consumption.

Questions: Task one

In presenting your findings to Task one (Condition A and B), respond to the following:

- a. Describe and account for any differences in the amount of fluid consumed, nett fluid loss (NFL) and body temperature for the participants in Condition A compared to the participants in Condition B (6 marks).
- b. Describe and account for differences in the 15 minute and 29 minute-measures for the participants in Condition A compared to the participants in Condition B for the:
 - i. Thermal Sensation Scale (1 mark)
 - ii. Rating for Perceived Exertion (1 mark).

Questions: Task two

- a. Discuss one possible anatomical difference and one physiological difference that may allow some athletes to cope better than others when exercising in hot and humid conditions (2 marks).

- b. An athlete is preparing to undertake a game that includes repetitive bouts of moderate-high intensity exercise in hot and humid conditions. Identify and explain how the athlete could improve their performance:
 - i. In the month leading up to the game. This includes the minutes immediately prior to the start of the event (3 marks).
 - ii. During the game (2 marks).

Equipment

- Oral thermometer (n=6).
- Bathroom scales.
- Plastic cups (n=60).
- Towels (n=8).
- Heater/s.
- Access to refrigerator.
- Kettle.
- Two rooms – one pre-heated; the other at ambient room temperature or air-conditioned.
- Steps for step-up exercise (n=6).
- Fan.
- The Rating for Perceived Exertion (n=2). (see Appendix 3.A)
- The Thermal Sensation Scale (n=2). (see Appendix 3.B)
- Clock (n=2).
- Calculator.

Appendix 3.A

Rating of Perceived Exertion

(Borg, 1982)

6	
7	VERY VERY LIGHT
8	
9	VERY LIGHT
10	
11	FAIRLY LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD
16	
17	VERY HARD
18	
19	VERY, VERY HARD
20	

Appendix 3.B

Thermal Sensation Scale

(Toner et al 1986)

0	UNBEARABLY COLD
1	VERY COLD
2	COLD
3	COOL
4	NEUTRAL (COMFORTABLE)
5	WARM
6	HOT
7	VERY HOT
8	UNBEARABLY HOT

Task: Evaluate the implications of preparing for and performing exercise in hot/humid conditions: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to exercise and thermoregulation in hot and/or humid conditions.	1 mark
Provides clear statements of the expected results or anticipated outcomes in relation to exercise and thermoregulation in hot and/or humid conditions.	2 marks
Introduction (3 marks)	
Identifies and defines the variables associated with thermoregulation in hot and/or humid conditions and some actions that can enhance and limit these variables and performance.	1 mark
Shows an understanding of the principles that govern thermoregulation in hot and/or humid conditions and the factors, including anatomical and physiological differences, pre-, in- and post-performance actions that can enhance and limit these variables and the outcomes for performance.	2 marks
Shows a comprehensive understanding of the principles that govern thermoregulation in hot and/or humid conditions and the factors, including anatomical and physiological differences, pre-, in- and post-performance actions that can enhance and limit these variables and the outcomes for performance.	3 marks
Results (2 marks)	
Satisfactory presentation of data.	1 mark
Accurate and relevant presentation of data.	2 marks
Response to Questions (15 marks)	
<i>Task one: Question a: 6 marks, Question b: i 1 mark, ii 1 mark (8 marks).</i>	
<i>Task two: Question a: 2 marks, Question b: i 3 marks, ii 2 marks (7 marks).</i>	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	1 mark
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	2 marks
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with thermoregulation in hot and/or humid conditions and some actions that can enhance and limit these variables and performance.	3 marks
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with thermoregulation in hot and/or humid conditions and the factors, including anatomical and physiological differences, pre-, in- and post-performance actions that can enhance and limit these variables and performance.	4 marks
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the principles that govern thermoregulation in hot and/or humid conditions and the factors, including anatomical and physiological differences, pre-, in- and post-performance actions that can enhance and limit these variables and the outcomes for performance.	5 marks
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the principles that govern thermoregulation in hot and/or humid conditions and the factors, including anatomical and physiological differences, pre-, in- and post-performance actions that can enhance and limit these variables and the outcomes for performance.	6 marks
Conclusion (2 marks)	
Summarises some of the factors associated with the variables associated with thermoregulation in hot and/or humid in relation to the hypotheses.	1 mark
Fully summarises the impact of the factors affecting variables associated with thermoregulation in hot and/or humid conditions in relation to the hypotheses. Limitations discussed.	2 marks
Comment:	Total
	/30

Appendix B2

Practical Investigation and Report: Exercise Physiology

Evaluate the impact of post-exercise recovery strategies

Weighting: Unit 4

Type: Investigation

Content:

- Describe, evaluate and apply to selected activities and sports the physiological responses to post-exercise recovery strategies.

Total marks = /30

Task outline

When completing the experiment outlined below you are to record, describe and evaluate the impact of a combined massage, mobility and cold-water immersion post-exercise recovery strategy on the dominate arm when compared to no specific recovery strategy on the non-dominant arm in the 24 hour period (approximate) after exercise.

NB: Athletes who are injured, recovering from injury, currently undertaking specific post-exercise recovery strategies or are participating in an important competition in the near future should be excluded from this experiment.

Experiment: Task one

Exercise regime

- Determine a hand-weight (dumbbell) that can be repetitively lifted in a bicep curl for a maximum of 3 to 4 minutes. The same weight is to be used for both the dominant and non-dominant arm.
- Undertake a bout of single arm bicep curls with the dominate arm until

fatigued (3 to 4 minutes maximum).

- Record the time to fatigue, and count and record the number of curls completed.
- Immediately upon completion of the exercise bout, ask the participant to report a 'rating of perceived exertion' using the scale provided.
- Next, undertake a bout of single arm bicep curls with the non-dominant arm until fatigued (3 to 4 minutes maximum).
- Record the time to fatigue, and count and record the number of curls completed.
- Immediately on completion of the exercise bout, ask the participant to report a 'rating of perceived exertion' using the scale provided.
- Repeat the process described above until three sets of bicep curls have been completed for each arm with the workload (time to fatigue and number of repetitions) and rating of perceived exertion recorded for each of the six sets.

Post-exercise recovery strategy for all participants

- Non-dominant arm: Undertake no-specific recovery strategy.

- Dominant arm: Within the time-frames specified (or within reason) undertake the following recovery strategies. They can be combined or undertaken individually.
 - Within 5 minutes of completing the final bout of bicep curls:
 - ◇ Cold water immersion of the dominant arm for 5 minutes, 2 minutes of general arm massage, and a repeat of 5 minutes of cold water immersion and 2 minutes of general arm massage. The cold water for immersion should come from the refrigerator and have ice blocks floating in it.
 - ◇ 2 minutes of stretching – combination of static stretches and active/mobile activities.
 - Within 3 hours of completing the final bout of bicep curls:
 - ◇ Cold water immersion of the dominant arm for 5 minutes, 2 minutes of general arm massage, and a repeat of 5 minutes of cold water immersion and 2 minutes of general arm massage.
 - ◇ 2 minutes of stretching – combination of static stretches and active/mobile activities.
 - Within 6 hours of completing the final bout of bicep curls:
 - ◇ Cold water immersion of the dominant arm for 5 minutes, 2 minutes of general arm massage, and a repeat of 5 minutes of cold water immersion and 2 minutes of general arm massage.
 - ◇ 2 minutes of stretching – combination of static and active/mobile activities.
- After 12 hours or within 24 hours of completing the final bout of bicep curls:
 - ◇ Cold water immersion of the dominant arm for 5 minutes, 2 minutes of general arm massage, and a repeat of 5 minutes of cold water immersion and 2 minutes of general arm massage.
 - ◇ 2 minutes of stretching – combination of static and active/mobile activities.
- Non-dominant arm: No post-recovery strategy.

Repeat Exercise regime: Post-recovery strategy (approximately 24 hours after the first bout of bicep curls)

- Before beginning the exercise regime, record a score for both the dominant and non-dominant arms using the ‘Rating of perceived soreness scale’.
- Repeat the exercise protocol from the day before, using the same weight for both the dominant and non-dominant arms as that used in the first bout of exercise.
- Undertake a bout of single arm bicep curls with the dominant arm until fatigued (for 3 to 4 minutes maximum).
- Record the time to fatigue, and count and record the number of curls completed.
- Immediately upon completion of the exercise bout, ask the participant to report a ‘rating of perceived exertion’ using the scale provided.
- Next, undertake a bout of single arm bicep curls with the non-dominant arm until fatigued (3 to 4 minutes maximum).
- Record the time to fatigue, and count and record the number of curls completed.
- Immediately on completion of the exercise bout, ask the participant to

report a ‘rating of perceived exertion’ using the scale provided.

- Repeat the process described above until three sets of bicep curls have been completed for each arm with the workload (time to fatigue and number of repetitions) and rating of perceived exertion recorded for each of the six sets.
- At the end of the sixth set of bicep curls, record a score for the dominant and non-dominant arms using the ‘Rating of perceived soreness scale’.
- Compare performance (time to fatigue and the number of repetitions completed) between the two days for each arm.

Questions: Task one

In presenting your findings to Task one, respond to the following:

- a. Identify the specific health-related component of fitness required to complete the experimental task (1 mark).
- b. Using physiological principles, account for the fatigue experienced whilst completing the 6 sets of bicep curls for the first time (pre-recovery strategy exercises) (1 mark).
- c. Describe and account for how each of the three post-exercise recovery activities (cold water immersion, massage and stretching) could impact on the participants physiology to facilitate a relatively better repeat-performance on the dominant arm (treated arm) than the non-dominant (no specific treatment arm) (6 marks).
- d. Describe and account for why the post-exercise ‘perceived soreness’ ratings may have been better (lower) for the dominant arm (treated arm) than the non-dominant arm (no specific treatment arm) (1 mark).

Questions: Task two

- a. Discuss an additional two post-exercise recovery strategies (activities) that were not undertaken in this experiment. Explain the best use of these strategies (how should they be implemented) and the physiological impact that these two strategies may have (4 marks).
- b. An endurance athlete who does not respond to post-training recovery strategies within 48 hours may be experiencing overtraining. Explain how the symptoms of overtraining might differ from that of typical post-training fatigue (2 marks).

Equipment

- Dumbbell hand weights.
- The Rating for Perceived Exertion (see Appendix 4.A).
- The Perceived Soreness Rating scale (see Appendix 4.B).
- Cold water immersion tubs.
- Clock.
- Calculator.

Appendix 4.A

Rating of Perceived Exertion

(Borg, 1982)

6	
7	VERY VERY LIGHT
8	
9	VERY LIGHT
10	
11	FAIRLY LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD
16	
17	VERY HARD
18	
19	VERY, VERY HARD
20	

Appendix 4.B

Rating of Perceived Soreness

0	NORMAL (NOT SORE)
1	
2	
3	UNCOMFORTABLE
4	
5	SORE
6	
7	
8	VERY SORE
9	
10	EXTREMELY SORE

Task: Evaluate the impact of post-exercise recovery strategies: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to fatigue, recovery and recovery strategies.	1 mark
Provides clear statements of the expected results or anticipated outcomes in relation to fatigue, recovery and recovery strategies and the factors that impact on these variables in subsequent performances.	2 marks
Introduction (3 marks)	
Identifies and defines the variables associated with fatigue, recovery and recovery strategies.	1 mark
Shows an understanding of the principles that govern fatigue, recovery and overtraining and the physiological responses to a range of post-exercise recovery strategies that can enhance and limit these variables.	2 marks
Shows a comprehensive understanding of the principles that govern fatigue, recovery and overtraining and the physiological responses to a range of post-exercise recovery strategies that can enhance and limit these variables.	3 marks
Results (2 marks)	
Satisfactory presentation of data.	1 mark
Accurate and relevant presentation of data.	2 marks
Response to Questions (15 marks)	
<i>Task one: Questions a, b and d: 1 mark for each correct answer; Question c: 6 marks (9 marks).</i>	
<i>Task two: Question a: 4 marks, Question b: 2 marks (6 marks).</i>	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	1 mark
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	2 marks
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with fatigue, recovery and overtraining and the physiological responses to a range of post-exercise recovery strategies.	3 marks
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with fatigue, recovery and overtraining and the physiological responses to a range of post-exercise recovery strategies that can impact on these variables.	4 marks
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the principles that govern fatigue, recovery and overtraining and the physiological responses to a range of post-exercise recovery strategies that can enhance and limit these variables.	5 marks
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the principles that govern fatigue, recovery and overtraining and the physiological responses to a range of post-exercise recovery strategies that can enhance and limit these variables.	6 marks
Conclusion (2 marks)	
Summarises some of the factors associated with fatigue and recovery and the physiological responses to a limited range of post-exercise recovery strategies in relation to the hypotheses.	1 mark
Fully summarises the impact of the factors affecting fatigue and recovery and the physiological responses to a range of post-exercise recovery strategies in relation to the hypotheses. Limitations discussed.	2 marks
Comment:	Total
	/30

Appendix C (I)

Revision questions

1. What foods should be limited in consumption according to the Australian Guidelines for Healthy Eating?
2. List the two fates of glucose obtained from the digestion of dietary carbohydrate.
3. The main difference between a simple and complex carbohydrate is
 - a. simple carbohydrates are smaller molecules.
 - b. complex carbohydrates are broken down faster.
 - c. simple carbohydrates are more likely to be low GI.
 - d. complex carbohydrates are glucose while simple carbohydrates are glycogen.
4. Using your knowledge of glycaemic index (GI), explain the difference between honey (GI=87) and a banana (GI=50).
5. Endurance athletes typically consume a greater amount of carbohydrate than the average Australian diet. What type of athlete may need to increase the percentage of fat intake in their diet?
6. What is a triglyceride?
7. Briefly explain why a body builder might choose to increase their protein intake.
8. Along with carbohydrate and fat, protein plays a major role in the aerobic production of ATP. True or false?
9. A good guide for determining the amount of fluid required on a daily basis is
 - a. the amount of sleep you have and caffeinated drinks in your diet.
 - b. the ratio of carbohydrate to fat in your diet.
 - c. to ensure that your urine is a dark yellow colour.
 - d. to ensure that your urine is a pale yellow colour.
10. To meet total daily fluid requirements everyone should simply consume 2 L of Gatorade per day. Provide two reasons why this statement is incorrect.
11. Provide an argument to reject the following statement; ‘Tour de France bike riders should eat 6 loaves of bread at the end of each days ride.’
12. Briefly explain why a meal that is high in fat and protein is not recommended prior to competition (pre-competition meal).
13. Given that an athlete has a limited capacity to store carbohydrate, explain the benefits of carbohydrate loading during the pre-event tapering period.
14. You have a friend who rings you two days before running the City-to-Surf Half Marathon. They have just heard about a concept called carbohydrate loading and want you to identify a method of carbohydrate loading that they can implement before the run.
15. Why might lollies (with a high GI) not be an appropriate pre-competition snack prior to a prolonged endurance event?
16. A pre-competition snack should
 - a. occur 10 minutes prior to exercise.
 - b. be high simple glucose so it is readily absorbed.
 - c. be used to top-up glycogen stores.
 - d. not be a liquid.
17. Use your knowledge of nutrition strategies during exercise to argue for the use of gel satchels containing approximately 30 g of liquid carbohydrate for endurance-based performance.
18. For a sporting event lasting 45 minutes, the recommended total water intake would be...?
19. Briefly explain why fruit juice is not an appropriate drink during competitive performances that last longer than one hour in duration.

20. Provide an argument for the role of the following foods in sports nutrition: Fruit juice, soft drink, lollies or a white bread roll with banana and honey.
21. Provide general recommendations for an athlete's post-exercise fluid replacement.
22. The transfer of heat through direct contact is called
 - a. conduction.
 - b. convection.
 - c. radiation.
 - d. electromagnetic.
23. Of the four mechanism of heat exchange between the body and the environment, which provides the most significant effect during exercise?
24. Explain why wiping sweat off the skin during exercise, and exercising in humid conditions, have a similar effect on the effectiveness of evaporative cooling.
25. As the ambient temperature gets hotter, the need for evaporative heat loss becomes greater. Explain this statement.
26. Explain how experiencing a double heat load and cardiac drift can be detrimental to endurance performance.
27. Briefly explain how drinks containing relatively large amounts of caffeine could have a detrimental impact on endurance performance in hot conditions.
28. Which of the following best relates to the process of hyperhydration?
 - a. A post-performance fluid
 - b. Consuming excess fluid in the hours prior to performance
 - c. Consuming less fluid in the hours prior to performance
 - d. Getting wet under the shower prior to performance
29. Explain how wearing an ice jacket before exercising in the heat could improve performance.
30. How does having a large skin surface area to body mass ratio provide any advantage when exercising in the heat?
31. What are three physiological outcomes of undertaking heat acclimatisation exercise training 5–10 days before competition in hot conditions?
32. Exercising in hot conditions is made more physiologically demanding when it is also humid. Which of the following best explains this situation?
 - a. Convective heat accumulation is increased
 - b. Radiation heat accumulation is increased
 - c. Evaporative heat loss is diminished
 - d. Sweat on the skin evaporates more quickly
33. Using your knowledge of the body's physiological response to cold environmental conditions, explain why people often look paler when cold compared to when they are hot.
34. What is wind-chill?
35. Identify sports that are likely to be advantaged and disadvantaged when undertaken at altitude?
36. An athlete, who resides and trains at sea level, travels to altitude. List two physiological effects they could expect within a few days of arriving?
37. Identify two long-term physiological adaptations, which could positively impact on endurance performance, as a result of spending a prolonged time at altitude?
38. Identify which of the following is not a long-term physiological adaptation from spending a prolonged time at altitude?
 - a. a loss of body mass
 - b. greater anaerobic power
 - c. less training tolerance
 - d. detraining

39. Explain the term: Live high train low.
40. A 50 kg female marathon runner decides to significantly reduce her coffee consumption in the week leading up to a race. On the morning of the event she consumes 150 mg of caffeine. Provide a rationale for this approach and identify how it may assist her performance.
41. Provide a reason why the athlete in question 40 might not want to consume caffeine prior to her event.
42. A benefit for males taking anabolic steroids is an increase in the size and function of the testes. True or False?
43. Protein supplementations is most likely
- to benefit a strength-based athlete who's dietary protein intake is low.
 - to be undertaken by endurance athletes.
 - to benefit a strength-based athlete who's dietary liquid protein intake is high.
 - needed to counterbalanced a low caffeine intake.
44. The season for an AFL player is broken up into three main phases of training. What are these phases called?
45. When transitioning from the general preparatory phase to the specific preparatory phase of training would you expect the intensity of training to increase or decrease?
46. What is the emphasis of the period of training in the immediate lead up to competition (pre-competition phase); volume or intensity?
47. What is the primary goal of the competition phase of training?
48. In what phase of training is cross-training typically recommended?
49. Define a microcycle and explain its relationship with a macrocycle.
50. Divide the following list into health-related and skill-related components of fitness:
- Balance, cardiorespiratory endurance, coordination, muscular endurance, power, flexibility, and body composition.
51. Which energy system is the slowest to supply ATP?
52. Which energy system can only use carbohydrate as a fuel source?
53. Which energy system is predominantly sourced when executing a softball pitch?
54. What are the two basic requirements to a successful taper?
55. What are the possible effects of inadequate recovery between training sessions?
56. List three ways an athlete might use water immersion to enhance the recovery from training.
57. List two symptoms of an athlete suffering from overtraining.
58. What purpose is there in an AFL footballer who has a shoulder injury riding a bike?

Appendix C (II)

Revision answers

1. Foods that are high in total fat intake (especially saturated fat), high in salt and high in sugars.
2. Some of the glucose is:
 - i. released into the bloodstream to circulate and provide fuel for the brain or a source of energy for ATP repletion
 - ii. converted into glycogen and stored in the muscle and in the liver.
3. a. Simple carbohydrates are smaller molecules.
4. Glycaemic index (GI) is a measure of the speed at which glucose is released into the bloodstream after eating carbohydrates. Consuming honey, a high GI carbohydrate, results in a rapid release of glucose into the bloodstream. In contrast, bananas have a low GI and result in a slow, sustained release of glucose into the bloodstream.
5. Generally no athlete should need to increase the percentage of fat intake in their diet. It may be advisable to increase the levels of unsaturated fat, and to decrease the levels of saturated fat, but not to increase overall fat consumption.
6. A triglyceride is a molecule resulting from the combination of three free fatty acids.
7. Protein plays a vital role in the growth and repair of muscle tissue. With the consistent heavy-load resistance training undertaken to overload muscle and stimulate muscle hypertrophy, there is considerable need for muscle growth and repair, and therefore protein.
8. False. When carbohydrate and fat sources are available, protein plays a minor role in energy production.
9. d. To ensure that your urine is a pale yellow colour.
10. The consumption of plain water is adequate (electrolyte drinks are not necessary) for those who do not undertake prolonged endurance-based activity. Furthermore, consuming 2 litres of water is a minimum recommendation. Fluid requirements will potentially be higher than 2 L for people who: i) live in a humid or hot environment; and ii) undertake exercise (particularly those who participate in strenuous training or competition).
11. Tour de France riders require a relatively high kilojoule (kJ) intake to meet the energy demands of the bike race. Whilst the daily energy demands may be equivalent to the amount contained in 6 loaves of bread, the riders require a balanced diet for optimal athletic performance that includes healthy amounts and proportions of the three macronutrients – carbohydrate, fat (lipid) and protein – as well as a variety of minerals and vitamins. Eating bread alone will not supply the balanced nutritional needs of the race or provide for optimal athletic performance.
12. Meals that are high in fat and protein are not recommended since they take longer to digest and will not be the primary source of energy during exercise.
13. Increased carbohydrate intake and reduced training load results in almost double the levels of glycogen stored in the muscle. Therefore, an athlete will be able to work for longer at a higher intensity before the limited carbohydrate stores become depleted.
14. Undertake one 3 minute bout of very high-intensity exercise followed by one day of high glycaemic carbohydrate intake (~10 g/kg). Use compact sources of carbohydrate such as carbohydrate drinks and/or supplements. This will result in almost doubling of carbohydrate stores within 24 hours.

15. A high GI carbohydrate snack (like lollies) results in a rapid release of glucose into the bloodstream. This in turn causes a sudden rise in the levels of insulin, leading to rebound hypoglycaemia, which can be detrimental to performance. A low or medium GI snack (for example, fruit like strawberries, apples and oranges) is preferable 30–60 minutes prior to an endurance event.
16. c. Be used to top-up glycogen stores.
17. The goal of nutritional strategies during exercise is to minimise the depletion of carbohydrate stores and to replace fluid lost via sweat. Carbohydrate feeding in the form of a liquid gel containing 30 g of carbohydrate, prior to or during exercise will:
 - i. minimise gastric discomfort
 - ii. assist in prolonging high intensity endurance performance by maintaining blood glucose levels, which in turn will spare some muscle glycogen.
18. A rate of 100–200 mL per 15 min would equate to providing a total consumption of approximately 300–600 mL.
19. During exercise, the absorption of both water and carbohydrate in the gastrointestinal tract is optimised by consuming fluids with a carbohydrate concentration of 6–8% in solution. Fruit juice has a higher concentration of carbohydrate and therefore will impair fluid replacement and delay the availability of ingested carbohydrate in the bloodstream.
20. Immediately following prolonged exercise (post-exercise), the consumption of high glycaemic index (GI) carbohydrates such as fruit juice, soft drink, lollies or a white bread roll with banana and honey have been shown to facilitate a faster rate of glycogen repletion.
21. As a general guide, athletes should consume fluid (in mL) equivalent to that which was lost in sweat (in grams), plus an extra 50% in the post-exercise period. This can be calculated by measuring the loss of nude body mass (in grams) and converting this to an equivalent amount of fluid (in mL) and then adding an additional 50% (for example, consume 1500 mL of fluid if 1000 g of body mass was lost during exercise).
22. a. Conduction.
23. Evaporative heat loss – the transfer of heat resulting from the evaporation of sweat on our skin.
24. Sweat must evaporate on the skin surface in order to have a cooling effect. By wiping the sweat off the skin, or by working in a humid environment in which the ambient air is heavily saturated with water vapour (and sweat simply drips off the skin), there is limited evaporation of sweat on the skin surface. Both actions will be counterproductive in terms of cooling the body.
25. When exercising in the heat (when the external surroundings are warm), conduction, convection and radiation are not very effective for heat loss from the body because each of these mechanisms of heat transfer involves the passage of heat along a temperature gradient from warmer to cooler objects. In addition, the actual amount of heat transfer is dependent upon the magnitude of temperature difference between the body and the environment. As the ambient temperature approaches that of the body, there is a reduction in the gradient for heat loss. If the ambient temperature exceeds that of the body, the body will actually gain heat. Under these conditions, evaporation is the only mechanism by which heat can be dissipated from the body.

26. When exercising in hot conditions, a high rate of sweating results in a significant loss of body fluid and consequently blood plasma volume. The reduced blood plasma volume impairs the ability to continue to deliver blood to both the working muscles and the periphery for cooling via sweat evaporation. This is defined as a double heat load. In addition, there is a decreased stroke volume, leading to an increased heart rate (called cardiac drift) to compensate. With significantly reduced plasma volume, the body will prioritise blood supply to the working muscles, rather than the periphery. This means less blood flow to the skin, limiting further cooling by evaporation and ultimately inhibiting continued performance.
27. Caffeine, if taken in large doses, can act as a diuretic which increases urine production and may increase the risk of dehydration.
28. b. Consuming excess fluid in the hours prior to performance
29. Pre-cooling the body by wearing an ice jacket works to lower the core body temperature. With a lower core temperature prior to performance, there is scope for a greater increase in temperature during exercise before the critical threshold is reached.
30. There is an advantage when exercising in the heat in possessing relatively less heat producing muscle and a larger skin surface area from which sweat can be evaporated and heat lost.
31. Three physiological outcomes of undertaking heat acclimatisation exercise training 5–10 days before competition in hot conditions are:
- a faster onset of sweating, that is, you begin to sweat at a relatively lower body temperature
 - a greater rate of sweating, and
 - an increase in plasma volume.
32. c. Evaporative heat loss is diminished
33. When cold, constriction of the blood vessels on the skin surface called ‘peripheral vasoconstriction’ serves to shunt blood away from the periphery where it will be cooled, towards the core. This leaves the skin with relatively less blood flow and therefore looking paler than when vasodilated or flushed with peripheral blood flow in hot conditions.
34. Wind-chill is the effect of wind magnifying heat loss by constantly replacing the layer of warm air around the skin with fresh cool air.
35. Sports that may be advantaged at altitude include short sprint running events and events that throw, hit or kick a projectile for maximum distance. The benefit is the result of the relatively lower air resistance and drag at altitude. Sports that are disadvantaged at altitude include those that require prolonged aerobic activity (endurance-based) or those that demand repeat-sprints (for example, team sports) because less oxygen is available to replenish CP and remove lactic acid.
36. Physiological effects they could expect within a few days of arriving at altitude include:
- increased pulmonary ventilation
 - decreased plasma volume
 - increased heart rate at rest and during submaximal exercise
 - increased cardiac output at rest and during submaximal exercise.
37. Long-term physiological adaptations, which could positively impact on endurance performance, as a result of spending a prolonged time at altitude include:
- increased red blood cell and haemoglobin concentration
 - increased capillarisation
 - increased mitochondria
 - increased aerobic enzymes.

38. b. greater anaerobic power
39. Live high train low relates to obtaining the benefits of both living at high altitude to gain the long term benefits and training at sea level to ensure high intensity quality training sessions.
40. The body generally cannot store enough carbohydrate to meet the energy demands of running a marathon (2.5+ hours). Caffeine increases the availability of free fatty acids for ATP production, which in turn stimulates increased fat oxidation. This may assist in sparing some muscle glycogen and consequently enhance performance, particularly late in the race. Coffee contains caffeine, and for a regular coffee user, a reduction in coffee consumption in the lead up to the race, will assist to washout caffeine and increase the physiological effects of her race day caffeine consumption. The amount of 150 gm is equivalent to 3 mg per kg of body mass, within the suggested dose for the desired effect.
41. Caffeine may lead to restlessness, feeling overanxious, muscle twitching, irritability, an elevated heart rate and blood pressure. Caffeine is also a diuretic, which may lead to dehydration and limit endurance performance.
42. False. Prolonged use of anabolic steroids by males may result in impaired natural production of testosterone, and decreased testicular volume.
43. To benefit a strength-based athlete who's dietary protein intake is low.
44. a. The preparatory phase (pre-season), the competition phase (in-season) and the transition phase (off-season).
45. The intensity of training would be increased.
46. There is an emphasis on the quality (intensity) of training.
47. During the competition phase, the amount of work completed in training is simply enough to meet the goal of maintenance of fitness levels (reduced volume: maintained intensity).
48. The transition phase (off-season).
49. Microcycles are small periods of training (typically a week). A number of microcycles combine to make up a macrocycle (typically 4-6 weeks). Both macrocycles and microcycles have specific goals, however, the goals of each microcycle are small and designed to contribute towards the overall focus of the macrocycle.
50. The health-related components of fitness include:
- Cardiorespiratory endurance
 - Muscular endurance
 - Flexibility
 - Body composition.
- The skill-related components of fitness include:
- Balance
 - Coordination
 - Power.
51. The aerobic energy system.
52. The lactic acid system.
53. The ATP-CP system.
54. Tapering involves:
- i. decrease in training load (between 1/3 to 1/2 of overall training volume)
 - ii. maintaining or possibly even increasing training intensity.
55. The body fails to develop the physiological training adaptations or training effect. The athlete will become progressively more tired and fatigued, ultimately resulting in decreased performance.
56. Three ways an athlete might use water immersion to enhance the recovery from training.
- i. Cold water immersion – typically involves immersion of the body in cold

water (< 15°C) for a period of 10–20 minutes after exercise to reduce blood flow, inflammation, muscle spasm and pain.

- ii. Warm water immersion – may involve immersing the body in warm water (> 37°C) for a period of 10–20 minutes which increases body temperature and blood flow.
- iii. Contrast water therapy – requires the athlete to alternate between heat and cold exposure. This is believed to reduce

swelling and inflammation due to a ‘pumping action’ caused by the blood vessels as they relax and constrict as the athlete moves from the hot to the cold water.

- 57. Symptoms of overtraining include:
Lack of energy, muscle aches, impaired performance, lack of enthusiasm, injury, and illness.
- 58. Riding a bike will serve to minimise detraining and maintain cardiorespiratory fitness during the time of recovery.

Appendix D

Personalised project – Units 3 and 4: Performance evaluation

This assessment task is framed by the principles of Bloom’s taxonomy. The mark allocations respect the level of complexity of individual task requirements. The following table differentiates for the complexity of each task, beginning with Level 1 (for example, label) to Level 6 (for example, create) (adapted from O’Brien & White 2001).

This project could be undertaken as the respective content areas are studied (biomechanics, functional anatomy, exercise physiology) or at the end of studying these units.

1	2	3	4	5	6
REMEMBERING	UNDERSTANDING	APPLYING	ANALYSING	EVALUATING	CREATING
Label	Explain	Measure	Identify	Justify	Create
Describe		Undertake	Analyse	Evaluate	Predict
			Compare & contrast		
			Discuss		

Weighting:

- Unit 3 – 25 marks
- Unit 4 – 25 marks

Type: Investigation

Content:

- Biomechanics
- Functional Anatomy
- Exercise Physiology

Total marks = /50

Content

1. Use diagrams *label and analyse* one of the following options (Unit 3: 4 marks):
 - the golf drive and the player’s action, club/ball as a collision and the flight phase of the ball
 - the gymnast running in, taking off (from the floor or minitramp) and performing a forward somersault, and landing on their feet
 - the soccer ball moving toward an oncoming kicker, the player’s kicking action of the leg kicking the ball, the

collision of the player's foot and the ball, and the flight phase of the ball.

2. *Measure* your own performance in the sport-specific action chosen above. Ensure that you record data for all of the variables that contribute to the quality of the action performed. For example, in the golf drive, include the distance the ball travels, approximate trajectory of the ball, and approximate mean in-flight speed or velocity of the ball (0 marks).
3. Using anatomical and local muscular qualities (neuromuscular function and muscle fibre type) *describe* and briefly *explain* four desirable qualities of a high-performance athlete of the sport chosen (Unit 4: 2 marks)
4. Using biomechanical principles *compare and contrast* your performance with a high-performance athlete (Units 3 and 4: 8 marks).
5. *Predict* for yourself, the four primary technical (skill) limiting factors to your performance success. Consider the contributions of technical actions using biomechanical principles (Units 3 and 4: 4 marks).
6. *Discuss* one piece of the chosen sports equipment that when modified could enhance your performance (Units 3 and 4: 2 marks).
7. *Identify* and *evaluate* the key nutritional components (pre-, during- and post-competition) and how they contribute to a high-performance athlete undertaking a game/day-long competition of the sport chosen (Unit 3: 8 marks):
 - The golfer playing eighteen holes.
 - The gymnast performing a 90 second floor routine and performances on other apparatus (female: beam, uneven bars, and vault; male: rings, high bar, vault, pommel).
 - The soccer player in a game.
8. *Create* three different sessions (one

pre-season, one in-season, and one off-season) of a training program specific to the action chosen. The program should be targeted to you. *Identify* and *justify* the specific needs of the different seasons, energy system requirements, that are targeted in your sessions and how they apply to your performance in the specific action chosen and more generally to the selected sport (Unit 4: 12 marks).

9. *Identify* and *justify* a comprehensive recovery regime for the sport chosen (Unit 4: 4 marks).
10. *Predict, justify* and *evaluate* the implications and strategies for preparing and performing the chosen sport in one of the following environmental conditions: heat/humidity or altitude (Unit 3: 6 marks).

Process or support

- Individual and elite performance evaluation assisted by the teacher.
- Review texts or scientific journals and, in a small group, hold a teacher-facilitated debate and discussion of the evidence at hand.
- Review video material.

Product or outcome

Verbal or written explanation

- Variables that contribute to or impact on the forces applied, the resultant of those forces and preparation for high performance of the skills/sport during a season and in differing environmental conditions.

Written

- Variables that contribute to or impact on a personal performance.

- Personal and high-performance athlete qualitative and quantitative evaluation.
- Identify and evaluate nutritional components that support or enhance performance.
- Create training sessions that differentiate for seasons.
- Identify and justify the impact of recovery strategies on performance.

- Predict, evaluate and justify the implications and strategies to overcome extreme environmental conditions.

Tabulate or graph

- Diagrams and label.
- Measure and record personal performance.
- Tabulate and identify the differences between personal and elite performance.

Appendix E

Glossary of key terms

Amino acids: Smallest units of protein.

Anabolic steroids: Drugs that simulate the anabolic actions of the male sex hormone testosterone.

Balanced diet: Includes healthy amounts and proportions of the three macronutrients – carbohydrate, fat (lipid) and protein – as well as a variety of minerals and vitamins.

Caffeine: Found in a variety of foods and drinks including chocolate, coffee, tea, many soft drinks and energy drinks. A stimulant, diuretic, and also increases the availability of free fatty acids for ATP production, which in turn may stimulate increased fat oxidation.

Carbohydrate loading (or glycogen loading): Enhancing the amount of carbohydrate stored in the muscle by consuming high amounts of dietary carbohydrate in the days leading up to competition, in combination with reduced training load.

Competition phase of training: Is divided into: A ‘pre-competition phase’ to approach peak condition, and a ‘competition phase’ in which the athlete performs at their peak.

Complex carbohydrates: Larger molecules found mainly in plant-derived foods, such as potatoes, bread, cereal, rice and pasta.

Conduction: Transfer of heat through direct contact.

Convection: Transfer of heat by the motion of moving substances (typically air or water).

Detraining: Loss of physiological capacities associated with rest or inadequate training load.

Double heat load: Decreased blood flow to both the working muscles and the skin.

Electrolytes: Minerals (e.g. sodium, potassium, magnesium, chloride, calcium, and bicarbonate) dissolved in solution.

Energy systems: ATP-CP system, lactic acid system, and the aerobic energy system.

Ergogenic aids: External influences that assist physical work.

Erythropoietin (EPO): Hormone that is found naturally in the body and is responsible for stimulating the production of red blood cells.

Evaporation: Transfer of heat resulting from the evaporation of water (sweat) on the skin surface.

Free fatty acids: The smallest unit of fats.

Glucose: A small sugar molecule. The basic unit of carbohydrate.

Glycaemic index (GI): A measure of the rate at which glucose is released into the bloodstream after eating carbohydrates.

Glycogen: The storage form of carbohydrate. Results from the combination of a large number of glucose molecules together to form one large molecule.

Haematocrit: The percent of blood made up by red blood cells.

Health-related components of fitness: Cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition.

Heat acclimatisation: 5–10 days of exercise training in the heat resulting in increased plasma volume, an earlier onset of sweating and increased rate of sweating.

High glycaemic index (GI) foods: Result in a rapid release of glucose into the bloodstream.

Hyperhydration: Consumption of excess fluid in preparation for loss of fluid in upcoming exercise.

Hypobaric chamber: Replicates conditions similar to altitude.

Hypoxia: Lack of adequate oxygen.

Low glycaemic index (GI) foods: Result in a slow, sustained release of glucose into the bloodstream.

Macrocycles: Periods of time within the training plan (typically 1 month) in which there is a specific focus/goal for training.

Microcycles: Periods of time within the training plan (typically a week) which combine to contribute towards the goal of the macrocycle.

Overcompensation: Physiological training effect associated with recovery between training sessions.

Overtraining: The result of an imbalance between training load and recovery which is characterised by: Lack of energy, muscle aches, impaired performance, lack of enthusiasm, increased risk of injury, and illness.

Peaking: The achievement of optimal performance at the appropriate time in the training plan.

Performance/skill-related components of fitness: Agility, balance, coordination, reaction time, speed, and power.

Periodisation: Planned organisation of training into phases, typically: Preparation phase, competition phase, and transition phase.

Piloerection: Making the body hairs stand on end to trap and warm air at the skin surface.

Pre-cooling the body: Using cooling jackets, cold water immersion, or crushed ice ingestion to lower core temperature prior to exercise.

Preparation phase of training: Is divided into: A ‘general preparation phase’ to establish a base-level of fitness and skills, and a ‘specific preparation phase’ in which training becomes more sport and competition specific.

Radiation: Transfer of heat by electromagnetic waves.

Recovery strategies: Massage, compression garments, cold water immersion, warm water immersion, contrast water therapy and stretching.

Saturated fatty acids: Found in full cream milk, cheese and fatty meats and are considered unhealthy.

Simple sugars: Small molecules of carbohydrate found in foods such as honey, table sugar and fruit juice.

Taper: The reduction in training load prior to competition.

Training plan: Is typically divided into three main phases: Preparation phase, competition phase, and transition phase.

Transition phase of training: Focused on active recovery and avoiding detraining.

Triglycerides: Storage form of fat. A molecule resulting from the combination of three free fatty acids that is stored in adipose (fat) tissue of the body.

Unsaturated fatty acids: Found in avocados, fish, nuts and olive oil and can be beneficial for health if consumed in moderation.

Vasoconstriction: A reduction in the diameter of blood vessels.

Vasodilation: An increase in the diameter of blood vessels.



Sport Psychology

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and Ms Monica Leslie

BACKGROUND INFORMATION

The following dot-points provide a revision of the key concepts from Units 1 and 2.

Individual zone of optimal functioning

Key point summary:

- The IZOF model proposes that individual athletes react differently to the same level of an experienced emotion.
- Optimal performance is more likely when the intensity of an athlete's emotion falls within a specific bandwidth that is right for him/her.

to perform within their zone of optimal functioning.

- It is possible to possess intrinsic and/or extrinsic motivation, regardless of your age.
- Intrinsic motivation depends on satisfying needs such as competence, so developing a higher skill level may serve to increase this type of motivation.
- Intrinsic motivation is only possible for tasks that are perceived to be interesting, novel, challenging, or which have aesthetic value.

Motivation and the 'zone'

Key point summary:

- People who pursue an activity for the inherent satisfaction (because they enjoy it) that the activity provides are demonstrating intrinsic motivation.
- People use extrinsic motivation when they pursue a task for contingencies other than inherent satisfaction.
- Motivation can influence emotion, and it is therefore an important consideration when preparing athletes

Arousal and anxiety

Key point summary:

- Arousal refers to a state of heightened psychological and physical activation.
- Arousal can stem from positive or negative events.
- Anxiety is a negative emotional state characterised by nervousness, apprehension and worry (cognitive anxiety), and it is associated with arousal of the body (somatic anxiety).
- Trait anxiety reflects a disposition

that predisposes a person to interpret non-dangerous circumstances as threatening.

- State anxiety is an emotional response, or a changing mood state, to particular situations.
- The inverted-U hypothesis indicates that performance is best when athletes experience a moderate level of arousal. Performance can suffer when arousal is above or below this level.
- A number of factors can influence the relationship between arousal and performance, such as the nature of the task, skill level of the performer and individual differences.
- Arousal influences performance by causing changes to muscle tension, fatigue, coordination, attention and vision.

Arousal and anxiety and the ‘zone’

Key point summary:

- Techniques to reduce anxiety can focus more specifically on cognitive anxiety or somatic anxiety.
- Multimodal techniques focus equally on both cognitive and somatic anxiety.
- Athletes should be recommended to follow the matching hypothesis, which is the idea that cognitive anxiety should be reduced with mental relaxation, whereas somatic anxiety should be reduced with physical relaxation.
- Techniques such as listening to up-tempo music, acting energised, using energising imagery and engaging in positive self-talk can increase arousal.

Stress and the ‘zone’

Key point summary:

- Stress is a process in which there is a substantial imbalance between demand and response capability, under conditions where failure to meet that demand has important consequences.
- McGrath (1970) has proposed that the stress process consists of the following four stages:
 - Environmental demand
 - Perception of demand
 - Stress response
 - Behavioural consequences
- Problem-focused coping involves methods to manage the issue that is causing the problem.
- Emotion-focused coping involves the regulation of emotions to deal with the problem.
- Coping with stress can involve problem-focused coping, which entails a focus on addressing the stressor. Alternatively, athletes can cope by regulating their emotions in response to the stressor, termed emotion-focused coping.
- The choice of a coping strategy should depend on whether a long-term stressor causes the stress and whether there is a possibility of changing the stressful situation.

Self-confidence and the ‘zone’

Key point summary:

- Confidence reduces anxiety and influences concentration, emotions, goal setting and persistence levels.
- Highly successful athletes generally have more confidence than less successful athletes.
- Self-confidence and self-efficacy are primarily influenced by:
 - performance accomplishments (having done it well)
 - vicarious experience (watching others)
 - verbal persuasion (being encouraged by others and oneself)
 - physiological states (how you physically feel at the time) and emotional states (your mood at the time).
- A variety of techniques can be used to increase self-confidence, such as focusing on performance accomplishments, acting confidently, using positive self-talk, engaging in imagery and carefully planning and preparing for events via pre-game and/or pre-shot routines.

Concentration and the ‘zone’

Key point summary:

- Concentration involves an ability to:
 - focus on relevant cues in the environment
 - maintain that focus over time
 - possess situational awareness
 - shift attentional focus.

- Nideffer argues that attentional focus can vary according to whether it is narrow or broad, internal or external.

Goal setting

Key point summary:

- Goal setting is a proven method to influence performance. A simple tactic to encourage effective goal setting is to use the SMARTS acronym.

Set SMARTS goals

Specific –

Goals should be specific rather than general and broad.

Measureable –

An athlete should be able to measure goal accomplishment.

Action-oriented –

Athletes should specify how a goal is going to be achieved.

Realistic –

Moderately difficult goals are best.

Time-bound –

A timeframe for goal achievement should be identified.

Self-determined –

Goals should have input from the participant.

Sport Psychology: ATAR Units 3 and 4

A similar approach is followed for each section of the ATAR Units 3 and 4 curriculum. Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the ‘Content that follows’ and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A ‘Key point summary’ box is presented at the end of each section.

Two practical investigations are included as Appendix B1 (Unit 3 content: Evaluate the use of mental skills) and Appendix B2 (Unit 4 content: Group cohesion). A format for report writing can be located at the end of this chapter (Appendix A) to assist students with their preparation of a practical investigation. Marking matrices are also included in Appendices B1 and B2. Answers are provided for teachers only.

Revision questions (with answers) are included near the end of this chapter as Appendix C. A ‘Glossary of key terms’ appears on the final pages of this chapter (Appendix E).

At the end of the Motor Learning and Coaching chapter is the ‘Personalised project’, which requires students to apply knowledge and understanding from ‘Sport Psychology and Motor Learning and Coaching’ (Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision.

Text outcomes:

Sport psychology (Unit 3)

- *Analyse the following mental skills strategies used pre-, during and post-performance to manage arousal, stress, motivation, concentration, and self-confidence:*
- *Performance routines*
- *Imagery*
- *Relaxation*
- *Self-talk*
- *Goal-setting.*

Content that follows: *Mental skills (Unit 3)*

- *The influence of performance routines on arousal, stress, motivation, concentration, and self-confidence.*

Routines

A **performance routine** is ‘sequence of task-relevant thoughts and actions which an athlete engages in systematically prior to his or her performance of a specific sport skill’ (Moran 1996, p. 177). In this chapter, we will discuss routines that an athlete might use in the hours or minutes prior to performance (for example, before kick-off) as well as those routines that might be used ‘during performance’ (for example, before a free throw shot in basketball). Researchers have found that routines with a consistent set of thoughts and behaviours aid successful skill execution in the midst of distractions (Cohn 1990; Lonsdale & Tam 2008). These routines can influence athletes in numerous ways, but we will focus

our discussion on how they can influence arousal, stress, motivation, concentration, and self-confidence.

Routines and arousal

In Units 1 and 2, you would have learned that arousal refers to a mixture of physiological and psychological activation. It can involve a host of physiological changes (for example, increased heart rate, dilated pupils, sweaty palms) and/or a range of psychological responses (for example, worry, fear, excitement). Arousal can be associated with positive or negative events; it can result from your excitement about the grand final (a positive experience), or it can be associated with anxiety in relation to the grand final (a negative experience). Sport psychologists often use the inverted-U hypothesis to describe the relationship between arousal and performance. This hypothesis states that athletes are more likely to perform at their best under moderate levels of arousal, as can be seen in Figure 4.1. One of the most important implications of this model is that athletes can be under-aroused or over-aroused, and they require skills at decreasing as well as increasing arousal.

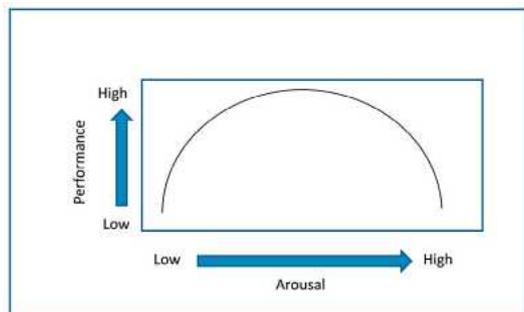


Figure 4.1: *The inverted-U hypothesis*

A key goal of any performance routine is to regulate arousal. It makes sense that thoughts and actions prior to performance can influence

physical as well as psychological activation. A boxer who warms up with a skipping and punching routine, all the while focusing on strategies to overcome the opponent, is likely to increase arousal. Kobie McGurk (Figure 4.2), a member of the Australian Hockeyroos and Beijing Olympian, uses pre-performance routines to optimise arousal; her comments follow:

“The morning of a game, my routine starts with a one hour walk that includes a coffee and a read of the newspaper. One hour before the game, it’s always the same; shower, get into my uniform, strap my ankle, hair, moisturise, socks, shoes – with left shoe first.”

Kobie’s routine also includes music.

“I use the ghetto blaster when getting changed – loud and I have a pump-up play list with ‘Zero’ by ‘Yeah Yeah Yeahs’ a current favourite. When in the bus, I continue to maintain a heightened arousal level with music on my iPod. I know I am right to play when I have a spring in my step and I am chirpy or bubbly.”

Kobie McGurk, Australian Hockeyroo 2010.



Figure 4.2: *Kobie McGurk*

Conversely, a darts player may decrease arousal by using a routine in which they slowly roll their shoulders back and forth and think about ‘smooth’ elbows. Performance routines can be used prior to events or during events. The darts player could use this routine prior to an important game or just before an important shot in the middle of a game.

Golfers frequently use these performance routines to maximise their consistency. These actions are most noticeable when the golfers are disturbed by the crowd in the final seconds before their shot. They often walk away from the ball and re-start the process again, undertaking the same number of practise swings, the same tug of the shirt, cap and pants, the same manner of addressing the ball, and the same shuffle of the feet. Indeed, some elite golfers have been timed with their pre-shot routine requiring the same time-period, almost to the second, for each and every shot.

Key point summary:

- The inverted-U hypothesis indicates that performance is best when athletes experience a moderate level of arousal. Performance can suffer when arousal is above or below this level.

Arousal and anxiety tend to result as a consequence of the athlete's perception of threat. McGrath (1970) has proposed that stress consists of the following four interrelated stages: environmental demand, perception of demand, stress response, and behavioural consequences (see Figure 4.3). In the section below, we revisit material from Units 1 and 2 to refresh your memory on these stages.

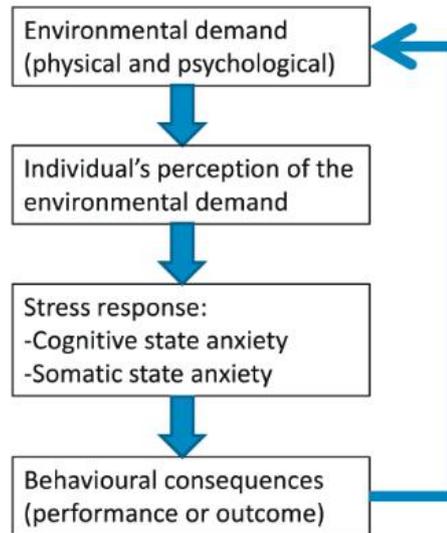


Figure 4.3: *The stress process according to McGrath (1970)*

Stage 1: Environmental demand

In the first stage of the stress process, an environmental demand is placed on the individual. Environmental demands are consistently placed on athletes, such as when a Physical Education teacher asks a student to demonstrate a skill in front of the class. Another example of an environmental demand is when a parent places pressure on their child to win a tennis tournament.

Stage 2: Perception of demand

The next stage of the stress process is the individual's perception of the demand. This subjective perception of the demand is what is important in the determination of subsequent stages in the stress process. One tennis player might perceive a significant imbalance between the demand placed on her and her ability to meet the demand, whereas another tennis player might perceive little imbalance between the same demand and her response capability.

Stage 3: Stress response

Athletes are likely to experience physical and psychological responses when they appraise a situation as threatening. These responses constitute the third stage of the stress process. An appraisal of a situation as threatening is likely to lead to worry and apprehension (cognitive state anxiety), as well as a series of physical responses (somatic state anxiety). Somatic responses include an increased heart rate, shallow breathing, and muscle tension, while a cognitive response includes a narrowing of attention. These are all common reactions to such a threatening appraisal.

Stage 4: Behavioural consequences

The fourth stage in the stress process is termed ‘behavioural consequences’. What is the result of the behaviour? Does state anxiety improve or impair performance? You might notice that there is an arrow from Stage 4 to Stage 1 in Figure 4.3. This indicates that behavioural consequences feed back into environmental demand. One of the tennis players in the previous example might feel overly anxious about a demonstration, perform the task poorly, and be criticised by an onlooking parent. This criticism is likely to be perceived as an additional social demand on the athlete.

Routines and Stress

Stress is often defined as a process in which there is a substantial imbalance between demand and response capability, under conditions where failure to meet that demand has important consequences. In other words, stress involves a demand, a perception of the demand relative to available resources, and a sense that failure to meet the demand has important consequences. How can routines influence the process outlined above? The answer is that an athlete can use

their performance routine to take their mind off the demand, their response capability, or the importance of the occasion. Imagine a tennis player in a situation where they are required to win their service game to stay in the final of a Wimbledon championship. All of a sudden, the player begins to wonder whether their serve is strong enough to win the game, and they become acutely aware of repercussions of failing to win the game. In this instance, a performance routine can help the tennis player take their mind off such debilitating thoughts. Perhaps the player has a routine in which they bounce the ball three times while thinking about the area of the court in which to serve (Figure 4.4). By definition, if they are thinking about such task relevant cues, then they are not thinking about any doubts they have about their capability to meet performance demands or about the importance of the occasion. Even if an athlete perceives a situation as threatening, they might be able to moderate the stress response by engaging in a performance routine. For example, a squash player might think that they have little chance of beating a highly ranked opponent, but their feelings of worry and physical tension are likely to be reduced after engaging in a familiar warm-up prior to the game.

Kelly Harrison – a rhythmic gymnast, an Australian representative and winner of multiple State Championships, uses carefully crafted pre-performance routines to manage stress.

“I use routines to help me relax. I have the same dinner the night before. I have the exact same stuff in my bag every time. I lay it out first, and then put it in my bag – all my good luck stuff as well – things that people have given me. In the morning,



Figure 4.4: Tennis player bouncing ball prior to serve

I have the same breakfast – muesli and fruit. I always put my training gear on first, and then do my hair and my make-up. I don't spend too much time on it, this helps to minimise the stress. I listen to my performance routine music when I am in the car – it helps if there is not much talk. My warm-up is also exactly the same – cardio (involves skipping), then stretching, simple body work and then specific performance work which is from my competition routine.”

Kelly Harrison, Australian Gymnast 2010.

Key point summary:

- An effective pre-performance routine can ward away a perception that a demand is threatening and can moderate the athlete's reaction to stress.

Routines and motivation

Motivation can be defined as the *direction* and *intensity* of one's effort (Sage 1977). Direction of effort refers to which situations an individual seeks out, approaches, or is attracted to. Some people are highly motivated in this regard; they obtain a gym membership, they try out for school sport teams, and they arrive to training sessions early. Intensity of effort, on the other hand, refers to how much effort a person puts forth in a particular situation. Although a student might try out for the school soccer team (reflecting approach behaviour), he/she might not try very hard during training. Routines are particularly effective at influencing the intensity, rather than the direction, of an athlete's effort.

It is desirable to be motivated (but not too much so!) before a performance and during a performance, and athletes can use routines in these instances to stimulate their motivation on days when they are 'off colour'.

One of the authors of this chapter has spent much of the last couple of years examining the automaticity of motivation. His research indicates that motivation can become linked with particular cues through repeated association. Such 'automatic' motivation can have important consequences. For instance, if a netballer usually feels intrinsically motivated when playing netball at a particular gymnasium, then she would be more likely to develop intrinsic motivation for other activities in this same gym (for example, a PUMP class). The point that we would like to make here is that motivation can be aroused automatically, and cues from a performance routine might be useful for such automatic activation. If we usually feel excited about playing soccer, but find that we are a bit unenthusiastic on one day, a performance routine is likely to activate the motivation that has come to be associated with the sport over time. Performance routines can be used to



Figure 4.5: Kelly Harrison

influence motivation prior to the beginning of a competition, or prior to the performance of a specific skill within a competition (e.g. bounce the ball just before a free throw).

Key point summary:

- When used often enough in competition, routines can come to trigger motivation automatically.

Routines and concentration

Concentration is crucial to effective performance in sport. Sport coaches often plead with their athletes to remain focused, fearing that a loss of concentration among the player group will jeopardise the team's position. By definition, routines help an athlete to concentrate on task-relevant cues (remember that a routine can be defined as a sequence of *task-relevant thoughts and actions* which an athlete engages in systematically prior to his or her performance of a specific sport skill). Kobie McGurk, Australian Hockeyroo, highlights the importance of routines in maximising her concentration.

“When setting up for a penalty corner, be it in offense or defence, routines are important to preparation. We decide on a strategy, and I always verbalise my role out loud. When we are taking an offensive penalty corner, I am a shooter, and my routine is the same; I look at the trapper, then I look at the injector, then back to the trapper. Then I am ready.”

Kobie McGurk, Australian Hockeyroo 2010.

Figure 4.6: Kobie McGurk

Imagine you are about to make an important putt in a golf tournament. You have completed your pre-shot routine in which you assessed the green in your usual manner, made some practice swings, shuffled your feet in your usual way to ensure that your position is comfortable, and taken one final look at the hole. You are now able to ‘release’ the mind and focus on replicating your last practice swing. If you did not possess such a well learned routine, it is possible that you might neglect some important task-relevant thoughts or behaviours prior to your putt. This is especially likely to happen in high pressure situations in which you are prone to feeling rushed and distracted. Without a rehearsed routine, you might become distracted by the crowd or by a competitor, or you might forget to engage in enough practice swings



for optimal performance. Thus, a performance routine can be a useful tool to focus an athlete on relevant cues immediately prior to skill execution (that is, during competition). Warm-up routines prior to a competition might also be useful at helping athletes to adopt a particular focus of attention that is necessary for effective performance. Jessica Jordan – an Australian Taekwondo competition fighter and World Championship competitor – knows the importance of pre-performance routines to maximise her level of concentration.

“The day before competition, we have weigh-in, which definitely gets you focussed. You get to see your draw – you learn who you will be fighting first. Once I see my draw – that impacts – its focus time. If I know my first opponent, then I start to put my game plan together for that style of fighter. The night before, my routine is to have everything packed and my uniform is hung out the same way each time.”

Jessica Jordan, Australian Taekwondo Representative 2010.

Class task: Routines

In small groups, brainstorm examples of routines that you use to aid performance in your sport. Describe any experiences you have had in which a performance routine has influenced your self-confidence, concentration or level of arousal.

Discuss whether these routines would be most useful before the start of a game, during play or after performance.

Key point summary:

- Routines can help athletes to concentrate on relevant cues.
- Concentration on task-relevant cues is important to performance success.

Routines and self-confidence

Confidence is usually a wonderful attribute for athletes to draw upon – it reduces anxiety and influences concentration, emotions, goal setting, and persistence at tasks. In most cases, confidence is beneficial for performance, and most sport psychologists tend to work on increasing confidence among athletes. Confidence is good when an athlete feels that they will succeed if they work hard at their pursuit, but there are occasions when confidence can be detrimental. These situations occur when athletes are so confident that they think they don't have to try hard to win. Complacency can set in with athletes that are overly confident, and performance can suffer as a result of this complacency. The relationship between confidence and performance is sometimes drawn as a skewed inverted-U (see Figure 4.8).



Figure 4.7:
Jessica Jordan

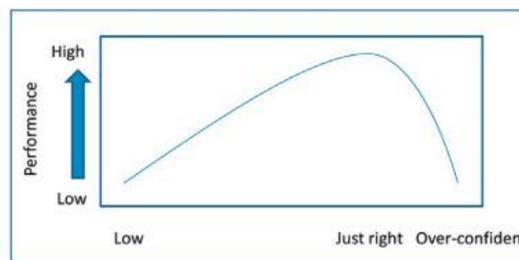


Figure 4.8: *Relationship between confidence and performance*

Athletes can manage their confidence in the *build-up* to important games by entering into a set pre-game routine. A pre-game routine that includes positive self-talk or imagery, for instance, can boost an athlete's belief in their ability. Jessica Jordan – Taekwondo competition fighter, talks of using a pre-performance warm-up routine to enhance her self-confidence.

“I do the same routine for my warm-up every time – walking stretching, jogging, music and positive self-talk. It depends on the strength of my opposition, but if I'm preparing for a strong opponent I really focus on flushing out any negative thoughts. I have to focus on my own strengths and not her strengths, it's important to feel confident about the upcoming bout.”

Jessica Jordan, Australian Taekwondo Representative 2010.

Skills such as self-talk can also be used effectively in routines during the game, such as when it is used by a tennis player while they bounce the ball prior to serving.

Research has found that behaviours that an athlete exhibits during a routine might even influence the confidence of an opponent. In one study, researchers asked participants to view images of table tennis players in either table tennis sportswear or in general sport clothing. The players also differed according to whether they were acting confidently or not. Participants were not aware of the intention of the research and were not told about the differences between the experimental conditions. After asking the participants about their expectations for success if they were to play against the people in the images, the researchers found interesting results. More specifically, participants were not as confident in their chances of success against opponents wearing table tennis specific clothing or against opponents portraying positive body

language. The point that we would like to make here is that routines can influence an athlete's confidence, and to the extent that behaviours in a routine are witnessed by an opponent, they can influence the opponent's confidence as well.

Performance Routines: Examples

Arousal

A basketball player bounces the ball three times and exhales deeply before each free throw in order to release physical tension.

Stress

Figure skaters might focus on the key words, “Height then tight,” as part of their routine before every jump. Focusing on technique helps to put worries about the importance of a competition out of mind.

Motivation

Many tennis players use routines that include spinning their racquets and bouncing the ball the same way before every serve. This can help to trigger feelings of motivation that have come to be associated with the routine.

Concentration

By using a routine that involves lining up his shot, getting into a comfortable position and eyeing the hole one last time, a golfer can make sure he focuses on the right cues before every shot.

Self-confidence

A high jumper might think the phrase, “I can do this,” before every jump in order to boost self-confidence.

Key point summary:

- Routines before and during a performance can influence the confidence of athletes as well as the confidence of their opponents.

Revision questions:

Test yourself on revision questions 1–4 located at the end of this chapter.

Imagery

Imagery is sometimes referred to as the process in which an individual ‘goes to the movies inside their head’, but this is a misleading definition. Going to the movies entails an attendance to only sight and sounds, but sport psychologists encourage athletes to engage as many of the senses as possible when practising imagery. As well as using sight and sound stimuli for imagery, athletes should attempt to ‘feel’ the movements that they are imagining. They should also try to ‘smell’ the environment in which they are performing. If used effectively, imagery can influence arousal, stress, motivation, concentration, and confidence.

Imagery and arousal

Imagery can be useful for increasing or decreasing arousal. Thinking about lifting a sought-after trophy can help to increase arousal, whereas imagining oneself lying at the beach is likely to reduce arousal. Imagery can be used before, during, or after performance to regulate arousal. Prior to a game, an AFL midfielder might wish to engage in imagery in which they make a strong tackle and dispossess an opponent. Taekwondo competition fighter, Jessica Jordan, describes the use of imagery in her pre-performance warm-up.

“When I am listening to my music and stretching, I visualise one kick over and over again, my best kick – a right leg back foot turning kick. I picture this hitting every time, it’s fast and strong, and I convince myself that there is nothing that my opponent can do to stop it. This really gets me ready to push hard in my fights.” *Jessica Jordan, Australian Taekwondo Representative 2010.*

During a game, Aaron Sandilands, ruckman for the Fremantle Dockers, might like to use imagery [briefly] prior to a bounce-down so that he energises himself for the actual contest.

Finally, many athletes find it difficult to sleep at night following a game. Physical and mental activation can disturb sleep patterns, so techniques such as imagining oneself at the beach can help players to relax post-game.

Practical activity:

Using imagery

Think of something that you would like to achieve in your sport (for example, executing a new skill or scoring a goal or basket). Then find a space where you can sit quietly and close your eyes. Concentrate on creating a vision of you achieving this task. Try to use as many of your senses as possible. ‘See’ yourself completing the task, ‘feel’ the movements, and ‘hear’ the noises. After undertaking this imagery, think about whether you feel more enthusiastic about achieving the goal.

Equipment:

- None.

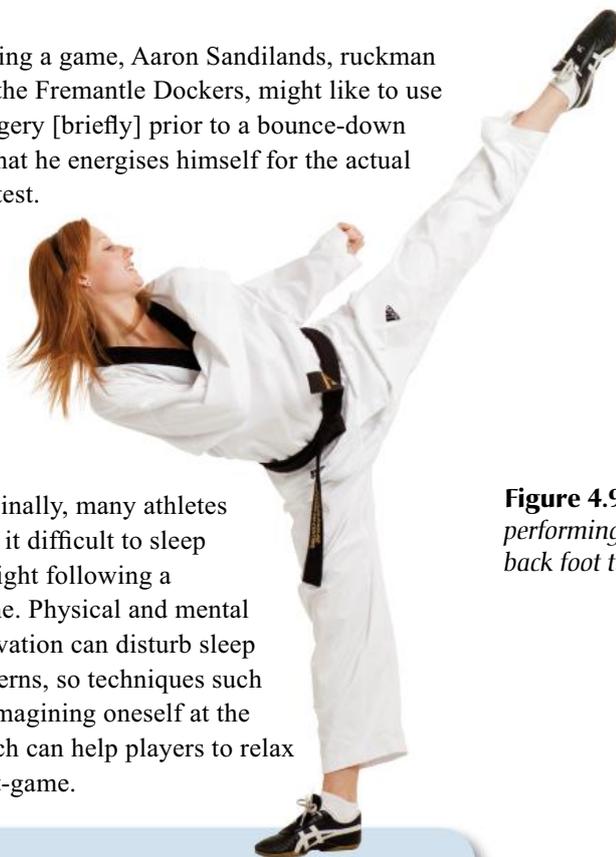


Figure 4.9: *Jessica Jordan performing a right leg back foot turning kick*

Key point summary:

- Imagery is most useful when it incorporates as many of the senses as possible.
- Different scenes can be imagined to either increase or decrease arousal.

“Before I go to sleep... while using controlled breathing, I try to correct any bad performances that I have had lately – I visualise me doing my performance well. This is important, because gymnastics is a sport that can focus on errors more than the positive aspects.”

Kelly Harrison, Australian Gymnast 2010.

Imagery and stress

Imagery can be used to alter perceptions about one’s ability to meet an environmental demand, and it can also be used to moderate physical symptoms following the perception of threat. For example, a footballer who imagines himself performing well in the grand final might re-evaluate his capability to meet environmental demands posed by an upcoming game. Kelly Harrison, a rhythmic gymnast, uses pre-performance imagery to manage the stage 2 stress process.

Thinking about past accomplishments in tasks similar to the current demand can also help an athlete to reinterpret the demand or one’s response capability. Even if an athlete appraises a situation as threatening, they can still imagine a relaxing situation, such as taking a bath, which can reduce the physical symptoms of stress. Imagery can be used prior to an event, during an event, or after an event to alter perceptions of threat or the stress response.

Key point summary:

- Imagery can be used to alter an athlete's perception of environmental demands, or to alter their reaction to a perception of threat.

Imagery and motivation

A way that athletes can increase motivation is by engaging in imagery. Athletes can influence both the direction and intensity of their efforts by thinking about successful performance. Taekwondo competition fighter, Jessica Jordan, describes the use of pre-performance imagery to assess her motivation.

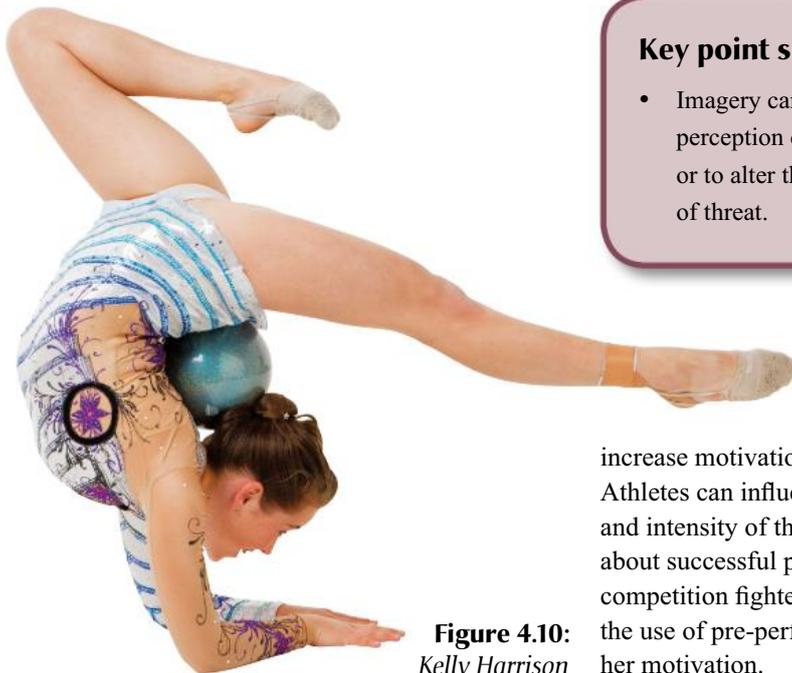


Figure 4.10:
Kelly Harrison

“The night before – when I go to sleep, I start to visualise my whole day. I foresee the process right from getting up, to shower, breakfast, taxi – right through to the time when I walk into the stadium. I also visualise myself bowing to the referee, to my opponent and then my first kick – and it being successful – making good solid contact and scoring a point. This thought process helps me to focus, to concentrate... but this also relates to my motivation. I find if I am struggling with this process of imagery, then the tournament or the upcoming fight is probably not as important to me. It’s a good way of ensuring that I am appropriately motivated.”

Jessica Jordan, Australian Taekwondo Representative 2010.

If an athlete’s goal is to exercise to lose weight, it can be beneficial for them to imagine themselves at their goal weight or think about themselves exercising successfully. The wife of one of the authors of this chapter has often used imagery to motivate herself to exercise. On the occasions when she has felt too tired to exercise, she often imagines how relaxed and proud she would feel after engaging in physical activity. This imagery typically motivates her to undertake the exercise.

Imagery is a particularly useful strategy prior to performance, but it can sometimes be employed during performance as well. For example, a soccer forward who is starting to feel fatigued might use imagery of herself striking the winning goal in order to maintain motivation through the second half. Imagery can be useful in training after competition too, because athletes might need to motivate themselves for the next goal.

Key point summary:

- Imagery of successful performance can help an athlete approach activities (motivational direction) and persist at those activities (motivational intensity).
- Using imagery to influence motivation is useful when undertaken prior to, during or after a performance.

Imagery and concentration

It can be very useful to use imagery prior to performance to prepare an athlete for an appropriate attentional focus during skill execution. Kelly Harrison, rhythmic gymnast, employs pre-performance imagery to improve her concentration.



Figure 4.12: Kelly Harrison



Figure 4.11: Jessica Jordan

“In the five minutes before I go on, I stand facing the wall, close my eyes, and tense all of my muscles, every body part has to be tight – finishing with me standing on my toes. Then I visualise one specific skill or throw – generally one that has not been going well and I see myself doing it well and then I relax. I have about three or four rises. This really helps me to focus – to concentrate.”

*Kelly Harrison,
Australian Gymnast 2010.*

Using imagery, athletes can work on plans of action and on what they should focus upon in different situations. Emma Beckett, a Western



Figure 4.13: Emma Beckett

Australian netball representative, uses imagery at half-time to re-focus.

“It is really important in the 7 minutes that we have together at half time, to re-focus on strategies. You need to be able to visualise the application of plans. We have set plays for an in-bound or centre pass where we try and get the ball into the space that a designated receiver will be to take the pass.”

*Emma Beckett, Western Australian
Netballer 2010.*

A goal attack (GA) in netball might like to use imagery prior to a grand final to focus on strategy if she were to be faced with an important shot in the dying moments of the game. She might like to imagine herself focusing on relaxing her shoulders and elbows before successful shot execution. If she were to encounter this moment in the actual game, she would know to focus on these relevant cues to increase her chances of making a successful shot. Typically, imagery would be used to improve concentration in instances such as this before an event (Figure 4.14). Athletes should be cautious about using imagery to improve concentration during performance. Although imagery in a pre-shot routine can help an athlete to focus on relevant cues, imagery involving task-irrelevant cues can be distracting and lead to performance decrements. Imagining oneself lifting a trophy immediately prior to shooting a free throw in basketball is inadvisable for this reason.



Figure 4.14: A netballer (GA) engaging in ‘deep’ thought prior to a game

Key point summary:

- Imagery can be used by athletes prior to an event to identify task-relevant cues to focus on during the event.

Imagery and self-confidence

Imagery involving effective performance can be used to build confidence. Emma Beckett, a Western Australian netballer, uses imagery to improve self-confidence.

“After training sessions we do self-performance imagery. We visualise a successful performance or play – with all of the crowd noise, etc. For example, seeing a really good defensive intercept – this involves slowing it down. The important thing is to see it completed successfully, over and over again. This helps with self-confidence.”

Emma Beckett, Western Australian Netballer 2010.

Prior to executing a tee shot, many elite golfers will point their club down the fairway and imagine the ball following this line (Figure 4.15). Similarly, a hockey player might imagine the ball thumping into the goal prior

to a penalty stroke. Such imagery can help the athlete feel that effective performance is within their grasp. These examples show how pre-shot imagery can build confidence during a game, but imagery can be useful in pre-game situations to improve confidence as well. Athletes might wish to use imagery to picture an outstanding performance whilst they sit in the changing rooms prior to a game. This strategy can focus the athlete on important cues, but it also enables the athlete to build confidence in their ability.

Class task: Imagery

Imagery is one technique that can be useful to athletes before, during and after competitive events. With a partner, come up with examples of how imagery might be used to influence arousal at each of these times.



Figure 4.15: Golfer using imagery by pointing her club down the fairway

Imagery: Examples

Arousal

If a slalom skier was feeling highly tense and anxious before his event, he could take a moment to engage in imagery. Imagining himself relaxing on the beach would help to decrease his level of arousal.

Stress

A shot-putter who was experiencing intense worries before a major event could use imagery to bring her last successful performance to mind. This would help to strengthen her belief that she was capable of meeting environmental demands.

Motivation

If a wrestler was feeling relaxed and complacent before a match, he could use imagery of himself celebrating after a win to trigger stronger feelings of motivation.

Concentration

Soccer players can imagine possible set-piece plays (e.g., corner kick) prior to important matches in order to identify which cues would be important to focus on in each situation.

Self-confidence

A gymnast might use imagery to visualise, feel and hear herself performing a flawless routine. Imaginal experiences encourage athletes to perceive that effective performance is within their grasp.

Key point summary:

- Imagery can be used by athletes to help them feel that effective performance is within their grasp.

Revision questions:

Test yourself on revision questions 5–8 located at the end of this chapter.

Personal Relaxation

Four common techniques are used to help an athlete to relax. These are progressive relaxation, breathing control, thought stopping, and listening to music. These skills will be reviewed in the introduction to the section before each is specifically discussed in relation to arousal, stress, motivation, concentration, and self-confidence. Although self-talk can also be defined as a relaxation skill, it will be reviewed under its own heading and is presented immediately following this section on personal relaxation.

Class task:***Your methods of relaxing***

What do you like to do to relax? List one activity that might help you relax before an important game. List another activity that might help you relax during an important moment in the game. Finally, list an activity that might help you relax after a game.

Progressive relaxation

This technique requires the performer to tense and relax the muscles of the body in a set order.

The idea is to focus on the different sensation between the relaxed and tense states. After practising this technique over time, athletes learn to detect tension in areas of their body and can subsequently relax that area. Athletes may spend about thirty minutes performing this technique in the early learning stages (Figure 4.16), but once learned, athletes are able to utilise this technique in short breaks during games. In summary, this technique is most likely to be used before or after games, but with training an athlete can even use it during performance.

Practical activity:***Progressive relaxation***

Table 4.1: Adapted from Weinberg and Gould (2007), details a progressive relaxation session.

Equipment:

- Table 4.1.
- Enough space for each student to lie down.



Figure 4.16:
Athletes using progressive relaxation prior to performance

Table 4.1: *Progressive relaxation session*

1. Overall instruction: You will be asked to tense a muscle group and then relax it. Pay close attention to how it feels to be relaxed as opposed to tense. For each muscle group, perform each exercise twice before progressing to the next group. Each phase should take about 5 to 7 seconds. As you develop skill with progressive relaxation, you can omit the tension phase and just focus on relaxation.
2. Find a quiet place, dim the lights, lie down, and take a couple of deep breaths. Exhale slowly and relax.
3. Raise your arms so that your fists point to the roof. Make a tight fist with each hand. Notice the tension in your fingers and hold that tension for 5 seconds. Now, keep your fists clenched but not as tight as before. Hold this state for 5 seconds and focus on the tension. Finally, relax your hands completely for 10 to 15 seconds. Notice how the tension and discomfort drain from your hands. Focus on the difference between the tension you felt and the comfort you now feel.
4. Tense your upper arms tightly for 5 seconds and focus on the tension. Let the tension out halfway for another 5 seconds, again focusing on the tension. Now let your arms rest limply at your sides for 10 to 15 seconds. Focus on the contrast in feeling in your upper arms.
5. Curl your toes as tight as you can. After 5 seconds, relax the toes halfway and hold for another 5 seconds. Now relax your toes completely for 10 to 15 seconds. Focus on the different feelings in your toes.
6. Point your toes away from you and tense your feet and calves. Hold for 5 seconds. Relax these muscles halfway for another five seconds before finally relaxing them completely for 10 to 15 seconds.
7. Extend your legs, raising them about 6 inches off the floor and tensing your thigh muscles. Hold for 5 seconds. Return your legs to the floor but keep your thigh muscles reasonably tense for another 5 seconds. Now relax your thighs and focus on the relaxation in your feet, calves, and thighs for 30 seconds.
8. Tense your stomach muscles as much as possible for 5 seconds. Relax halfway for another five seconds, and then relax completely for 10 to 15 seconds. Remember to focus on the different sensation between tense and relaxed states.
9. Press the palms of your hands together as tightly as possible (this should work the chest and shoulders). Hold this tension for 5 seconds, then relax halfway for another 5 seconds. Now relax the muscles and concentrate on the relaxation until your muscles are completely loose and relaxed. Concentrate also on the muscle groups that have been previously relaxed.
10. Push your back on to the floor as hard as possible for 5 seconds. Now reduce the tension halfway for another 5 seconds. Now relax your back and shoulders completely for 10-15 seconds, focusing on the relaxation in the area.
11. Keeping your torso, arms, and legs relaxed, tense your neck muscles by bringing your head forward until your chin digs into your chest. Hold this tension for 5 seconds before relaxing slightly for another 5 seconds. Now return your head to the floor and focus on the relaxation developing in your neck muscles.
12. Finally, take a series of short inhalations, about 1 per second, until your chest is filled. Hold this breath for 5 seconds, then exhale slowly for 10 seconds while thinking the word 'calm' or 'relaxed'. Repeat this breathing process at least 5 times.

Breathing control

Breath control is perhaps a more commonly used tactic to reduce anxiety than progressive relaxation. When you are confident and in control, your breathing will be smooth, deep and regular. When you are anxious, your breathing is likely to be shallow and irregular. The trick to breath control is to consciously regulate your breath so that it is smooth, deep and regular. A greater relaxation response will be achieved if you take a series of deep and controlled breaths rather than a single breath. However, a single deep breath with slow exhalation can be a useful technique to reduce arousal during performance.

Practical activity: *Breath control*

To practice breath control, take a deep breath by first filling the lower part of your lungs. Push your stomach out and feel the lower portion of your lungs expand. Once this section is full, try to fill the middle portion of your lungs by filling the section beneath your rib cage. The sensation of your rib cage pushing outwards is a sign that this portion of the lungs is filling. The final section of the inhalation requires you to fill the top portion of your lungs. Your shoulders might lift slightly during this stage. It is important that you exhale slowly. A 1:2 ratio of inhalation to exhalation is recommended as a mechanism to strengthen the relaxation response. So, your exhalation would be 8 seconds if you spent 4 seconds inhaling.

Equipment:

- Clock.

Thought stopping

When anxious, many athletes find it difficult to control the negative self-talk in their minds. “What if I make a fool of myself in front of the spectators”? “I’ve got a bad feeling about today”. “I bet I’ll get substituted after only a few minutes on the court”. **Thought stopping** is a technique that helps athletes cope with this type of negative self-talk. It can be used prior to events, during gaps in play, or even after a performance if the athlete dwells on a poor performance. The idea is to use a word or a physical cue, such as a pat on the hip, whenever a negative thought comes to mind. This cue should then be followed by an attempt to reframe the negative thought into a positive one. A soccer player might want to use thought stopping after missing a penalty. As soon as a negative thought enters the mind of the player, he/she could pat himself/herself on the hip and then engage in positive self-talk. After the pat on the hip, the player could think “let’s stay focused, I’m still going to play well today” (Figure 4.17). In summary, thought stopping is most effectively used before or during play.

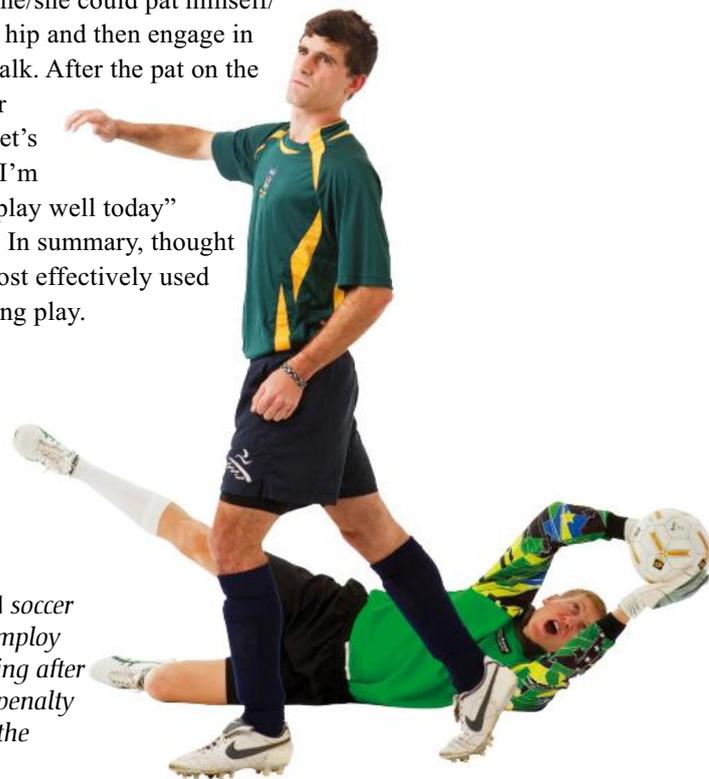


Figure 4.17: A soccer player could employ thought stopping after having had a penalty shot saved by the goalkeeper

Listen to music

Music can cause dramatic changes in arousal. Upbeat music can give us energy and stimulation; slow music can calm us. Have you ever noticed the slow and soothing music that is played when you board an aeroplane, when you take an elevator, or when you wait in a medical centre? This type of music is important in these environments to reduce people's anxiety. Conversely, music that is upbeat is often played just before a sport team runs onto the field, a technique that can increase arousal levels of spectators as well as players. Many athletes listen to music prior to competition to regulate arousal, and many exercisers listen to music during their fitness sessions. Music can also be used after a performance to relax. Thus, a benefit of music is that it is highly accessible and can be used to regulate arousal before, during, or after performance.

Key point summary:

- Arousal regulation techniques can include progressive relaxation, breathing control, imagery, thought stopping, performance routines, listening to music, and self-talk.

Personal relaxation and arousal

The primary purpose of personal relaxation is to reduce arousal. All of the techniques that have been described above can be used in this regard, but there are a variety of other personal relaxation techniques that can be used for the same purpose. As was mentioned in the textbook for Units 1 and 2, athletes are advised to use physical techniques (for example, breath control) to reduce physical symptoms of arousal or anxiety, whereas they are advised to use mental techniques (such as self-talk) to reduce

cognitive symptoms of arousal or anxiety. This is known as the *matching hypothesis*.

Techniques such as self-talk and breathing control can be used during events to reduce arousal, whereas other relaxation techniques, such as progressive relaxation, are more suitably used before or after an event. In between rounds of Taekwondo fighting, Jessica Jordan benefits from personal relaxation techniques.

“Immediately the round is over, after two minutes of intense fighting, I sometimes need to regain my breathing. I turn and walk to my coach and I can ‘gag’ and need time to recover. My coach helps me to regain control of my breathing and reduce my arousal levels so I can make the most of the rest. We use breathing control techniques, such as breathing in and pausing a little before a controlled exhalation. After using this, I’m much better placed to recover, to listen to his feedback and re-set my focus for the next round.”

Jessica Jordan, Australian Taekwondo Representative 2010.

Key point summary:

- Athletes are recommended to use physical anxiety reduction techniques to reduce physical symptoms of anxiety, and mental techniques to reduce cognitive symptoms of anxiety.

Personal relaxation and stress

Using personal relaxation techniques can significantly impact the level of stress experienced by an athlete. In recent times, many athletes have found that the demands of professional sport are extreme. These athletes

can experience physical and mental exhaustion as a result of their profession, and some use personal relaxation to withdraw themselves from these demands. It is not uncommon, for instance, that cyclists will withdraw from some multi-day events in order to freshen themselves for more important races such as the Tour de France. The decision by athletes to withdraw from events removes some of the environmental demands placed on the athlete. Even if an environmental demand is placed on an athlete, personal relaxation can be used to focus attention away from thoughts relating to the threat posed by the demand. For example, a swimmer might wish to watch a movie in the evening before an Olympic final so that she doesn't think about her highly ranked opponents. By using personal relaxation techniques such as self-talk, imagery, progressive relaxation and breathing control, an athlete can reduce any worrying or physical symptoms of stress.

Both Kelly Harrison, a rhythmic gymnast, and Jessica Jordan, a Taekwondo fighter, use controlled breathing to reduce stress prior to performance.

“I hardly ever sleep the night before a competition – it can be pretty stressful. I use breathing techniques to help: I take two deep breaths – breathe in as deep as I can and breathe out. While using controlled breathing, I try to correct any bad performances that I have had lately – I visualise me doing my performance well.” *Kelly Harrison, Australian Gymnast 2010.*

“If I am feeling too nervous pre-fight – that is negative thoughts are creeping in or I can't visualise my performance – I will use breathing control to assist me.” *Jessica Jordan, Australian Taekwondo Representative 2010.*

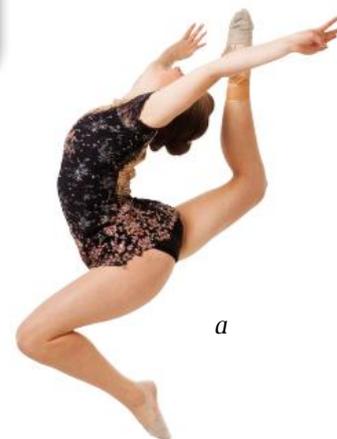
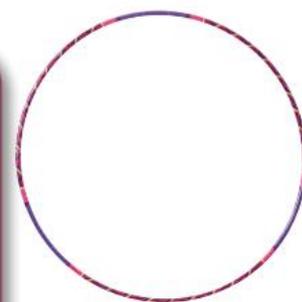
Key point summary:

- Personal relaxation techniques can be used to decrease the number of environmental demands placed on an athlete, reduce an athlete's perception of threat or help to regulate an athlete's physical symptoms of stress.
- Using relaxation to reduce stress is most useful when undertaken prior to and after competition.

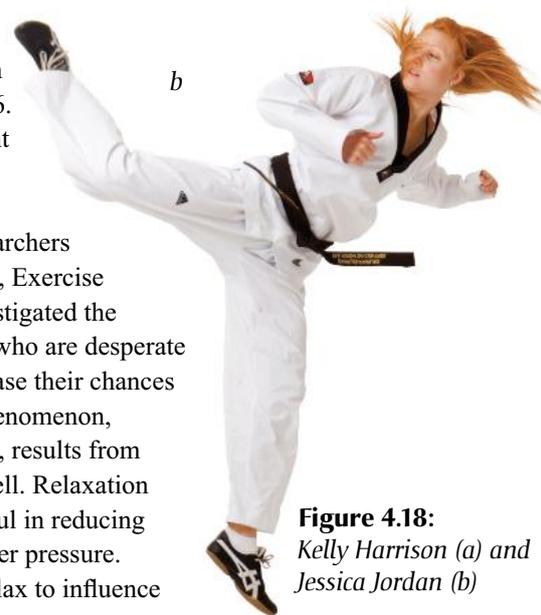
Personal relaxation and motivation

It is sometimes the case that relaxation techniques are needed to moderate the impact of motivation on performance. There are some occasions when people are so motivated to perform well that it becomes a problem. Imagine how you would feel if you needed to score a penalty to qualify Australia for the World Cup of soccer.

John Aloisi (Figure 4.19) experienced this very situation prior to the World Cup in 2006. It is likely that you would want to score the penalty so badly that you might tighten up and perform badly. A team of researchers at the School of Sport Science, Exercise and Health at UWA have investigated the phenomena whereby athletes who are desperate to perform well actually increase their chances of performing poorly. This phenomenon, otherwise known as ‘choking’, results from too much desire to perform well. Relaxation techniques might be very useful in reducing such instances of choking under pressure. Rarely will athletes need to relax to influence



a



b

Figure 4.18:
Kelly Harrison (a) and
Jessica Jordan (b)

their motivation after performance, so these strategies are most likely to be used before and during competition.

Key point summary:

- Personal relaxation techniques can be used to reduce excessive levels of motivation, which helps to prevent choking under pressure.

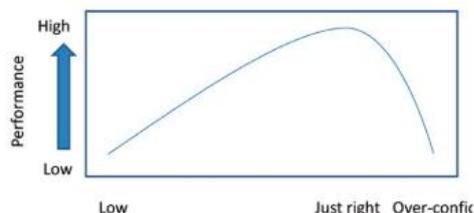


Figure 4.19: John Aloisi (Australian Soccer Representative)

Class task: *Personal Relaxation*

Athletes can use a range of personal relaxation techniques to reduce anxiety. Examples of some personal relaxation techniques include breathing control, progressive muscle relaxation and thought stopping. Break into small groups and discuss whether or not each of these techniques would be appropriate for use:

- Before a game
- During play
- After the game

Personal relaxation and concentration

You might remember from Units 1 and 2 that one of the ways that arousal can influence performance is via its effect on attention and vision. We explained that an overly-high level of arousal narrows a performer's attentional field, and that highly aroused athletes tend to scan the playing environment less often. In addition to this, high arousal can cause an athlete to revert to a dominant attentional style that may be inappropriate for the task at hand, or can cause athletes to attend to inappropriate cues. You can appreciate this issue in relation to sitting examinations at school. Imagine that you have a lot of work to complete when it is announced that only ten minutes remain for the exam. It is likely that your panic to complete the exam will cause you to spend the last ten minutes unproductively. You might feel that your brain is 'scattered' and unable to focus on any particular question. Relaxation techniques aimed at reducing anxiety can be beneficial at helping an athlete to develop an appropriate focus of attention. Breathing control, progressive relaxation, and a number of other relaxation techniques can be useful in this regard, and depending on which technique is used, they can be used pre-, during, and/or post-event.

Key point summary:

- Relaxation methods affect concentration through their effect on an athlete's arousal.
- Regulating arousal helps athletes to adopt an appropriate focus of attention.

Personal relaxation and self-confidence

According to Bandura (1997), physiological and emotional states can influence the confidence of athletes. Physical fitness and positive emotions can influence athletes' self-belief, and personal relaxation can help to improve both physical fitness and affective (emotional) states. From a physical perspective, endurance athletes are advised to taper their training on a regular basis to enable their bodies to adapt to increasing training loads. Methods of personal relaxation during these taper phases will also enable athletes to maintain a positive and healthy mindset for performance and training. The physical and emotional benefits of such tapering prior to performance are likely to influence an athlete's confidence in their ability. Also, relaxation techniques such as breathing control

might influence confidence via their effect on mood states and physical readiness during a performance. For example, if an athlete feels that their level of arousal promotes effective performance, their self-confidence is likely to increase as a result.

Key point summary:

- Relaxation methods that are incorporated into a tapering process can be used to influence confidence.

Revision questions:

Test yourself on revision questions 9–14 located at the end of this chapter.

Personal Relaxation: Examples

Arousal

By regularly practising progressive muscle relaxation, a long-distance runner could learn to detect and release physical tension in her upper body in order to conserve energy.

Stress

A rower who was experiencing doubts during a race against a tough opponent could use thought stopping to re-evaluate his perception of threat.

Motivation

Prior to the final serve of a game, a volleyball player who was feeling overly-motivated might use positive self-talk to calm her mind and avoid 'choking' under the pressure.

Concentration

Quarterbacks in American football can use breath control to decrease their level of arousal. Doing so would help to broaden their scope of attention so that they could assess the whole playing field.

Self-confidence

A swimmer who was feeling anxious just prior to a race could listen to some relaxing music. Returning her body and mind to her ideal performance state would help to boost her self-confidence.

Self-Talk

As the name implies, *self-talk* refers to a process in which an athlete engages in dialogue with themselves. This dialogue can be audible to others (spoken out loud) or it can be completely internal. Self-talk is commonly used by athletes and is a simple technique that can influence arousal, stress, motivation, concentration, and self-confidence.

Self-talk and arousal

Positive self-talk can provide athletes with energy for performance. Phrases such as ‘get tough’, ‘go hard’, and words such as ‘fight’ and ‘push’ can help to move the athlete away from an under-aroused state. On the other hand, words such as ‘relax’, ‘smooth’, and

Practical activity: Testing the impact of self-talk on performance

Split the class into two groups. With a piece of chalk, each person marks a spot on a wall that is representative of their standing reach. Undertake 5 warm-up vertical jumps to start the activity. Then, before each of the following five vertical jump trials, half the class repeat the word ‘push’ to themselves 10 times in quick succession. The other half of the class complete the same vertical jump trials but repeat the word ‘tired’ to themselves 10 times before each trial.

For each person, measure the vertical distance between the most successful trial and the standing reach position.

Equipment:

- Chalk.
- Long ruler or tape measure.
- Wall.

‘control’ can reduce arousal levels. Self-talk takes very little time, so it is a particularly useful technique immediately before and during competition. It can also be useful to reduce anxiety about performance after competition. You can try using self-talk to influence arousal (and performance) in the class activity detailed below.

Key point summary:

- Athletes can use self-talk to either increase or decrease their level of arousal.

Self-talk and stress

A decision about whether to commit to an event is likely to be influenced by self-talk, such that athletes can talk themselves into, or out of, a decision to enter a future competition. In deciding whether to enter a marathon, for instance, a recreational runner might engage in self-talk such as “I’m good at running...I can do this” or “I won’t be able to finish”, and such dialogue with the self is likely to influence the final decision that is made. Therefore, self-talk can influence the environmental demands placed on an athlete. Self-talk can also be used to re-appraise an environmental demand or one’s ability to meet the it, or it can work to decrease perceptions of the significance of the demand. Statements such as “what doesn’t kill me will make me stronger” can be used to reduce the perceived significance of the competition.

Finally, self-talk can be used to moderate worry and physical symptoms of stress. By using phrases such as “breathe deep”, an athlete can reduce the symptoms that are associated with anxiety.



Figure 4.20: An athlete engaging in self-talk

Key point summary:

- An athlete's use of self-talk influences their likelihood of approaching potentially stressful sporting events.
- Self-talk also influences how threatening an event is perceived to be.
- Calming cue words help to regulate cognitive and physical symptoms of stress.

Self-talk and motivation

There are many situations in which people wonder about a course of action. Should I try out for the team? Should I pay to join the gym for another year? Should I miss training tonight? Self-talk can be used to sway decisions on these types of questions. When an athlete is experiencing reduced motivation in relation to direction of effort, he/she could repeat sentences such as “don't ask...just do” or “just do it”. Athletes might experience times when the intensity of their effort also wanes. After a difficult day at work, the coach's request to run laps might be met with despondency. Once again, self-talk can be used to increase motivation here (for example, “you can do it”; “keep pushing”). Self-talk is useful at increasing motivation just before performance, during performance, or in training after a performance. Elite athletes, such as Jessica Jordan from Taekwondo, highlight the use of self-talk to impact on motivation.

“I use my journal when I'm preparing for some of my fights. I know it seems pretty corny, but I think that self-talk can have an impact and I use my journal as a stimulus for this. I have some Mohammad Ali quotes, poems like ‘Dare to Dream’ and some cues like ‘stay focused’, ‘you're the best’, and ‘take the chance’.”
Jessica Jordan, Australian Taekwondo Representative 2010.

Key point summary:

- Self-talk can influence the direction and intensity of an athlete's motivation, and it can be used pre-, during, and post-performance.

Self-talk and concentration

Self-talk is commonly used to maintain or change concentration. In sports such as cricket and golf it is important to change concentration on a regular basis. Sport psychologists recommend that athletes in such sports develop their skills at switching their attention on and off particular stimuli. Self-talk can be particularly useful in this regard. A wicket-keeper in cricket might like to use the word ‘on’ as the bowler begins their run-up, and ‘off’ after the play has ended.

Self-talk can be useful for creating an internal perspective, such as when an athlete repeats the word ‘feel’, or it can help to create external perspective, such as when an athlete uses the word ‘see’ as a prompt. Self-talk is a useful technique for maintaining or changing concentration during performance, but it can also be used in the build-up to events.



Figure 4.21: Putting in golf is improved by self-talk

**UWA research snapshot:
Measuring the effect of self-talk**

A study undertaken at the School of Sport Science, Exercise and Health at the University of Western Australia indicates that the effects of self-talk can be dramatic. In this study, highly skilled golfers performed better at putting while thinking about words such as ‘easy’ and ‘smooth’ than when thinking about words that were either irrelevant to putting (such as ‘red’) or related to the mechanics of putting (such as ‘weight’) (Gucciardi & Dimmock 2008). The researchers argued that highly skilled athletes should concentrate on holistic processes rather than individual components of the skill.

Examples of using self-talk to maximise concentration pre- and during performance are included below. Firstly, Hockeyroo Kobie McGurk identifies her cue words. Secondly, gymnast Kelly Harrison talks of staying focused.

“I normally focus on three game objectives and I use cue words in my head to assist to re-focus prior to a game and during a game. At the moment these include concept cues like tackling lines, ball movement, and communication. Self-talk is important when you get subbed-off. It can be difficult when you are playing well to hold onto that momentum when subbed-off, so I try and stay in the zone.” *Kobie McGurk, Australian Hockeyroo 2010.*

“If I catch myself losing focus during training or during competition, I use a cue in my head like ‘focus Kelly’; and I find if I massage my leg muscles it helps me stay connected and to concentrate.”
Kelly Harrison, Australian Gymnast 2010.

Key point summary:

- Athletes can use self-talk to either maintain or change their concentration.

Self-talk and self-confidence

Dialogue with the self is likely to have a strong influence on confidence. Bandura (1997) indicates that verbal persuasion can influence self-efficacy, and although he focuses his discussion on persuasion from other people, it stands to reason that self-persuasion, over time, can influence the

confidence of athletes. If statements such as “I’m useless” are repeated often enough by an athlete, the athlete will come to believe them. Athletes are advised to use positive self-talk before, during, and after performances to increase their overall confidence. Elite athletes provide examples of how they use positive self-talk to resurrect their self-confidence.

“If I am struggling in a game, I get down on myself and I go quiet. I lose confidence, so I use my cue words, like ‘communication’, to keep me involved.”
Kobie McGurk, Australian Hockeyroo 2010.

Class task: Self-Talk

Jacob, a track and field athlete, is preparing to defend his title as State Champion in the 400m event. However, he is currently experiencing doubts about his ability to win a second time, and is concerned about letting his coach and parents down. Given how stressed he is, discuss examples of negative self-talk that he is likely to be using. As a class, discuss the self-talk that Jacob could use to better manage his stress.

Extension: How might Jacob use self-talk to influence stress after performance?

“I use self-talk to help lift my confidence. Simple phrases like: ‘I can do it’, ‘I have done it before’, ‘I can do it well’ and ‘I



Figure 4.22: Kobie McGurk (a), Kelly Harrison (b) and Jessica Jordan (c)

am good at it'. I use these to stop the negative thoughts creeping in. Although, if I have one negative thought, it does give me a focus – and dealing with it – helps me to be in control and be more confident. Knowing that I'm not perfect helps me be better.'

Kelly Harrison, Australian Gymnast 2010.

“As soon as doubt comes into your head – your confidence can drop so quickly. While success leads to confidence – confidence can also lead to success. After a fight, during the cool-down, I tend to go negative and can think about all the things I did badly – I dwell. If I lose a fight, I lose confidence so quickly. I use positive self-talk, and I rely on my coach and training partner to re-focus and think positive things. They help to highlight my strengths and why I will

win my next bout. I need to weed out the negatives as quickly as I can. When I compete for Australia, sometimes my coach and training partner are not there, it's then that I notice a difference, it's not the same, they are really important to my routine to maintain my focus and my confidence.” *Jessica Jordan, Australian Taekwondo Representative 2010.*

Key point summary:

- Athletes can use positive self-talk to boost self-confidence before, during or after performance.

Revision questions:

Test yourself on revision questions 15–17 located at the end of this chapter.

Self-Talk: Examples

Arousal

A weight lifter who was feeling lethargic before a morning competition could use self-talk to remind himself of the importance of performing well. This technique helps to increase arousal.

Stress

In AFL, a footy player might use the phrase, 'I've done this before so I can do it again,' before taking a critical shot at goal. This would help to increase his belief in his capability to meet environmental demands.

Motivation

At the end of a long match, a cricket player who was feeling tired and demotivated could use self-talk cues such as 'Come on!' to elicit greater levels of motivation.

Concentration

A hockey player who was under pressure could use the phrase 'Scan' to remind herself to broaden her scope of attention. That way, she would increase her chances of noticing free team members to pass to.

Self-confidence

Just before her team's performance at Nationals, a synchronised swimmer might use the phrase, 'I've got this,' to persuade herself of her ability to deliver a successful performance.

Goal Setting

Clearly defined goals can energise and provide direction to athletes. Goals are particularly likely to be effective when they follow the ‘SMARTS’ (Specific, Measurable, Action-oriented, Realistic, Time-bound, Self-determined) principle that was outlined in Unit 2. The sections below highlight some ways in which goal setting can influence arousal, stress, motivation, concentration, and self-confidence.

Goal setting and arousal

One of the primary objectives of goal setting is to energise individuals. Have you ever set yourself a goal to finish an assignment before a certain time? If so, you are likely to have experienced the energy-giving properties of goals. A benefit of goal setting is that it is a strategy that can influence arousal before, during, or after a performance. For instance, before an important basketball game, LeBron James might set himself a goal to achieve a ‘triple double’ (double digits on three criteria, such as points scored, assists, and rebounds). Within the performance, James might set himself new goals or alter existing goals. If he injures his hand during the match, for instance, he might want to focus on achieving double figures on only two criteria rather than three. Then, after the performance, he might evaluate his performance and use this evaluation to establish new goals for the next match. Whether LeBron James sets goals before, during, or after performance, he is likely to become energised about the possibility of achieving them.

Key point summary:

- The energy-giving properties of goals can significantly impact an athlete's level of arousal.

Goal setting and stress

Goal setting is likely to influence all elements of the stress process. Individuals who set a goal to run in the Perth ‘City to Surf’ have imposed an environmental demand on themselves. The specific nature of an athlete’s goal can also influence an athlete’s experience of stress. For instance, a goal that has been self-set, rather than imposed onto an athlete by their coach, is more likely to be perceived as achievable and non-threatening. Goal setting can also influence one’s response to threat. Imagine that you have set yourself a goal to complete a marathon run in under 4 hours. If you looked at your watch at the 21 km mark (half-way) and noticed that you had been running for 2 hours and 10 minutes, you might become anxious about your chances of achieving your goal. In this respect, goal setting can influence anxiety.

Finally, evaluations of goal accomplishment can influence one’s desire to enter events and compete in sport in the future, which will influence the environmental demands faced by the athlete in the future.

Key point summary:

- Athletes can use goal-setting to influence which environmental demands they will experience.
- Self-set goals are generally perceived as less threatening.
- An athlete's progress towards their goals influences anxiety.
- Goal accomplishment will affect an athlete's decision to approach new goals in the future.

Goal setting and motivation

There is little doubt that goals influence both the direction and intensity of motivation.



Figure 4.23: *Lebron James (Basketball USA)*



Figure 4.24: *Ben McKinley*

A goal to lose 5kg of weight in 10 weeks is likely to encourage an individual to focus on eating healthy foods and to exercise (direction of motivation). He or she is likely to persist at these activities even when tempted to avoid them (intensity of motivation). Similarly, a netball player who has set a goal to play for Australia under 15's will be motivated to attend state and national trials (direction of motivation) and try her best at those trials (intensity of motivation). Goal setting can influence motivation before a performance, such as when an individual becomes motivated to enter a competition to fulfil a lifelong goal. Goal setting can also influence motivation during a performance, such as when canoeists in the Avon Descent promise to give themselves a reward if they persist until the finish. Finally, these same canoeists might finish the event and vow to beat their time the following year, suggesting that goal setting can influence motivation after a performance.

Ben McKinley, a past West Coast Eagles and Kangaroos forward, used goal setting for personal motivation and to focus his energy.

“In the days prior to games, my goals relate to how I can contribute to the team and how I can make the most impact. These goals include: Have a high work rate; be around the ball – and includes lay tackles, and get to the contest; and goal assists.”

Ben McKinley, AFL.

Key point summary:

- Goal setting can influence motivation before, during, or after competition.
- Athletes can use goal-setting to influence both the direction and intensity of their motivation.

Goal setting and concentration

Goals can be set to encourage an athlete to focus on particular things. For example, a soccer player who has a tendency to receive yellow cards in games can set a goal relating to tackling. They might then wish to concentrate on particular tackling techniques in training (pre-performance). They could also become more careful when playing so that they refrain from reckless tackles (during performance), and they could focus on relevant statistics after the game (post-performance), such as a statistic relating to the proportion of complete tackles versus missed tackles.

Past AFL player, Ben McKinley, talks of the need to refine goals and redirect concentration to specific aspects of performance.

“During a game, it is possible to reflect on performance. If one thing has not come-off, I use my goals to re-set and evaluate my game plan. When I have played well, sometimes it becomes obvious that aspects other than those identified in goals, influence performance success, and these are worthy of inclusion in future goals. For example, one game I had seven tackles and realised that this was another measurable aspect of being around the ball. It is indicative of when I play well, so I include tackling in my training and performance goals.”

Ben McKinley, AFL.



Figure 4.25: Ben McKinley, AFL.

Key point summary:

- Goal-setting can be used to identify relevant cues to focus on during performance.

Goal setting and self-confidence

Self-confidence is likely to be influenced by goal setting. Athletes who achieve their goals will boost their self-confidence, but athletes who fail at them will reduce their confidence. Retired AFL forward Ben McKinley talks of the influence of goal setting on self-confidence.

“A lot of my goal setting is undertaken prior to the season. They are based around deficiencies. In-season, some of my goals are heavily influenced by others, and therefore I have to be flexible and constantly revise and adapt them. For that reason, I break my long-term goals into short-term goals that are specific to training. For me as a forward, these goals are specific to kicking goals, and they assist with my self-confidence and how comfortable I feel.”

Ben McKinley, AFL.

Key point summary:

- Athletes' success or failure achieving goals can have a big impact on their self-confidence.

Revision questions:

Test yourself on revision questions 18 and 19 located at the end of this chapter.

Class task: Goal-Setting

As a class, discuss how a marathon runner may (or may not) use goal-setting to affect concentration, motivation, and arousal during the course of the event.

How, and why, might the use of goal setting differ for a 100m track sprinter when compared to a marathon runner?

Goal-setting: Examples**Arousal**

A track runner who has set himself a goal to beat his best time in the hurdles event is likely to experience greater levels of arousal just before he runs.

Stress

As stated by the ‘SMARTS’ principles of goal-setting, cyclists should set realistic goals for time trials that they feel capable of achieving. This helps to regulate the level of stress experienced.

Motivation

Setting a goal to compete at Nationals will influence a gymnast’s decision to participate and exert large amounts of effort in qualifying competitions throughout the year.

Concentration

In netball, a GS might set herself a specific goal to follow through with her wrist action on every shot at goal. This goal is likely to direct her attention towards this specific component of performance during the game.

Self-confidence

A triathlete who successfully achieves his goal of winning the swimming component of his race is likely to feel more confident in his ability to meet future goals that he sets for himself.

Practical investigation

Evaluate the use of mental skills

See Appendix B1 for a practical investigation, along with questions and report-writing format recommendations.

Text outcomes: Sport psychology (Unit 4)

- *Apply Carron's model of group cohesion to analyse own performance within a group setting in physical activity:*
 - *the relationship between social loafing and group cohesion*
 - *the influence of social loafing on individual and group performance.*

Content that follows: Group cohesion (Unit 4)

- *What is group cohesion?*
- *How is group cohesion measured?*
- *Carron's model of group cohesion*

What is Group Cohesion?

Most readers of this book will have heard at least some of the following sayings: 'There's no 'I' in TEAM', 'Together Everyone Achieves More', 'United we stand, divided we fall', and 'Teamwork is the fuel that allows common people to attain uncommon results'. Why is it that sayings such as these are commonly used by

leaders in military, business, and sport settings? The reason is that these leaders recognise that group cohesion is extremely important for a team's performance. The performance of the USA basketball team at the 2004 Olympic Games is testament to the fact that, without cohesion, teams with outstanding potential can fail (Figure 4.26). Referring to this US Olympic basketball team, Mariotti (2004, cited in Carron, Hausenblas, & Eys 2005) once wrote:

"The most deadly of basketball viruses, a disturbing lack of chemistry and complaints about playing time, threaten to sink this stink bomb as one of the all-time American disgraces in Olympic competition."



Figure 4.26: Reigning gold medalists from the Sydney 2000 Summer Olympics, the 2004 United States of America Olympic Basketball Team failed to retain its men's title, which went to Argentina. While some players chose not to represent their country, the team included plenty of stars; Carmelo Anthony, Carlos Boozer, Tim Duncan, Allen Iverson, LeBron James, Lamar Odom and Dwyane Wade.

The word *cohesion* stems from the Latin word *cohaesus*, which means to cleave or stick together. Of course, the sticking together of group members is not literal; it reflects the strength of the social and task-related bonds among the members of the group (Carron et al., 2005). More specifically, we define **group cohesion** as *a dynamic process which is reflected in the tendency for a group to stick together and remain united in the pursuit of task goals and/or to satisfy team members social needs*. There are a few parts of this definition that we would like to elaborate upon:

- Firstly, cohesion is a process. It can change over time, and the factors that are instrumental for binding a group together early in its development might not be important as the group ages.
- Secondly, as referred to previously, cohesion is essentially a sticking together or unity of group members.
- Thirdly, this unity can be reflected in terms of a common purpose and a shared perspective on task objectives (**task/instrumental cohesion**), or it could be reflected in terms of friendships among teammates (**social cohesion**).

Key point summary:

- Group cohesion is a dynamic process in which:
 - Team members stick together
 - In the pursuit of task goals
 - And/or to satisfy team members' social needs.

How is Group Cohesion Measured?

The group environment questionnaire

The Group Environment Questionnaire (GEQ; Carron, Widmeyer, & Brawley 1985) is a commonly used instrument for measuring sport team cohesion. In accordance with the definition of cohesion detailed above, the GEQ measures both social and task cohesion. In addition, both social and task cohesion can be assessed in terms of perceptions about the *group as a team* or in terms of how the *group satisfies personal objectives*. Items in the GEQ that assess perceptions about the group as a team are termed *Group Integration*, whereas items that assess how the group satisfies personal objectives are termed *Individual Attraction to the Group*. The GEQ therefore measures four dimensions: Group integration-social (GI-S), group integration-task (GI-T), individual attraction to the group – social (ATG-S), and individual attraction to the group – task (ATG-T). Perhaps the best way to get a feel for this measure is to complete it yourself. Complete the GEQ in Table 4.3 in relation to a sport team in which you have played.

Practical activity: *Measuring your team cohesion*

Think of a sport team that you have played for. Complete the Group Environment Questionnaire below (Table 4.3) in relation to your thoughts about this team. See the instructions at the bottom of the questionnaire to tally your scores.

Table 4.3: *Group Environment Questionnaire (GEQ)*

		Strongly disagree					Strongly agree				
Item		1	2	3	4	5	6	7	8	9	
1.	I do not enjoy being part of the social activities of this team.	1	2	3	4	5	6	7	8	9	
2.	I'm unhappy about the amount of playing time I get.	1	2	3	4	5	6	7	8	9	
3.	I am not going to miss the members of this team when the season starts.	1	2	3	4	5	6	7	8	9	
4.	I'm unhappy with my team's level of desire to win.	1	2	3	4	5	6	7	8	9	
5.	Some of my best friends are on this team.	1	2	3	4	5	6	7	8	9	
6.	This team does not give me enough opportunities to improve my personal performance.	1	2	3	4	5	6	7	8	9	
7.	I enjoy other parties more than team parties.	1	2	3	4	5	6	7	8	9	
8.	I like the style of play on this team.	1	2	3	4	5	6	7	8	9	
9.	This team is one of my most important social groups.	1	2	3	4	5	6	7	8	9	
10.	Our team is united in trying to reach its performance goals.	1	2	3	4	5	6	7	8	9	
11.	Members of our team would rather go out on their own than get together as a team.	1	2	3	4	5	6	7	8	9	
12.	We all take responsibility for any loss or poor performance by our team.	1	2	3	4	5	6	7	8	9	
13.	Our team members rarely party together.	1	2	3	4	5	6	7	8	9	
14.	Our team members have conflicting aspirations for the team's performance.	1	2	3	4	5	6	7	8	9	
15.	Our team would like to spend time together in the off-season.	1	2	3	4	5	6	7	8	9	
16.	If members of our team have problems in practice, everyone wants to help them so we can get back together again.	1	2	3	4	5	6	7	8	9	
17.	Members of our team do not stick together outside of practices and games.	1	2	3	4	5	6	7	8	9	
18.	Our team members do not communicate freely about each athlete's responsibilities during competition or practice.	1	2	3	4	5	6	7	8	9	

Scoring

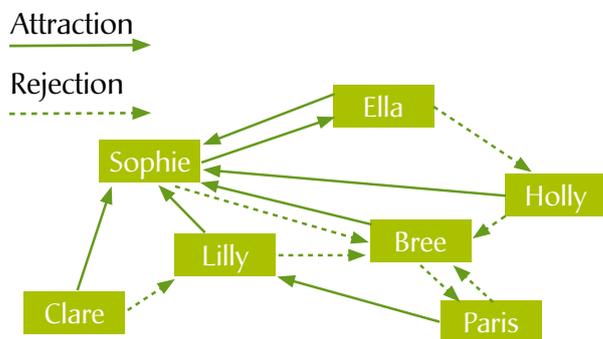
To tally the cohesion items, you should start by reversing the scores for items 1, 2, 3, 4, 6, 7, 8, 11, 13, 14, and 17 (i.e. if you circled 1, give yourself 9; if you circled 2, give yourself 8, etc...). then add the following totals:

- Attraction to the group-task – 2, 4, 6, 8 (range 4-36)
- Attraction to the group-social – 1, 3, 5, 7, 9 (range 5-45)
- Group integration-task – 10, 12, 14, 16, 18 (range 5-45)
- Group integration-social – 11, 13, 15, 17 (range 4-36)

The higher your score on each subscale, the greater you reflect that dimension with the team.

Sociograms

Although the Group Environment Questionnaire (GEQ) has proven to be a reliable and valid measure of group cohesion in sport, there is some information about cohesion that it doesn't reveal. In particular, it does not show how particular individuals relate to each other, whether cliques are developing, and if some group members are socially isolated. These issues associated with social cohesion can be measured with a sociogram. To generate information for the sociogram, each group member is asked specific questions, such as 'Name one person on your team you would most like to invite to a party and one person you would least like to invite'; 'Name one person on your team you would most like to room with on road trips and one person you would least like to room with'; and 'Name one person you would most like to practice with in the off-season and one person you would least like to practice with'. Once you have obtained this information, place the people who were listed most often toward the centre of a blank page (regardless of whether they were commonly listed as popular or not popular). Write the names of the other team members on the outside of the page. Your next task is to draw straight arrowed lines to denote attraction and to draw dotted lines to denote rejection. Below is an example of a sociogram for a female basketball team (Figure 4.27). You might notice that Bree is disliked by a number of players, whereas Sophie is popular among her teammates.



Coaches should take care when interpreting sociograms and using the information from them. To start with, the information should be kept strictly confidential. Players should complete the questions in the knowledge that their responses will not be shared with other players. Another issue that coaches should be aware of is that players might not dislike any of their teammates, and this could be particularly common in teams that are high in social cohesion. One of the authors of this chapter used to play soccer for a high school team, and the coach had done a terrific job at building team cohesion. I'm sure that the players of that team would have found it difficult to name a player they would have least liked to invite to a party. The point of this is that the dotted lines to indicate rejection do not indicate the *extent* of rejection. The opposite might also be true. Players might not like any of their teammates, an occurrence that could be particularly likely in teams with low cohesion. Consequently, straight lines in the sociogram indicate attraction, but they do not indicate the *extent* of attraction.

Carron's Model of Group Cohesion

Carron's model classifies the factors of group cohesion into four categories: (1) environmental factors, (2) personal factors, (3) leadership factors and (4) team factors. This model, shown in Figure 4.28, shows that team cohesion can relate to these factors in a bi-directional manner. For example, team success, which can be thought of as a team factor, is likely to lead to team cohesion, but team cohesion is also thought to lead to success. Each of the four factors of cohesion will now be discussed in turn.

Figure 4.27: A sociogram for a female basketball team

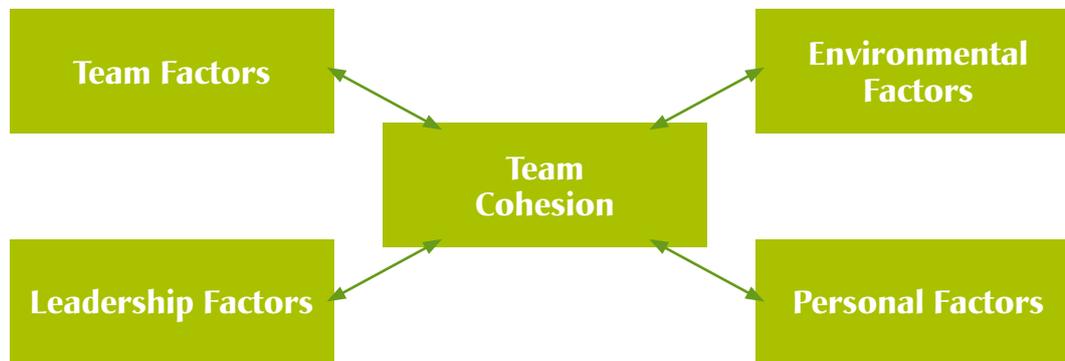


Figure 4.28: Carron's Model: Showing relationships involving team cohesion

Environmental factors

The *environmental factors* refer to the general situational factors that help to keep a group together. Contractual responsibility is an example of an environmental influence. Athletes might stay with groups due to transfer rules, geographical restrictions, or contractual obligations.

Another example of an environmental factor is organisational orientation. Sport teams differ in their goals and strategies for achieving those goals, and these differences can influence the extent to which members stick together. Consider the difference between a football team for a primary school and the West Coast Eagles. The school team will have a primary goal of enabling equal participation among all members of the squad, whereas the main goal of the West Coast Eagles is to win. According to Carron (1982), these environmental factors should be relatively consistent across teams within a particular league.

Personal factors

Personal factors, which refer to the individual characteristics of group members, also relate to team cohesion. Team members who are focused on completing the group's task (high task motivation) are likely to contribute to the group's task cohesion. Conversely, members who are oriented toward the maintenance of good relationships (affiliation motivation) are likely to contribute to the group's social cohesion. Another personal factor that is

likely to be related to team cohesion is satisfaction. It is speculated that athletes who are satisfied with the team are more likely to develop and report greater cohesion with the team. Social loafing, which refers to the reduction in effort when working in groups as opposed to working alone, is another personal factor related to cohesion. More will be discussed on the relationship between social loafing and team cohesion in the next section.

Leadership factors

Leadership factors include the leadership style and the behaviours that professionals exhibit. This category also includes the dynamics of the coach-athlete interpersonal relationships and the coach-team relationship. Coaches and captains can have a strong influence on the development of social cohesion by fostering a harmonious atmosphere within the team. They can also develop task cohesion by organising the team around goals and structures.

Team factors

Team factors, which are the variables that operate at a group level, can relate to cohesion in numerous ways. Have you ever been a member of a team for three or more years? If so, did you feel a strong sense of cohesion with the team? Team stability, which refers to the duration of time that members have stayed together, is a team factor that leads to cohesion. The longer the

team stays together, the greater the opportunity for social and task cohesion to develop (Carron 1982). Team stability is likely to possess a circular relationship with cohesion. That is, a stable group is likely to become cohesive and a cohesive group is likely to remain stable.

Another team factor that is referred to in Carron's model is the desire for group success. Teams that possess many members with a high desire for group success are more likely to be cohesive.

Finally, one of the more important team factors related to cohesion is team success. Cohesion is likely to facilitate absolute performance effectiveness as well as relative performance effectiveness. In other words, cohesive teams are more likely to possess higher win/loss ratios (absolute performance), but a team's performance is also likely to improve relative to their own standard (relative performance).

Additionally, performance can also lead to cohesion. In other words, a winning team might tend to bond together better as a result of success. Moreover, the relationship between cohesion and performance holds for both task and social cohesion, and is found in both coactive sports as well as interactive sports. Coactive sports are those in which teams are formed but performance is relatively independent of others (for example, golf), whereas interactive sports are those in which individual performance is closely tied with the performance of teammates (for example, basketball).

Key point summary:

- Carron's model states that environmental, personal, leadership, and team factors can influence cohesion, and cohesion can also influence these factors.

Revision questions:

Test yourself on revision questions 20–23 located at the end of this chapter.

Content that follows: Group cohesion (Unit 4)

- *Group cohesion and:*
 - *social loafing*
 - *the influence of social loafing on individual and group performance*
 - *strategies to improve group cohesion.*

Group Cohesion and Social Loafing

Social loafing is one of the constructs that is likely to relate to cohesion. Researchers have found that social loafing is likely to be reduced when:

- there is potential to identify individual outputs
- there is a relationship among the group members.

This second point indicates that members of cohesive groups are less likely to engage in loafing. For example, McKnight, Williams and Widmeyer (1991), found that swimmers in highly (task) cohesive relay teams did not engage in social loafing. This finding was strong and occurred regardless of whether their personal output was identifiable or not.

Social Loafing and Performance

By definition, social loafing refers to reduced levels of effort when individuals perform in groups versus when working alone. That is, the individual contribution of each teammate will be lower if they

are engaging in social loafing. Therefore, social loafing has a negative impact on the individual performance of each member within a team.

Social loafing also detracts from overall team performance. This detrimental effect is twofold. Firstly, if each member of a team is producing sub-standard performance, it stands to reason that the total performance of the whole team will suffer as a direct result.

However, social loafing may also exert an indirect effect on team performance through its influence on group cohesion. It is known that social loafing is associated with lower levels of team cohesion, and that lower levels of group cohesion are, in turn, associated with lower levels of team performance. Put simply, teams that have players who engage in social loafing are less likely to be cohesive, and less cohesive teams are less likely to be successful.

Perhaps the best way to discuss the relationship between social loafing and performance is to consider the **Ringelmann effect**. This effect refers to the situation in which the performance of members in a group decreases as the number of people in the group increases, and Ringelmann discovered this effect over 100 years ago (cited in Kravitz & Martin 1986). Participants in his study were asked to pull on a rope, which was connected to a strain gauge, as hard as they could in tug-of-war fashion. Groups of varying size were asked to pull on the rope, and strain was measured after individual performances as well as after group efforts. If there were to be no losses in coordination or motivation from working in a group, the strain of any group effort should be the same as the sum of the individual group members' efforts. Ringelmann's results indicated that group efforts were not a function of the sum of individual members' scores. He found that the individuals in the 2-person groups worked at only 93% of their potential, the individuals in the 3-person groups worked at only 85% of their potential, the

individuals in the 4-person groups worked at 77% of their potential, and individuals in the 8-person groups worked at 49% of their potential.

There are two broad explanations that can account for the Ringelmann effect. The first is that individuals in groups find it difficult to *coordinate* their efforts. In the case of the tug-of-war, it is more difficult for members of large groups to coordinate their pull on the rope at the same time. A second explanation is that *motivation* is reduced when individuals are placed in larger groups. This explanation relates directly to social loafing, which refers to a reduction in effort when working in a group due to motivation. It is easier for group members to engage in social loafing in larger groups because personal accountability is reduced. Which of these two explanations is most influential in determining the Ringelmann effect? Two interesting studies on this topic were undertaken in 1974 by Ingham, Levinger, Graves and Peckham. In both studies, participants were asked to pull on a rope that had been attached to a strain gauge. They were asked to pull on the rope alone and in groups of 2, 3, 4, 5, and 6 people. In support of the findings by Ringelmann, the first study by Ingham et al. found that individual performance tended to decrease when participants worked in larger groups. However, progressive increases in group size did not lead to corresponding decreases in individual efficiency.

Class Task: Social Loafing

Think of a team you have played in where some individuals did not work as hard as they could have. Was there the perception that these members were riding on the efforts of their teammates? Discuss how social loafing affected the team's social cohesion and task performance.

Instead, it was found that there was a general levelling off in individual performance from three-person groups onward.

The second study by Ingham et al. was designed to determine whether the reduction in individual performance as group size increased was due to coordination or motivation losses. In this study, participants were asked to perform the rope pulling task alone and in groups of 2, 3, 4, 5, and 6 people. The clever part of this study was that participants thought that they would be performing in groups, but, in reality, they performed alone in all conditions. Participants were blindfolded and were asked to pull on the rope as hard as possible. In the ‘group’ conditions, the experimenters held the rope and made noises to suggest that they were pulling it, but they did not actually pull on the rope at all. Thus, any differences in performance between the conditions would be the result of motivation rather than coordination (because coordination was controlled). Results were similar to the first study by Ingham and colleagues, although the performances of individuals in this second study were stronger in ‘groups’ of three people and above. Ingham et al. suggested that the Ringelmann effect was due to social loafing (motivation) more than coordination losses. Table 4.4 provides the results from the study by Ringelmann as well as the results from the two studies by Ingham and colleagues.

Key point summary:

- Social loafing refers to reductions in effort when working in groups, versus when working alone.
- Social loafing has a negative impact on both individual and group performance.

Table 4.4: Relationship between group size and rope-pulling performance (percentage of potential productivity for groups differing in size)

Researchers	Group size					
	1	2	3	4	5	6
Ringelmann	100	93	85	77		
Ingham et al. (1974, Study 1)	100	91	82	78	78	78
Ingham et al. (1974, Study 2)	100	90	85	86	84	85

Strategies to Improve Group Cohesion

Coaches, leaders and players can all play a significant role in the development of team cohesion. The next section will overview some of the strategies that can be employed by these people.

Coach and leader behaviour

Explain individual roles in team success

Apathy is created in a team when members consider their role to be unimportant, so it is essential that athletes are informed of the importance of their role. It is also important that athletes are informed of the importance of other team members. The belief that other teammates are ‘towing the line’ can damage group cohesion. To avoid this perception, the coach can have players observe and record the efforts of their teammates. Alternatively, the coach can assign players to different positions in training, thereby giving players the chance to appreciate the difficulty of other position.

Set challenging group goals

Group goals are an effective method to build cohesion. Athletes should help to develop these goals, but the coach has an important role in facilitating the development of them. You might recall from Units 1 and 2 that goals should be *Specific, Measurable, Action-oriented*,

Realistic, Time-bound, and Self-determined.

The coach should consider these issues when helping the team to develop group goals.

Encourage group identity

Teams should be given the opportunity to attend social functions to develop their sense of identity. Other techniques, such as the wearing of team jackets and other team items, can also reinforce this identity. The coach should be wary of the creation of social cliques, which can divide a team along a number of lines. To counter the development of cliques, coaches should never allow players to select their own teams in training. They can also ensure that players change their roommates when on trips, and make sure that small tables aren't used on social occasions.

Avoid excessive team member turnover

The relationship between cohesion and team member turnover is well known. It is sometimes difficult to determine the direction of the relationship between stability and cohesion, but this much is known: stable teams tend to be cohesive teams. Coaches should work hard at retaining team members by limiting player trading. It is essential any new player is made to feel welcome and a part of the new social environment.

Know the team climate

Coaches should identify the group members who have high interpersonal prestige and status in the group. These players can provide a useful link between the coach and the players; coaches can use them to become informed of issues and concerns among the player roster. Players are often willing to express their grievances and ideas to peers but are unwilling to express them to the coaching staff. Thus, these popular players can become a medium for the coach to hear ideas and concerns that they might not otherwise be exposed to.

What group members can do

The players also have a key role in the development of cohesion. They can help to avoid the development of social cliques by taking measures to ensure that the group interacts as an entire unit. They can make a conscious effort to get to know other members of the group, help other members whenever possible, and give encouragement and other forms of positive reinforcement. Players should also seek to resolve conflicts immediately and give 100% effort.

Key point summary:

- Coaches and leaders can help to build cohesion by explaining individual roles in team success, setting challenging group goals, encouraging group identity, avoiding excessive team member turnover, and by knowing the team climate.
- Group members can help to build cohesion by avoiding the formation of social cliques, learning about other group members, helping teammates, giving encouragement and other positive reinforcement, and resolving conflicts quickly.

Practical investigation

Group cohesion

See Appendix B2 for a practical investigation, along with questions and report-writing format recommendations.

Revision questions:

Test yourself on revision questions 24–28 located at the end of this chapter.

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Appendix A:

Writing the practical investigation report

Writing the report

If you are required to write a report as part of your practical investigation, you may choose to use the following format.

Title: Title of the practical investigation.

Aim: State what you hope to achieve in the experiments (~30–50 words).

Introduction: Define and discuss the sport science principles being investigated (~200 words).

Hypotheses: Identify the expected results or anticipated outcomes (*statements*).

Method: Identify the steps taken to complete the experiments (~100 words).

Results: Present the data and findings in the appropriate format (*for example, graphs, diagrams and tables*).

Response to the questions: Write the questions out and respond.

Discussion: Provide a detailed discussion of the results. Apply the sport science principles under investigation to other sporting contexts (~400 words).

Conclusion: Summarise the discoveries made. Make links to each hypothesis and include limitations of the experiment (~100 words).

Appendix B1

Practical Investigation and Report: Sport Psychology

Evaluate the use of mental skills

Weighting: Unit 3

Type: Investigation

Content:

- To evaluate the application of mental skills to selected activities and sports.

Total marks = /30

Task outline

When completing the experiment outlined below, you are to record, describe and evaluate the impact of pre-, during and post-performance mental skills, including arousal control, imagery and focusing strategies on volleyball service performance.

Experiment: Task one

Condition A:

- In groups of three, you will be required to serve a volleyball from the service line (under-hand or overhand) over the net to land in the point scoring target zone (Figure 4.29).
- Use the scoring chart to score for each of the 10 serves (Figure 4.29).
- Scoring only occurs when the ball clears the net and lands in the designated zones.

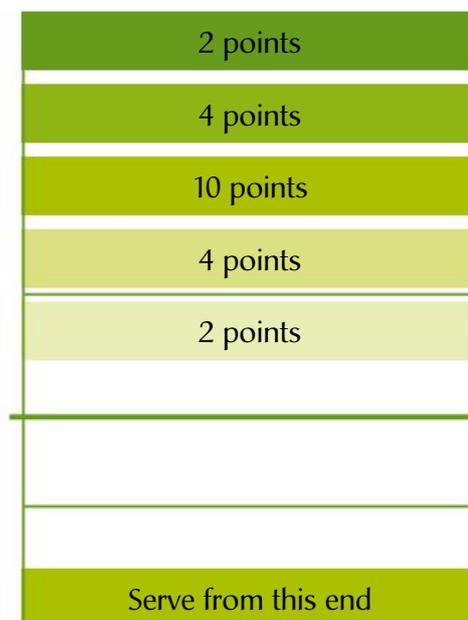


Figure 4.29: Volleyball point scoring zone

Condition B:

- Read the following mental skills preparation (modified; Singer 1988) before repeating a second set of 10 serves.
- Ensure that you repeat the 5-step mental skills process with every serve.
- Use the same scoring system to measure your success.

5-step mental skills process

Pre-performance

- Readying:** Ensure that your level of arousal is optimal. Use two deep breaths with a controlled exhalation. Use a positive self-talk cue in your head (such as; 'I can do this well').
- Imagining:** Visualise (in your own mind) a good ball-toss, hear the deep thud of a good strike, and see the ball going over

the net and landing in the highest scoring zone.

- Focusing: Ensure that you block out distractions, by looking at the target zone and re-focus back to the ball that is positioned for the first part of the sequence – the ball toss.

During-performance

- Executing: Clear your mind – just do it! Do not focus on the mechanics of the hit.

Post-performance

- Evaluate: Watch where the ball lands and judge how successful you were. Mentally re-visit what you did well and what could be improved. Use this evaluation to make any technical adjustments.

Questions: Task one

In presenting your findings to Task one, Condition A and B, respond to the following:

- Describe the performance outcome for the 10 serves undertaken in Condition A and those from Condition B. Also describe any differences in the ‘feelings’ (arousal, concentration, and self-confidence) that you had when undertaking the two tasks (2 marks).
- Account for any differences between your performance in Condition A when compared with Condition B, discuss how specific components of the 5-step process identified below may have impacted on the following (8 marks):
 - Arousal – readying and imagining
 - Stress – imagining and routine
 - Motivation – routine
 - Concentration – focusing
 - Self-confidence – imagining and routine

Questions: Task two

- Identify and explain the potential impact on performance of one mental skill that could be used for the specific situation and sporting context in the following examples. Examples of mental skills include: positive self-talk, imagery, thought stopping, personal relaxation and engaging in performance routines. Note: Ensure that you use a different mental skill for each response to each example. That is, to complete Task two (i-v), five different mental skills must be discussed:
 - Pre-performance for reducing arousal when preparing for a basketball game (1 mark).
 - Pre-performance for reducing stress while preparing for a tennis match (1 mark).
 - During-performance for improving concentration of a 10,000 metre steeple-chase runner when the race is nearing the final laps and they are doubting their ability to keep the required pace (1 mark).
 - During-performance for improving the goalies self-confidence immediately after a goal has been scored against them. Assume the goalie's made an error (1 mark).
 - Post-performance for improving personal motivation to attend gymnastics training after the coach said there are a lot of improvements to make before the next competition in 2 months time (1 mark).

Equipment:

- Volleyballs.
- Markers.
- Scoring chart (Figure 4.29).

Task: Evaluate the use of mental skills: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to the use of mental skills and the impact on the performer's mental state and volleyball serve performance.	1 mark
Provides clear statements of the expected results or anticipated outcomes in relation to the use of mental skills and the impact on the performer's mental state and volleyball serve performance.	2 marks
Introduction (3 marks)	
Identifies and defines some of the variables associated with a performer's psychological state and some of the mental skills used for performance.	1 mark
Shows an understanding of performance and the variables associated with a performer's psychological state and the use of mental skills to enhance performance.	2 marks
Shows a comprehensive understanding of performance and the variables associated with a performer's psychological state and the use of mental skills to enhance performance.	3 marks
Results (2 marks)	
Satisfactory presentation of data.	1 mark
Accurate and relevant presentation of data.	2 marks
Response to Questions (15 marks)	
<i>Task one: Question a: 2 marks, Question b: 8 marks (10 marks).</i>	
<i>Task two: Question a: 5 marks.</i>	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	1 mark
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	2 marks
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with a performer's psychological state and the use of some of the mental skills.	3 marks
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with a performer's psychological state and the use of mental skills to enhance performance.	4 marks
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to a performer's psychological state (arousal, stress, motivation, concentration, and self-confidence) and the use of mental skills (self-talk, imagery, thought stopping, personal relaxation, and routines) to enhance performance.	5 marks
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to a performer's psychological state (arousal, stress, motivation, concentration, and self-confidence) and the use of mental skills (self-talk, imagery, thought stopping, personal relaxation, and routines) to enhance performance.	6 marks
Conclusion (2 marks)	
Summarises some of the impact of mental skills on the performer's psychological state and performance in relation to the hypotheses.	1 mark
Fully summarises the impact of mental skills on the performer's psychological state and performance in relation to the hypotheses. Limitations discussed.	2 marks
Comment:	Total
	/30

Appendix B2

Practical Investigation and Report: Sport Psychology

Group cohesion

Weighting: Unit 4

Type: Investigation

Content:

Describe and discuss the importance and impact of the following on task cohesion and social cohesion:

- Individual goals
- Group goals.

Total marks = /30

Task outline

By completing the experiment and discussion questions outlined below, you are to observe and evaluate the impact of individual and group team goals on task cohesion and social cohesion.

Important instruction: Students allocated to play in the basketball game should not read the instructions that follow. That is, students who are not playing in the experimental basketball game (non-participant data collection team and observers) should read the following instructions.

Experiment: Task one (A)

Instructions:

- Form two basketball teams of approximately equal ability. Select seven

players per team.

- Inform the teams that they are playing a game of basketball, with five player's on-court and two substitutes.
- The game consists of two 10 minute halves with a 3-5 minute half-time break.

Only the **non-participant data collection team and observers** should read the following instructions and then direct the active participants to complete the task requirements.

Instructions: To be read to the basketball players

1. The teams are to move to separate ends of the basketball court.
2. Provide one team with seven copies of the 'Team goal data collection chart' (Chart A). **Request that the team record on the sheet their target number for each statistical category. That is, write one number that they think is an ambitious, but achievable, target for the team for each of the five measures.**
3. Provide the other team with seven copies of the 'Personal goal data collection chart' (Chart B). **Request that each member of the team record on the sheet their own individual target number for each statistical category. That is, each player writes a number that they think is an ambitious, but achievable, target for themselves for each of the five measures.**
4. **Do not** inform the players that the data collection charts are different for each team.
5. Inform both teams that statistics and the game score will be recorded to evaluate performance.

6. Inform the teams that they must play man-on-man defence for the whole game.
7. Inform the players that they, as a team, are responsible for substitutions which can happen for both teams, unlike normal basketball rules, at any time during the game.

Instructions: For the non-participant data collection team and observers

Before the game begins:

1. Allocate two non-playing students to collect performance data for the team using the ‘Team goal data collection chart’ (Chart A). These students are to familiarise themselves with the Chart. One of these students is to collect all seven copies of the Chart from the team.
2. Allocate one student to score the game points scored for both teams.
3. Allocate as many students as possible (seven students would be optimum) to collect performance data for the team using the ‘Personal goal data collection chart’ (Chart B). These students are to familiarise themselves with the Chart. One of these students is to collect all seven copies of the Chart from the team.

During the game:

4. Record statistics using the scoring charts.
5. At half-time separate the teams to sit at each end of the court and allow them to see the data collection chart.
6. At half-time, the allocated non-playing data collection team and observers are to listen to the discussion between the team members. Make mental (or pen/paper recordings) notes of what is said, their attitude to the team and general behaviour.

After the game:

7. Tally-up the Chart scores and give them to the teacher.

Task one (B)

Instructions:

1. Re-group the players. Sit them together in their respective teams.
2. Show the team members their respective data collection charts and confirm the game score.

Task one (C)

Instructions:

1. The teacher is to inform the whole class of the two different scoring charts: Chart (A) – Focused on team goals; Chart (B) – Focused on personal or individual goals.
2. The teacher confirms that the scores recorded for the game or the Charts (A and B) are not the priority of the following discussion.
3. The teacher confirms that the priority of the following discussion is the impact of the two different foci – team goals versus personal (individual) goals.
4. The teacher is to facilitate discussion of the following concepts. Students are to record personal notes and student quotations that reflect the discussion of each concept from each team’s perspective. These data are essential to answering the Task questions.

Discussion Concepts

- i. Discuss the overall attitude to the game, and the performance behaviour of the two different teams.

- ii. Describe each team's attitude to and the management of substitutions.
- iii. Observers describe the half-time discussion between the players of each team. Discuss any potential differences between the focus of the half-time discussions.
- iv. Observers and team members are to describe the team's attitude at half-time.
- v. Team members describe the level of personal enjoyment experienced.
- vi. Observers and team members describe any team cohesion behaviours displayed during the game (general play and half-time).

Equipment:

- Basketball.
- Basketball court.
- Photocopies (minimum 8 of each) of Chart A and Chart B.
- Pen.
- Whistle.
- Coloured ribbons/bibs to identify teams.
- Game clock.

Questions: Task one

In presenting your findings to Task one (A) respond to the following:

Describe and account for, using sport psychology principles, any differences, **or potential differences that could be expected**, between the two teams related to each of:

- a. On and off-court attitude and behaviour of the players (4 marks).
- b. Half-time attitude and behaviour displayed and focus of player discussion (2 marks).
- c. Level of player enjoyment (2 marks).
- d. Task cohesion behaviours (3 marks).

Questions: Task two

Assume that the two teams from the experiment, with their different focus (Team A – team goal focus; Team B – personal/individual goal focus) were to continue to train for and play weekly in a competition that extended a full season.

- a. Predict and account for how social cohesion might be influenced by the two different task cohesion environments (4 marks).

Task: Group cohesion: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to team cohesion attitudes/behaviours and performance of basketball team members with a team goal focus and with a personal goal focus.	1 mark
Provides clear statements of the expected results or anticipated outcomes in relation to team cohesion attitudes/behaviours and performance of basketball team members with a team goal focus and with a personal goal focus.	2 marks
Introduction (3 marks)	
Identifies and defines the variables associated with group/team cohesion.	1 mark
Shows an understanding of group/team cohesion (task cohesion and social cohesion) and their potential relationship to personal performance and team performance.	2 marks
Shows a comprehensive understanding of group/team cohesion (task cohesion and social cohesion) and their potential relationship to personal performance and team performance.	3 marks
Results (2 marks)	
Satisfactory presentation of data.	1 mark
Accurate and relevant presentation of data.	2 marks
Response to Questions (15 marks)	
<i>Task one: Question a: 4 marks, Questions b and c: 2 marks for each correct answer, Question d: 3 marks (11 marks).</i>	
<i>Task two: Question a: 4 marks.</i>	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	1 mark
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	2 marks
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with group/team cohesion and their potential relationship to personal and team attitudes, behaviours and performance.	3 marks
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with group/team cohesion (task cohesion and social cohesion) and their potential relationship to personal and team attitudes, behaviours and performance.	4 marks
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to group/team cohesion (task cohesion and social cohesion) and their potential relationship to personal and team attitudes, behaviours and performance.	5 marks
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to group/team cohesion (task cohesion and social cohesion) and their potential relationship to personal and team attitudes, behaviours and performance.	6 marks
Conclusion (2 marks)	
Summarises some of the factors associated with group/team cohesion (task cohesion and social cohesion) and personal and team attitudes, behaviours and performance in relation to the hypotheses.	1 mark
Fully summarises the impact of the factors affecting group/team cohesion (task cohesion and social cohesion) and personal and team attitudes, behaviours and performance in relation to the hypotheses. Limitations discussed.	2 marks
Comment:	Total
	/30

CHART A: TEAM GOAL DATA COLLECTION CHART

Team points scored	Number of team passes	Help defence	Setting a screen	Time in possession

Team points scored: Game score with normal basketball scoring.

Number of team passes: Every pass made by a member of the team counts as one pass.

Help defence: Record a point – every time two players work together to, double team, or defend another player that is not their own.

Setting a screen: Record a point – every time a players attempts to perform an intentional screen to try and protect a team member.

Time in possession: Use a stop watch to record the total time that the team is in possession of the ball in general play (not when making an inbound pass or free throw).

CHART B: PERSONAL GOAL DATA COLLECTION CHART

Player name	Personal points scored	Number of possessions	Rebounds	Steals or forced turnovers	Last passer before an offensive turnover

Personal points scored: Individual player scoring with normal basketball scoring.

Number of possessions: Record a point for the individual player – every time the player possesses the ball.

Rebounds: Record a point for the individual player – every time the player collects a rebound.

Steals or forced turnovers: Record a point for the individual player – every time the player steals or forces a team turnover.

Last pass before an offensive turnover: Record a point for the individual player – every time the player, who was the last player to pass (not a shot at goal) before the ball was turned-over.

Appendix C (I)

Revision questions

1. A performance routine is best represented by which one of the following statements?
 - a. Replicating accurate actions
 - b. Having relevant thoughts
 - c. Being able to adapt to a variety of external stimuli
 - d. A sequence of task relevant thoughts and actions
2. Performance routines can influence stages 2 and 3 of the stress process. Using the example of bouncing the ball before a tennis serve, describe how this performance routine can positively impact each of stage 2 and 3 of the stress process.
3. Routines are particularly effective at influencing the intensity, rather than the direction, of an athlete's effort. What does this mean?
4. Identify two ways a well learned performance routine can assist immediately prior to skill execution (that is, during competition).
5. Taekwondo competition fighter, Jessica Jordan, describes the use of imagery in her pre-performance warm-up. When preparing for a fight, she describes stretching and visualising “one kick over and over again, my best kick – a right leg back foot turning kick. I picture this hitting every time, it's fast, and strong and convince myself that there is nothing that my opponent can do to stop it.”
Identify three aspects other than the sight of the kick which she could visualise.
6. Choose the statement that best represents how imagery can impact on a performer's arousal.
 - a. It can only be used to increase arousal
 - b. It can be used to both increase and decreases arousal
 - c. It can only be used to decrease arousal
 - d. It is best used after the performance to impact on arousal
7. Athletes should be cautious about using imagery to improve concentration during performance. Briefly explain this statement.
8. How does imagining a successful performance prior to execution assist with self-confidence and the actual performance?
9. Choose the statement that best represents the process of personal relaxation techniques.
 - a. They only work during performance
 - b. They only work to reduce the symptoms of feeling sick
 - c. They include breath control, self-talk and progressive relaxation with a primary aim of reducing arousal
 - d. They only include listening to up-beat music and self-talk
10. What does breath control involve?
11. Describe the technique called ‘thought stopping’.
12. Briefly explain the ‘matching hypothesis’ and how it applies to personal relaxation and levels of arousal.
13. Relaxation techniques aimed at reducing anxiety can be beneficial at helping an athlete to develop an appropriate focus of attention. What are the errors related to attention that an overly-aroused athlete might display?
14. Explain the benefits of an endurance

athlete undertaking personal relaxation techniques during the tapering phase of pre-competition. How could these outcomes improve the athlete's confidence for the competition?

15. Self-talk can
 - a. include calming words to regulate cognitive and physical symptoms of stress.
 - b. be used to influence how threatening an event is perceived to be.
 - c. be used to increase or decrease arousal.
 - d. all of the above.
16. In using self-talk you choose to say; 'what doesn't kill me will make me stronger'. Explain how this might impact on stress.
17. When self-talk is specifically undertaken to assist concentration; is it best done pre-, during, or post-performance?
18. Briefly explain how goal setting can influence the direction of motivation and the intensity of motivation.
19. How is concentration in a game or performance likely to be positively impacted by goals set prior to performance?
20. If group cohesion is reflected in the tendency for a group to remain united in the pursuit of its objectives; what defines 'task cohesion' and 'social cohesion'?
21. What do straight arrowed lines and dotted lines represent on a sociogram. What limitations do sociograms have, that is, what don't they show?
22. Define each of the four categories or correlates of Carron's model of team cohesion?
23. Team cohesion can relate to the four categories/correlates in a bi-directional manner. What does this statement mean?
24. What defines the Ringelmann effect?
25. Give two strategies that you could use to reduce the Ringelmann effect or social loafing.
26. Is the likelihood of social loafing going to increase or decrease with an increase in the number of participants in a team?
27. What is the key reason for social loafing and performance decrement?
28. List two ways a coach and the players can reduce social loafing.

Appendix C (II)

Revision answers

1. d. A sequence of task relevant thoughts and actions
2. By engaging in and focusing on the routine of bouncing the ball before a serve, an athlete can take their mind off the demand, their response capability, or the importance of the occasion (that is, stage 2). By definition, if they are thinking about such task relevant cues, the player is warding away thoughts about demand and response capability or the importance of the occasion. Even if an athlete perceives a situation as threatening, they might be able to moderate the worry and apprehension (cognitive state anxiety), as well as physical responses (somatic state anxiety) (that is, stage 3) by engaging in a performance routine.
3. Direction of effort refers to whether an individual seeks out, approaches, or is attracted to certain situations. Intensity of effort refers

to how much effort a person puts forth in a particular situation. That is, performance routines assist with your efforts to be involved, rather than deciding on what to do.

4.
 - i. Routines can assist you not to neglect some important task-relevant thoughts or behaviours prior to execution, especially in high pressure situations in which you are prone to feeling rushed and distracted.
 - ii. Routines assist you to avoid the distractions of the crowd or other competitors.
5. Jessica could not only imagine the sight of the kick, but the sound it makes, the feelings she gets when executing the kick and making contact with her opponent and any smells associated with the environment in which she performs.
6. b. It can be used to both increase and decreases arousal
7. Imagery is used by athletes to focus on task-relevant cues. If the imagery involves task-irrelevant cues, such as imagining lifting a trophy immediately prior to performance, it can be distracting and lead to performance decrements.
8. Imagining a successful performance prior to execution can help the athlete to focus on important cues and feel that effective performance is within their grasp, and can therefore build confidence in their ability before and during a game.
9. c. They include breath control, self-talk and progressive relaxation with a primary aim of reducing arousal
10. Breath control is a conscious regulation of your breath so that it is smooth, deep and regular. A greater relaxation response will be achieved if you take a series of deep and controlled breaths rather than a single breath.
11. Thought stopping uses a physical action (such as a pat on the hip) combined with positive self-talk (let's stay focused, I'm still going to play well today) to help athletes cope with negative self-talk and therefore reduce anxiety.
12. The matching hypothesis involves matching the personal relaxation technique to the context of the situation and the outcome sought. That is, athletes are advised to use physical techniques (for example, breath control) to reduce physical symptoms of arousal or anxiety, whereas they are advised to use mental techniques (such as self-talk) to reduce cognitive symptoms of arousal or anxiety. Techniques such as self-talk and breathing control can be used during events to reduce arousal, whereas other relaxation techniques, such as progressive relaxation, are more suitably used before or after an event.
13. An overly-high level of arousal can serve to narrow a performer's attentional field, allow them to revert to a dominant attentional style, and highly aroused athletes tend to scan the playing environment less often.
14. Personal relaxation undertaken during the tapering phase will enable the athlete to maintain a positive and healthy mindset for performance and training. The physical and emotional benefits of such tapering prior to performance are likely to influence an athlete's confidence in their ability.
15. d. All of the above.
16. Using the self-talk statement; 'what doesn't kill me will make me stronger', serves to influence stage 2 of the stress process (perception of demand). It is an attempt to decrease perceptions of the significance of the demand or competition.
17. Using self-talk to influence concentration is most useful when done during performance.

18. Goal setting can influence motivation before a performance or during the performance. For example, a netball player who has set a goal to play for Australia under 15's will be motivated to attend state and national trials (direction of motivation) and try her best at those trials (intensity of motivation).
19. Goals can be set to encourage an athlete to focus on particular aspects of performance. Goals can provide a reference point to evaluate the quality of performance and can be re-set to accommodate successes.
20. Task cohesion is defined by a common purpose and a shared perspective on task objectives. Social cohesion is reflected in terms of friendships among teammates.
21. Straight arrowed lines denote attraction and dotted lines denote rejection. While the lines do indicate attraction and/or rejection, they do not indicate the extent or intensity of these feelings.
22. The four categories or correlates of Carron's model of team cohesion are:
- Environmental factors: Refer to the general situational factors that help to keep a group together. They include contractual obligations, transfer rules, geographical restrictions, or organisational orientation (goals and strategies for achieving goals).
- Personal factors: Refer to the individual characteristics of group members.
- Leadership factors: Include the leadership style and the behaviours that professionals exhibit. Also included are the dynamics of the coach-athlete interpersonal relationships and the coach-team relationship.
- Team factors: Are the variables that operate at a group level, and include team stability and the desire for group success.
23. A bi-directional correlate means that the association between the two variables can be influential in both directions. For example, team success, which can be thought of as a team factor, is likely to lead to team cohesion, but team cohesion is also thought to lead to success.
24. The Ringelmann effect refers to the phenomenon in which the performance of members in a group decreases as the number of people in the group increases.
25. i. identify individual outputs, and
ii. develop relationships among the group members.
26. The potential for social loafing will increase with an increase in the number of team members.
27. Performance decrements as a result of social loafing are thought to primarily relate to a loss in team members motivation.
28. Enhancing team cohesion can reduce social loafing. Therefore:
- Coaches can help to build cohesion by explaining individual roles in team success, setting challenging group goals, encouraging group identity, avoiding excessive team member turnover, and by knowing the team climate.
- Group members can help to build cohesion by avoiding the formation of social cliques, learning about other group members, helping teammates, giving encouragement and other positive reinforcement, and resolving conflicts quickly.

Appendix E

Glossary of key terms

Arousal: Refers to a mixture of physiological (physical) and psychological (mental) activation.

Group cohesion: A dynamic process which is reflected in the tendency for a group to stick together and remain united in the pursuit of its instrumental objectives and/or for the satisfaction of member bonds or friendship.

Imagery: The process in which an individual imagines the sight, sounds, feelings and smells associated with the environment in which they are performing.

Motivation: The direction and intensity of one's effort.

Performance routine: A sequence of task-relevant thoughts and actions which an athlete engages in systematically prior to his or her performance of a specific sport skill.

Progressive relaxation: A technique involving tension and then relaxation of muscle groups.

Ringelmann effect: The phenomenon in which the performance of members in a group decreases as the number of people in the group increases.

Self-talk: A process in which an athlete engages in dialogue with themselves.

SMARTS goal setting: Principles for setting goals and include: Specific, Measurable, Action-oriented, Realistic, Time-bound, and Self-determined.

Social cohesion: Friendships among teammates.

Social loafing: The reduction in effort when working in groups versus when working alone.

Somatic anxiety: A heightened state of physical activation.

State anxiety: Temporary and changing mood state of apprehension and tension - associated with arousal.

Stress: A process in which there is perceived to be a substantial imbalance between demand and response capability, under conditions where failure to meet that demand has important consequences.

Task/instrument cohesion: A shared perspective on task objectives.

Thought stopping: Involves the use of a cue or trigger to stop a negative thought and clear it from the mind.



Motor Learning and Coaching

Dr Brendan Lay (Associate Professor) and Dr Peter Whipp (Associate Professor)

BACKGROUND INFORMATION

The following dot-points provide a revision of the key concepts from Units 1 and 2.

Skill

- A motor skill is the ‘learned ability to bring about pre-determined results with maximum certainty, often with minimum outlay of time or energy or both’ (Guthrie 1952).
- In general, highly skilled performers are: faster, more consistent, able to display greater control and timing, more physiologically efficient and more efficient in decision making.
- Perceptual skill is the process of recognising and then interpreting information from the environment.
- Cognitive skill is the mental processing that incorporates problem solving, remembering and decision making.
- Motor learning is reflected by a relatively permanent change in motor skill capabilities that is associated with practice or experience.

- Motor performance is an observable behaviour at a specific time and location.
- The superior perceptual and cognitive skills of expert sportspeople often provide them with more time to execute motor skills than lesser skilled opponents.

Classification of motor skills

- Closed skills are observed when the performer dictates the timing of the skill and when the environment is predictable or stable.
- Open skills are observed when the timing of the skill is dictated by factors external to the performer and when the environment is unpredictable or unstable.
- Fine motor skills use controlled movement of small muscles.
- Gross motor skills use large muscles.

- Discrete skills have an identifiable start and finish.
- Serial skills are defined by the linking of discrete skills together to form more complicated skills.
- Continuous skills have no distinct beginning and end points and contain repetitive movements.
- The complexity of a motor skill is defined by: the amount of information to be processed, the required level of movement precision or accuracy and the time available to perceptually and cognitively process information.

Phases of motor learning: Cognitive phase

- The cognitive phase of learning is characterised by:
 - The athlete tries to gain an understanding of ‘what to do’
 - Errors are large in number and magnitude
 - The athlete has little capacity to correct their own errors
 - Instruction and feedback from a coach can be very beneficial.

Phases of motor learning: Associative phase

- The associative phase of learning is characterised by:
 - The athlete is able to perform the basic skill
 - The athlete is better able to adjust to the environment when performing the motor skill
 - Errors become less in number and magnitude
 - The athlete begins to detect and correct their own errors
 - The athlete is encouraged to use their own feedback.

Phases of motor learning: Autonomous phase

- The autonomous phase of learning is characterised by:
 - The athlete does not consciously think about the specific movement characteristics of the skill
 - The athlete can perform other tasks at the same time
 - Low performance variability
 - The athlete can detect their own errors and make adjustments to correct them.

Cues used to improve performance

- A visual cue includes a demonstration or piece of observable information that allows the learner to determine what the movement requires.
- A verbal cue is a concise phrase that directs attention to the most important feature(s) in the performance environment, or prompts performers to attend to the key components of the skill. They need to be appropriate for the learner.
- Kinaesthesia or proprioception provides internal sensory information about joints, muscles and the orientation of a body in space.
- Learners usually prefer to have information presented in one of four ways: visual, auditory, through reading or writing and by feeling or doing.

Information processing

- Three phases of information processing includes:
 - Stimulus identification—sensing and identifying a stimulus
 - Response selection—deciding if to respond and what response to make
 - Response programming—preparing and organising the desired movement.
- After completing information processing, a movement is initiated which is the output.
- Feedback, accessed during and after the performance, is used to improve subsequent performances.

Feedback

- Intrinsic (inherent) feedback is sensory information that is a natural part of performing the skill and includes visual, proprioceptive and auditory information.
- Extrinsic (augmented) feedback is extra information that is not inherent to the task and includes:
 - Knowledge of results (KR)—information about the movement outcome relative to the task goal.
 - Knowledge of performance (KP)—information about the nature of the movement pattern.
 - Terminal feedback—information presented after the performance that can be delayed or presented immediately after the performance is completed.
 - Concurrent feedback—information presented during the performance.
 - Verbal feedback serves to inform and reinforce or motivate and includes:
 - o qualitative—best used for the early phase of learning
 - o quantitative—best used for the later phase of learning
 - o descriptive—identifies the errors
 - o prescriptive—identifies the errors and a means to correct them.
 - Non-verbal feedback can be sourced from real-time cameras, mirrors, video and biofeedback.
- During the early phase of learning, extrinsic feedback should be provided consistently and immediately after the performance is completed.

- When learners are able, extrinsic feedback should not be presented too frequently, such that it creates learner dependence. Learners should be encouraged, through delaying extrinsic feedback, to self-evaluate performance using intrinsic feedback.

Skill learning and individual differences

- When designing skill learning programs, teachers or coaches need to consider:
 - The characteristics of the individual:
 - o age
 - ◇ respect and accommodate the limitations of growth and age
 - ◇ modify equipment, activities, conditions and teaching to maximise safety and learning
 - o skill level
 - ◇ provide activities, instructions and feedback to progress optimally through each phase of learning
 - o fitness level
 - ◇ matching training to the individual's readiness and needs of the sport
 - o injury
 - ◇ provide athlete support, preventing further damage and facilitating rehabilitation.
 - The characteristics of the task that is being practised:
 - o type of activity, which is impacted by all of the individual difference variables

- ◇ physical: age, skill level, fitness level and injury
- ◇ psychological: motivation, confidence, arousal, anxiety, concentration, personality, group dynamics and inter-personal relationships.
- The environment in which the task is being performed:
 - o level of competition
 - ◇ matching training to the needs and aspirations of the individual.

Motor Learning and Coaching: ATAR Units 3 and 4

A similar approach is followed for each section of the ATAR Units 3 and 4 curriculum. Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the ‘Content that follows’ and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A ‘Key point summary’ box is presented at the end of each section.

Two practical investigations are included as Appendix B1 (Unit 3 content: Transfer of learning) and Appendix B2 (Unit 4 content: ‘Ultimate’ game performance analysis of self and others). A format for report writing can be located at the end of this chapter (Appendix A) to assist students with their preparation of a practical investigation. Marking matrices are also included in Appendices B1 and B2. Answers are provided for teachers only.

Revision questions (with answers) are included near the end of this chapter as Appendix C. Following the revision questions is a ‘Personalised project’, which requires students to apply knowledge and understanding from ‘Sport Psychology and Motor Learning and Coaching’ (Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision. A ‘Glossary of key terms’ appears on the final pages of this chapter (Appendix E).

Transfer of Learning

Text outcomes: *Transfer of learning (Unit 3)*

Define and understand transfer of learning.

Content that follows: *Transfer of learning (Unit 3)*

- *Transfer of learning*
- *Why does transfer of learning occur?*

The primary goal of any training session should be to improve performance in competition. That is, the activities that you practice during a training session should **transfer** to the competition that you are practicing for. **Transfer of learning** is the gain (or loss) in proficiency in one skill as a result of practice on another skill.

Transfer of learning provides the foundation for applied principles of learning in education, sport and rehabilitation. For example, when a swimming teacher or coach takes the swimmers out of the water and practices the technique on dry land, they are assuming that the dry-land practice will transfer to performance in the water. In many sports there are aspects of the skill that, when rehearsed for the first time, can be too dangerous. An aerial ski jump coach or a gymnastics coach will, therefore, practice dangerous activities like a triple somersault while landing into a foam pit or a swimming pool to remove the potentially dangerous landing. The underlying assumption here is that the technique learnt will be transferred to the competition environment.

Transfer of learning is an important issue for coaches and teachers to understand because it will assist with making decisions about what to practice and how that will best improve performance.

Why does transfer of learning occur?

If we can understand why transfer of learning occurs, then we may be able to gain an

understanding of what a person learns about a skill that enables the person to adapt to the requirements of a new environment or to learn a new skill. There are two explanations as to why transfer of learning occurs:

1. The first relates to the similarity of the skill and the similarity of the context in which the skill is performed. This means that the greater the similarity between the movement components of two skills, the greater the amount of transfer between them. Similarly, if the performance context or environment is similar between two skills then there is likely to be more transfer.
2. The second explanation suggests that if the cognitive processing requirement of the two skills or environmental contexts is similar, then transfer will occur. If an athlete is practicing/training for a task that involves rapid decision making, application of rules and dual tasking (performing two tasks at once) then, to gain a large amount of transfer to competition, the training should also involve those elements.

Key point summary:

- Transfer of learning is the gain (or loss) in proficiency in one skill as a result of practice on some other skill.
- Understanding transfer of learning will assist with decisions about what to practice and how that will best improve performance.
- Transfer of learning occurs because:
 - previously learned skills that are very similar to new skills can be used to physically execute the new skill
 - skills that require similar cognitive processing transfer to other skills with similar needs.

Text outcomes: *Transfer of learning (Unit 3)*

- *Understand the effects of transfer of learning and their impact on improving skill execution and movement efficiency.*

Content that follows: *The effects of transfer of learning (Unit 3)*

- *Positive transfer of learning*
- *Negative transfer of learning*
- *Zero (neutral) transfer of learning*

Positive transfer of learning

Positive transfer of learning occurs when previous experience facilitates performance of a skill in a new context or the learning of a new skill. An example of positive transfer of learning of a motor skill to a new context would be when the practice that a tennis player performs on a grass court positively impacts upon the performance on a hardcourt or clay surface.

An example of positive transfer of learning from one skill to another, can be seen when individuals who are especially proficient at a motor skill such as an over-arm throw of a cricket ball (Figure 5.1a), easily transfer that high level of performance to a similar skill such as javelin throwing (Figure 5.1b). Notice that the throwing of a cricket ball and javelin throwing come from the same fundamental movement skill and, therefore, share many component parts. This example relates closely to the first explanation of why transfer of learning occurs.

There are a number of sportspeople that have



Figure 5.1 Throwing a cricket ball (a) has similar skill components to throwing a javelin (b)

made a switch from one sport to another and achieved outstanding success. Alisa Camplin (Figure 5.2), who is famous for winning the 2002 Winter Olympic Gold medal in the aerial ski-jump, was an excellent gymnast prior to becoming an aerial skier. When we compare the two sports, gymnastics and aerial ski-jumping, we can find a number of similarities between the skills (performing somersaults and twists while in the air and landing on your feet) that will result in positive transfer of learning.

Ricky Ponting (Figure 5.3), a former captain of the Australian Cricket team and one of the highest run scoring batsmen ever, is also renowned as an excellent golfer. It is interesting to see that the ball striking skill required for both golf and cricket, although having a different context (one ball is still and the other is in motion) will often result in positive transfer of learning between these sports.



Figure 5.2: Alisa Camplin a gymnast who became an Olympic gold medallist in aerial skiing

Negative transfer of learning

Negative transfer of learning occurs when previous experience inhibits or negatively affects performance of a skill in a new context or the learning of a new skill. Negative transfer of learning is exemplified by considering an individual who has learned the forehand in tennis (Figure 5.4a) before learning the forehand in badminton (Figure 5.4b). There is usually some negative transfer between these skills because the badminton forehand requires a wrist snap whereas the tennis forehand requires a relatively firm wrist. Interestingly, there are often many aspects that transfer positively between tennis and badminton because of the similarity of the cognitive processing requirements.



Figure 5.3: Ricky Ponting, Australian cricket batting champion, is also an excellent golfer

In reality, negative transfer of learning is relatively rare and is overcome quickly with practice. The occasions where negative transfer of learning occurs are more common when you are performing a skill in a familiar environment that requires a different response or skill than what you would normally provide. For example, you become very familiar with your own keyboard on your computer at home because of all of the homework that you have to do. When you are at a friend's house using their computer you may find that you make many more typing mistakes than normal because some of the buttons may be in a different position. In this example the same motor skill requires slightly different movements and the well-learned movements from your own keyboard can negatively affect performance on a new keyboard.

Negative transfer can also occur when an individual has to unlearn a well-learned skill. This can occur when an athlete moves to a new coach who recognises a movement characteristic that needs to be altered. It can be very difficult to unlearn a movement technique that has been rehearsed in a particular way for a long time. This is common in a rehabilitation or physiotherapy environment where an individual may have learned to move in a particular way because of an injury or disability. The physiotherapist will attempt to change the movement pattern to one that is more efficient and less likely to lead to other injuries. This change, may initially be difficult, but in the long term will bring about better outcomes.

The Australian Football League (AFL) has a history of trying to recruit footballers from all over the world. One famous example was Jimmy Stynes (Figure 5.5) from Ireland who won the Brownlow Medal (highest individual honour in the AFL) in 1991. With no prior knowledge of the game, at the age of eighteen the Gaelic (Irish) footballer was recruited by the Melbourne Football Club. While Jimmy

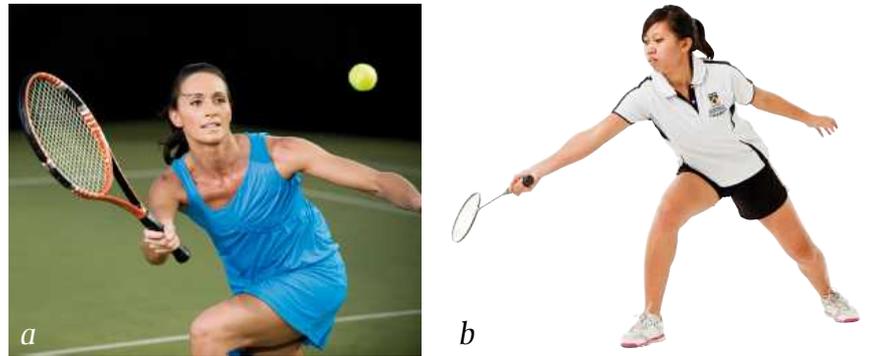


Figure 5.4: *Hitting a forehand in tennis (a) requires quite different skills when compared to a badminton shot (b)*

had excellent endurance and physical attributes that were well suited to the AFL, Gaelic football uses a round ball (similar to a soccer ball) and it took him three years of practice with the oval ball before his kicking skills and this information processing ability were of sufficient standard to play his first Senior game of football. Growing up and kicking only a round ball meant that initially there was a negative transfer of learning that required practice to overcome.

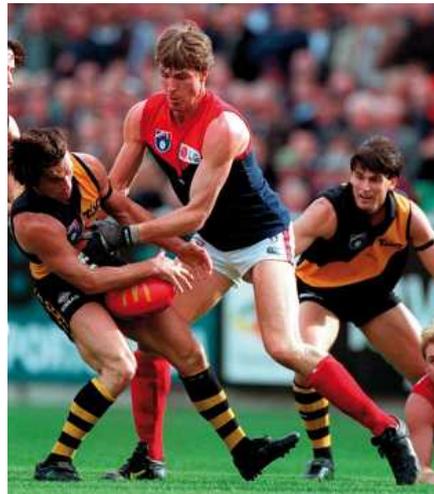


Figure 5.5: *The late, Jimmy Stynes, an Irish-born Gaelic footballer who became an AFL great*

In the first edition of this book we suggested that it will be interesting to see how high profile Israel Folau and Karmichael Hunt from Rugby League would transfer their skills to AFL. While there was some mixed success initially, ultimately both players have returned to either Rugby Union or League (Figure 5.6).

Just as we watched Hunt and Folau play AFL, it will be interesting to see if Jarryd Hayne (Figure 5.7) can positively transfer his Rugby League skills to American football (NFL; San Francisco 49ers).



Figure 5.6: Both Karmichael Hunt (a) and Israel Folau (b) have returned from AFL to Rugby Union or League - arguably examples of a failure of transfer of learning

Practical activity: *Negative transfer of learning*

- Rotate your computer mouse by 180° (so that it is upside down) and try to use it. Why is there negative transfer of learning? The task is very difficult because you have practiced for so long with the mouse in its normal orientation and trying to use it in any other way will result in performance that is affected by negative transfer of learning. A familiar environment (computer) that now requires opposite movements to those normally performed.

Equipment:

- Computer mouse.
- Computer.



Figure 5.7: Jarryd Hayne is trying to switch from Rugby League to the NFL in America

which skills can transfer, clearly there are many sports that are going to have no influence on each other such as hockey and swimming or driving a car and middle distance running. That is not to say that someone cannot be good at both, just that there is going to be little capacity for the motor skills, the context in which the skills are performed and the information processing requirements developed in one to affect the other.

Widely regarded as one of the greatest athletes of all time, Michael Jordan (Figure 5.8a), won six NBA championship titles with the Chicago Bulls basketball team in the NBA. In the middle of his basketball career, Jordan retired and was recruited by the Chicago White Sox baseball franchise (Figure 5.8b) under the assumption that a

Zero (neutral) transfer of learning

Zero transfer of learning occurs when previous experience has no influence on the performance of a skill in a new context or the learning of a new skill. While there will be certain sports between

sportsperson who was so good at one sport would also be able to excel at another. The problem was that there are very few similarities between the motor skills, the context in which the skills are performed and the information processing requirements of baseball compared to basketball.

Jordan may have been a reasonable baseballer but there was little transfer of learning from basketball that would allow him to be a superstar. Following his unsuccessful stint as a baseballer, Jordan returned to basketball to win the final three of his six NBA championships.

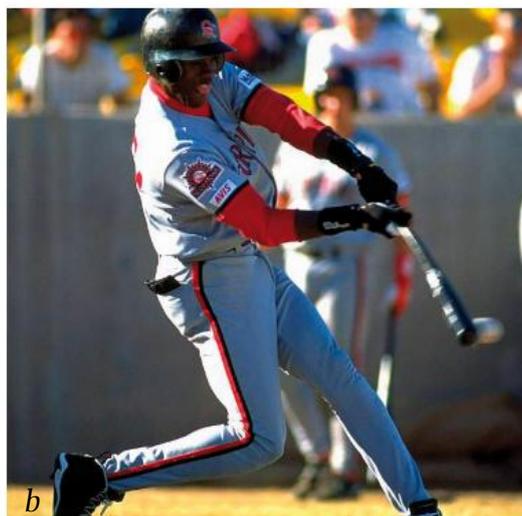


Figure 5.8: Michael Jordan playing basketball for the Chicago Bulls (a) and baseball for the Chicago White Sox (b)

Key point summary:

- Positive transfer of learning occurs when previous experience facilitates performance of a skill in a new context or the learning of a new skill.
- Negative transfer of learning occurs when previous experience inhibits or negatively affects performance of a skill in a new context or the learning of a new skill.
- Zero transfer of learning occurs when previous experience has no influence on the performance of a skill in a new context or the learning of a new skill.

Revision questions:

Test yourself on revision questions 1–3 located at the end of this chapter.

Categories of Transfer of Learning

Transfer of learning can occur in a number of scenarios and it is advantageous for a coach to understand these to achieve the best motor skill improvements possible. All of the categories of transfer learning can be positive, negative or neutral.

Text outcomes: *Categories of transfer of learning (Unit 3)*

- Identify the different categories of transfer of learning.

Content that follows: *Categories of transfer of learning (Unit 3)*

- *Skill-to-skill*
 - *Proactive transfer*
 - *Retroactive transfer*
- *Theory-to-practice*
- *Training-to-competition*

Transfer of learning: Skill-to-skill

Positive skill-to-skill transfer of learning

occurs when previous experience or practice of a skill facilitates the skill in a new context or improves performance of another skill.

Conversely, *negative skill-to-skill transfer* occurs when that previous experience inhibits performance of the skill in another context or performance of a new skill.

Practicing any skill can have an impact on motor skills that you will learn in the future but can also affect skills that you have previously learned. For example, if you learn one skill, say batting in baseball (Figure 5.9a), and it assists with another skill, maybe cricket batting (Figure 5.9b), that is performed at a later date then that is termed *proactive transfer* of learning.

If, however, a skill that you have learned previously is altered by a new skill that you learn, that is termed *retroactive transfer* of learning. An example of retroactive



Figure 5.9: Batting in baseball (a), has similar skill components to batting in cricket (b)

transfer of learning is when a soccer player (Figure 5.10a) performs explosive jumping-plyometric training (Figure 5.10b) as part of a general strength training program and then, at some point in the future, the plyometric training improves the player's heading capability because of their increased vertical jump (Figure 5.10c). The new training has improved a previously learned skill.

Proactive and retroactive transfer of learning can be positive, negative or neutral.

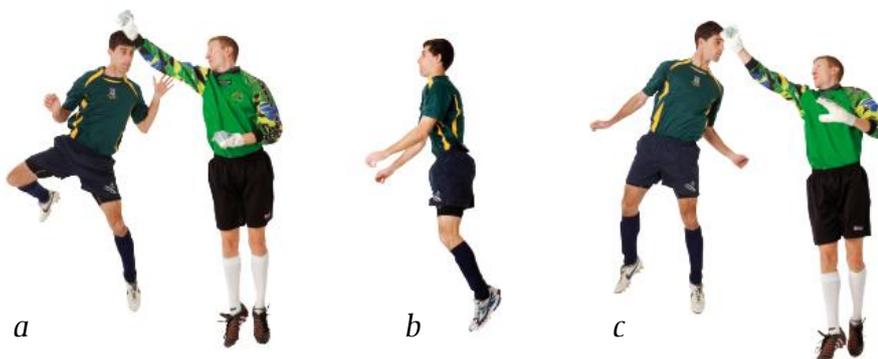


Figure 5.10: A soccer player (a) who undertakes plyometric training (b) may benefit in the future with a high-leap heading capability (c)

Transfer of learning: Theory-to-practice

Transfer of learning from theory-to-practice refers to transferring knowledge of sport or skill into the actual performance scenario. However, we all know that there is often a big difference between knowing what a team or individual athlete should be doing compared to actually being able to do it.

An example of a coach trying to transfer information from theory to practice is when a basketball coach draws on a whiteboard the 'zone' defence that the team is to employ in the upcoming game (Figure 5.11). After verbally explaining that the players are to defend areas of the court instead of their direct opponents, the coach will most likely take the players onto the basketball court and run through a number of drills. The drills will serve to transfer the knowledge gained from the explanation and the diagram on the whiteboard into practice for the up-coming game.



Figure 5.11:
A basketball coach using the whiteboard to convey theory-to-practice

Transfer of learning: Training-to-competition

We started this section on transfer of learning by stating that the goal of any training session should be to ensure that what you are practicing improves performance during competition. Therefore, the ultimate test

of any practice session is to increase the amount of positive *transfer of learning from training-to-competition*.

We also suggested that transfer of learning occurs because of the similarity of the skill and the context of the performance of the skill as well as the similarity of the cognitive processing requirements of the two skills.

To increase the positive transfer between practice and competition the practice should broadly emulate the competitive situation and, more specifically, emulate the aspects of the skill, context of the skill and cognitive processing of competition. It is important that perceptual stimuli (visual, proprioceptive and auditory cues) and the time critical nature of making decisions and responding to those stimuli are incorporated into a training session.

Class task: *How would you train to improve an individual's open-play pass in rugby?*

While discussing this question in pairs, remember that a rugby pass will be performed in open play and under pressure from opponents. In your answer be sure to consider the skill itself, the context of the skill and the cognitive processing requirements of the skill.



Figure 5.12: *A Rugby pass in open play*

Key point summary:

- Skill-to-skill transfer of learning occurs when previous experience or practice of a skill impacts on the execution of the skill in a new context or performance of another skill.
- Proactive transfer of learning occurs when skills practiced in the past have an effect on motor skills that you will learn in the future.
- When a skill that you have learned previously is altered by a new skill that you learn, that is retroactive transfer of learning.
- Theory-to-practice transfer of learning refers to transferring knowledge of sport or skill into the actual performance.
- To increase the positive transfer between practice and competition, the practice should imitate the competitive situation, by incorporating into the training session:
 - the aspects of the skill
 - the context of the skill
 - the perceptual stimuli (visual, proprioceptive and auditory cues)
 - the time critical nature of making decisions and responding to those stimuli.

Practical investigation

Transfer of learning

See Appendix B1 for a practical investigation, along with questions and report-writing format recommendations.

Revision questions:

Test yourself on revision questions 4–7 located at the end of this chapter.

Movement Analysis**Text outcomes: *Analyse movement skills of self and others (Unit 3)***

- *To identify errors.*
- *To provide feedback.*
- *To suggest corrections to improve performance.*

It is important for a coach to develop expertise in analysing motor skills within their sport. Without a skill analysis a coach will not be able to accurately determine which part of the skill is deficient. Determining the parts of the skill that are performed well and those that are deficient will enable the coach to intervene in a concise and effective manner. Further, if skill analyses are performed routinely, it is easy for the coach to track improvements.

Content that follows: *Movement analysis (Unit 3)*

- *Considering the type of movement analysis*
- *The motion analysis model*
- *Movement analysis to identify errors*
- *Movement analysis to provide feedback*
 - *Purpose of feedback*
 - *Augmented feedback: Visual, verbal, kinaesthetic, and written feedback*
 - The frequency and timing of feedback: Guidance hypothesis
- *Movement analysis to suggest corrections to improve performance*
 - *Descriptive and prescriptive augmented feedback*
 - *Visual cues: Demonstration, visual aids, and enhancing the visual environment*
 - *Verbal cues*
 - *Proprioceptive cues*

Considerations when determining the type of movement analysis

The type of movement analysis that a coach employs will depend on a number of factors, including the:

- ***Purpose of the analysis*** – is the aim of the assessment to improve performance or to prevent injuries?
- ***Assessment of the product (what the outcome is) or process (how the action is performed) of the motor skill*** – is the outcome of the skill or the movement technique the critical factor for success

(consider the sport of darts versus a gymnastics routine)?

- ***Skill level of performers/athletes*** – a more detailed and technical list of criteria will be required for higher level athletes to ensure that performance is not just improved but is at the highest level.
- ***Environment of the analysis*** – is the analysis going to be performed in the field without technological assistance compared to a video-based analysis?

The motion analysis model

The motion analysis model (Figure 5.13) provides a procedure to follow when analysing movement. A Biomechanist will use this model to identify errors, provide feedback and suggest corrections. However, it is the role of the coach (or motor learning specialist) to also understand how and when to provide this information to achieve the best learning and performance outcomes.

Movement analysis to identify errors

The primary aim of any movement analysis should be to identify errors that may be limiting performance or increasing the likelihood of an injury. Error information directs the

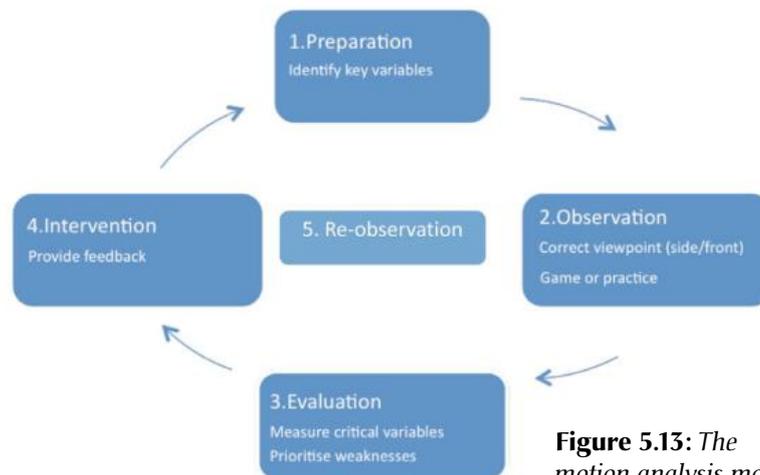


Figure 5.13: The motion analysis model

athlete to change the incorrect aspects of performance, whereas feedback concerning correct performance encourages the athlete to continue performing in that manner.

When undertaking the ‘Evaluation (or diagnosis) Phase of Motion Analysis’, errors in performance are identified. In this phase, the coach will compare what is observed to what the coach thinks is ideal for the performer being analysed. Remember that what is ‘ideal’ for one athlete may not be ideal for another due to age, gender or skill level.

Movement analysis to provide feedback

The ‘Intervention (or remediation) Phase of the Motion Analysis’ relates to how a coach would provide feedback to an athlete to correct any errors identified during the Evaluation Phase.

Purpose of feedback

Feedback has three main purposes:

1. To give the athlete information about their performance.
2. To reinforce aspects of the movement just performed.
3. To motivate the athlete to continue to strive towards their goals.

There are a number of guidelines that were outlined in the Units 1 and 2 Motor Learning and Coaching chapter for providing feedback and they will be summarised here.

Augmented feedback

Feedback that assists the learning of a motor skill can be inherent (intrinsic) to the task itself or it can be **augmented feedback** from an external source. Because all of the feedback that a coach would provide an athlete from *Movement Analysis* is classified as augmented feedback, we will be only discussing augmented feedback in this section.

Augmented feedback is the general term used to describe information given about the performance of a skill that enhances the intrinsic feedback that is naturally available from the performer’s senses. While verbal feedback provided by a coach is an example of augmented feedback, it can also be visual (e.g. video), kinaesthetic (when a coach physically moves a learner’s limbs into correct position) or in written form (e.g. a checklist) (Figure 5.14a-d).



Figure 5.14: An example of a coach providing visual feedback (a), verbal feedback (b), kinaesthetic feedback (c), and written feedback (d)

In general, it is important for the coach to consider whether the provision of augmented feedback, in whatever form, is going to enhance the learning of the skill. In situations where the task intrinsic feedback is sufficient for the learner to acquire the skill then it may be better if the coach refrains from adding any more feedback. In these situations, the learners can make appropriate adjustments to future movements based on their own sensory feedback from either their own performance or by watching the performance of others of the same or higher skill level. An individual learning a new motor skill at the cognitive stage of learning, for example, may not be able to perceive the meaning of their own task-intrinsic feedback and would benefit from augmented feedback. If the learner cannot utilise or fully interpret their task-intrinsic feedback to enhance their performance, then augmented feedback is essential. However, coaches need to be careful when providing augmented feedback because when provided, even if the feedback is wrong (erroneous) or inappropriate to the learners needs, learner's will generally use the augmented feedback instead of their own task-intrinsic feedback.

In a situation where a higher level athlete is injured, their proprioceptive feedback may be negatively affected and augmented feedback would be required for a skill to be learned.

The frequency and timing of augmented feedback

The skill level and age of the performer as well as characteristics of the task need to be taken into account when deciding what type of feedback is required for skill learning. Furthermore, whatever feedback is provided, it is important to consider the frequency and the timing of such feedback or, put more simply, how much and when feedback should be provided.

Some suggest that to promote optimal learning, augmented feedback should be presented as often as possible. Other research, in particular the guidance hypothesis (Salmoni et al. 1984), has rejected this idea. The **guidance hypothesis** has presented evidence suggesting that, if augmented feedback is provided too often, the learner will become dependent on the augmented feedback and will not utilise task-intrinsic feedback to improve. Many sports require the athlete to correct their own mistakes, as the rules do not allow the coach to provide feedback during the game, (for example, tennis) so it is important to practice or train without the provision of consistent augmented feedback. Lower frequency schedules of augmented feedback are advantageous because they promote problem-solving and encourage the learner to explore the skill using task-intrinsic feedback.

If a coach decides that augmented feedback is required following the execution of a skill, a further issue to consider is the timing of when to provide that information. In the past (and sometimes in literature that is not consistent with recent research evidence) it was suggested that augmented feedback should be provided as soon as possible following the execution of a skill, or as soon as practice has concluded. Recent evidence has suggested that, for augmented feedback to be most effective, it is important to allow learners to try to problem-solve for themselves and to utilise task-intrinsic error detection following the completion of the skill. Providing augmented feedback too quickly will, therefore, compromise learning as these processes will not occur.

Highly related to the question of when augmented feedback should be provided following skill execution, is the question of

how long the performer should wait following augmented feedback until they perform the skill again. Following the provision of augmented feedback from a coach, the performer requires time to process both the augmented feedback and task-intrinsic feedback to formulate an action plan for the next attempt. The interval of time following the feedback needs to be long enough for this process to occur.

By performing an analysis of the movement, the coach will be well placed to determine the type, frequency and timing of augmented feedback that is best suited to the skill level of the athlete and also the nature of the motor skill in question. Video as a form of augmented feedback, for example, can be used effectively for both performers at the autonomous and cognitive phases of learning. For an elite level athlete, video replays can consolidate much of the feedback that a coach is providing but, to be useful for a beginner, videos should be supplemented verbally by the coach with cues designed to focus the learner's attention on critical aspects of the skill (Newell & Walter 1981).

Movement analysis to suggest corrections to improve performance

When a coach delivers augmented feedback to athletes to improve performance, it can take the form of a description of the error or correct aspect of performance. In other situations a coach may also choose to not only provide feedback but also prescribe a means for the athlete to overcome an error that has been identified by movement analysis. You may recall from Units 1 and 2 course content that *descriptive augmented feedback* only describes the performance but *prescriptive augmented feedback* describes the performance and then prescribes a solution to the problem. In general, beginners require more prescriptive feedback because they are unaware

of how to correct their mistakes, whereas more advanced performers may only require descriptive feedback because they have sufficient knowledge of the skill to correct it themselves.

An important set of tools that a coach can use to suggest corrections to improve performance are visual, verbal and proprioceptive cues.

Visual cues

Visual cues give the learner an opportunity to see what the movement requires. Teachers or coaches often provide visual cues to improve performance through the demonstration of a skill because they are often more effective than a verbal description.

Demonstration

An accurate model or skill demonstration is a powerful *visual cue* to help the learner and present a lot of information in a short time (Figure 5.15). The teacher or coach should focus the learner's attention on specific components of any demonstration but this is a delicate balancing act. Too much talking by the teacher or coach can distract the learner, but too little instruction can lead the learner to view the skill as a whole but miss the specific aspects of the demonstration that will help them.



Figure 5.15: Using a demonstration as a visual cue (a & b)

The teacher or coach should recognise that what learners are ‘looking at’ may not be what they ‘actually see’. In other words, the learner could perceive information from the demonstration that may or may not be accurate. For example, if two learners watch a skilled tennis player demonstrate a fast serve (Figure 5.16), one may see the speed of the serve being due to the fast racquet speed, while the other may see that the speed of the serve was due to a combination of the leg drive and the sequential action of the hips, trunk and shoulder. Therefore, when practising in the future, both learners would approach the tennis serve emphasising different aspects of the skill.



Figure 5.16: A highly skilled tennis player demonstrating the tennis serve

Visual aids

Graphs, flow charts, pictures, mirrors and diagrams are all visual aids. The most commonly used aid is video, which can show images of a high-performance athlete or the

learner performing the skill (Figure 5.17). Elite athletes and coaches also regularly use computer analysis programs to qualitatively and quantitatively analyse performances.



Figure 5.17: A footballer and their coach using video to analyse performance

Enhancing the visual environment

To ensure the learner attends to important aspects of the display, the teacher or coach enhances the visual environment. Examples include, placing a target on a wall or floor at which learners can aim; placing chalk markings on the pitch for cricketers to bowl the ball in the desired area; positioning targets in the tennis service box to highlight the desired landing point of a service; and dance instructors outlining feet positions on the ground to represent a sequence of steps for beginners to follow.

Verbal cues

A **verbal cue** is a short, concise phrase that directs attention to the most important feature(s) in the environment, or prompts performers to attend to key components of the skill. When individuals are learning new skills, teaching or coaching instructions should clearly describe the movements or outcomes required. Learners in the *cognitive stage* of learning often have

many questions concerning how to perform the basics of the skill. Verbal instructions have been shown to have powerful and lasting effects on learning new motor skills, but they need to be appropriate for the age, comprehension and experience level of the learner. For example, ‘chin-over-knee and over-back-toe’, is a simple verbal cue that encourages the learner to position their body weight over their back foot whilst preparing to throw a ball or shot put (Figure 5.18). Complicated verbal cues can lead to confusion, so one needs to be succinct. Technical verbal cues can also be used to direct high-level performers in areas of already well-rehearsed motor skills that need some fine-tuning.



Figure 5.18: *Chin-over-knee and over-back-toe in the preparation phase of a shot put*

Teachers or coaches need to be aware that individuals can only absorb limited information. You probably can remember a teacher or coach standing in front of a class or squad who listed far too many points on which you needed to focus. Mostly, players end up forgetting half of the information and can only recall some components of the other half. While the expectation is that they remember everything,

they commonly feel overwhelmed and don't know where to start. This problem is sometimes called ‘paralysis by analysis’. Consider when the centipede was asked what the forty-fifth leg on the left was doing when the sixth leg on the right touched the ground, it became so confused and it fell into a ditch! To avoid over-complicating the teaching or coaching point, use around *three* brief verbal cues to relay important information for performing a skill successfully.

Proprioceptive cues

The terms kinaesthesia and proprioception are used interchangeably here, to refer to the collection of internal sensory information that informs us about our own joints, muscles and orientation of our bodies in space. ***Proprioceptive feedback*** often involves the coach physically moving the athlete through the required action to enhance their understanding of what a successful performance feels like. For example, when learning the breaststroke kick for the first time, swimmers lie on the side of the pool and replicate the desired action (Figure 5.19). The teacher or coach can provide proprioceptive cues by providing resistance and/or manoeuvring the swimmer's feet into the correct (toes-to-shins) position. They also can move the swimmer's legs through the full kicking action.



Figure 5.19: *A swimming teacher providing proprioceptive cues to improve the breaststroke kick*

Key point summary:

- By analysing motor skills a coach will be able to accurately determine:
 - which part of the skill is performed well
 - which part of the skill is deficient
 - training activities to improve performance and reduce injury
 - improvements in performance over time.
- The type of movement analysis that a coach employs will depend on:
 - the aim or purpose of the analysis
 - the need to assess the product (what the outcome is) or the process (how the action is performed) of the motor skill
 - the skill level of performers/athletes
 - the environment that the analysis will be performed in.
- The motion analysis model is a 5-step process of: Preparation, Observation, Evaluation, Intervention and Re-observation.
- The primary aim of analysis is to identify errors that may be limiting performance or injury prevention and is undertaken during the 'evaluation (or diagnosis) phase of motion analysis'.
- Feedback has three main purposes:
 - provide information about performance
 - reinforce aspects of the movement just performed
 - motivate the athlete to continue to strive towards their goals.
- Augmented feedback is extra information given about the performance of a skill that is not inherent to the task through the performer's senses.
- Augmented feedback can be provided via visual, verbal, kinaesthetic, or written cues.
- When learners are able, augmented feedback should not be presented continuously nor immediately after performance. Learners should be encouraged to self-evaluate using inherent feedback.
- Descriptive augmented feedback identifies the errors, while prescriptive augmented feedback identifies the errors and a means to correct them.
- Visual cues used to improve performance include demonstrations, visual aids, and enhancement of the visual environment.
- A verbal cue is a concise phrase that directs attention to the most important feature(s) in the environment, or prompts performers to attend to key components of the skill.
- Proprioceptive feedback refers to internal sensory information that informs us about our own joints, muscles and the orientation of our bodies in space (kinaesthesia). It often involves the coach physically moving the athlete through the required action to enhance their understanding of what a successful performance feels like.

Revision questions:

Test yourself on revision questions 8–12 located at the end of this chapter.

Improving Performance in Selected Skills

Text outcomes: *Design coaching/training activities (Unit 3)*

- *Design coaching/training activities to improve performance in selected skills.*

In a previous version of this text book (Units 1 and 2) we have discussed that as individuals practice a skill they generally move through three phases of learning: 1. The cognitive phase, 2. The associative phase and, 3. The autonomous phase. We also suggested, in the Background Information section of the affiliated text book, that practice time is important for moving through these 3-phases of learning, but it is more important to understand the best practice or teaching strategy to use in different circumstances to speed up an athlete's progression.

Here we will discuss a number of different teaching strategies that a teacher or coach can employ and provide specific sporting examples from different categories of motor skills.

Content that follows: *Improving performance in selected skills (Unit 3)*

- *Simple and complex skills*
- *Simplifying complex motor skills*
- *Shaping motor skills*
- *Chaining motor skills (forward and backward)*
- *What's the difference between shaping and chaining?*

- *Shaping and chaining – an example of transfer of learning*
- *The decision to break down a motor skill*
- *Static and dynamic skills*

Simple and complex skills

The complexity of any skill can be defined by a number of factors, including:

- the number of component parts involved in performing the skill
- the amount of attention or information processing required to perform the skill
- the required level of movement accuracy
- how quickly the task needs to be performed.

A **complex skill**, therefore, has a large number of components and demands a lot of attentional resources. In contrast, a **simple skill** has few components and less demand on attention. It is always important to remember that when skills are classified according to opposite ends of a continuum (as with simple and complex skills or open and closed skills for example) most skills will fit somewhere between these classifications. Two skills may be described or classified as complex, but one skill may be more complex than the other.

A coach can adopt a number of strategies when coaching or training individuals to acquire complex motor skills. In this section we will first consider a number of possibilities to **simplify complex skills** before looking at how to break down motor skills (shaping and chaining motor skills) and highlight some specific skill examples.

Table 5.1: *Methods of simplifying complex motor skills*

Method of Simplification	Skill Acquisition Example
<i>Reduce object difficulty</i>	Using silk scarves for juggling Using a foam bat and ball for baseball or cricket
<i>Reduce attention demands</i>	Decrease the number of opponents in a drill Reduce the number of options or cognitive processing
<i>Reduce speed</i>	Slow down speed of tennis serve, emphasise accuracy
<i>Add auditory cues</i>	Using a metronome to learn a piece of music
<i>Sequencing skill progressions</i>	Chaining and shaping skills (see further in this section)
<i>Simulators or virtual reality</i>	For driver and pilot training
<i>Shaping a motor skill</i>	Practicing incomplete versions of freestyle swimming <ul style="list-style-type: none"> • high elbow drills • body position drills • long-stroke drills • catching water (sculling) drills
<i>Chaining a motor skill</i>	Hockey – hitting the ball at goal <ul style="list-style-type: none"> • practice trapping the ball • practice dribbling towards goal • practice getting feet into hitting position • practice hitting • practice together – trap, dribble, feet position, hit

Simplifying complex motor skills

When simplifying a motor skill the difficulty of a certain aspect of the task is reduced. There are a number of ways that a coach can simplify a motor skill (Table 5.1).

Someone learning to juggle three balls may benefit from practising with silk scarves because they move more slowly through the air and do not bounce out of the hand. A child learning to hit a foam ball with an oversized plastic bat is also benefitting from simplifying a complex skill.



Figure 5.20: *An example of simplifying a complex skill by using an oversized bat and foam ball*

If we consider a pilot learning to fly a plane, an astronaut in a rocket or the driver of a haulpak truck on a mining site (see Figure 5.21a, b, and c), it would be a very costly exercise to allow learners to make all of their mistakes ‘on the job’. These tasks require the operation of extremely dangerous and expensive equipment and, given the number of mistakes that learners usually make, it is much better to utilise training simulators (Figure 5.22) which are becoming more realistic with advancing technology.



Figure 5.21: The cockpit of a plane (a), the capsule of a rocket (b), and the haulpak truck (c)



Figure 5.22: A flight simulator

Shaping and chaining motor skills are methods that a coach can utilise to assist learners performing a complex skill by breaking down the skill into simplified components.

Shaping a motor skill

Shaping is when simplified or incomplete versions of a skill are rehearsed initially (to allow the performer to perform the basic skill) and then missing components are gradually added. Usually a teacher or coach will use the shaping method by demonstrating and explaining the skill, get the athlete to practise a simplified version of the task, make corrections and adjustments and then allow further practice before adding the missing components, until the whole skill is rehearsed. When shaping a motor skill, the simplified parts of the skill do not have to precisely replicate any component of the original

skill. For example, you might practise an exaggerated version of the high elbow lift in freestyle swimming by trailing your thumb along your side during the initial part of the arm recovery (Figure 5.23). This clearly emphasises the importance of the high elbow recovery but, when other aspects of the skill are added to form the whole stroke, sliding the thumb along the rib cage is omitted.



Figure 5.23: Practice to emphasise a high elbow recovery in freestyle swimming

Chaining a motor skill

Chaining is different from shaping because the skill is broken down into components that are rehearsed separately, as if they were isolated skills. Over time, the components of the skill are then put together to perform the whole skill. Even though isolated components

of the skill are practiced, the order in which the isolated skills are practiced is important. Chaining can be executed in one of two ways, depending on the skill. In **forward chaining** the components of the skill are rehearsed in the order that the whole skill is performed (for example, starting with the first component of the skill). However, **backward chaining** is practised with the last component first and the whole skill is built by working backwards.

What's the difference between shaping and chaining?

The main differences between shaping and chaining are:

- when chaining a motor skill, the order of practising components of the skill is important
- when shaping a motor skill, the order of the rehearsed components is less important
- when chaining a motor skill, replication of movement components of the skill is important
- when shaping a motor skill, replication of the movement components of the skill is not important.

Shaping and chaining – an example of transfer of learning

As with much of the motor learning and coaching content it is important to recognise how this information (shaping and chaining motor skills) relates to other motor learning concepts. In this chapter we can see how the principles of shaping and chaining skills take advantage of the *positive transfer of learning* from simplified versions of the whole skill. The basic idea is that any simplified component of a skill that you practice will positively transfer to the whole skill when you put all of the components back together.

The decision to break down a motor skill

Some motor skills are easily broken down so that separate components of the skill can be practised and then put back together as we have just discussed with the shaping and chaining of motor skills. On the other hand, certain motor skills are best not broken down and always practised as a complete skill.

The general principles concerning whether or not a skill can be broken down to be chained or shaped are:

- motor skills that are high in complexity and low in organisation can be broken down into component parts to be practised separately
- motor skills that are low in complexity and high in organisation are best practised as a complete skill and not broken down.

Static and dynamic drills

The difference between static and dynamic drills refers to whether the individual is in motion, travelling forwards, backwards, or sideways while executing the motor skill. Therefore a **static drill** will require the athlete to stay on the same spot and perform the motor skill (or part of the motor skill), whereas, a **dynamic drill** will be performed while the athlete is in some form of locomotion.

Obviously, in sport it is most common to perform dynamic drills that replicate movements involved in the whole skill or parts of the skill. However, a coach might choose to utilise a static drill for a number of reasons. **Static drills** can be particularly useful for learners in the early (cognitive) phase of learning. Static drills assist by simplifying the skill as they reduce attention demands or close down the learner's environment. That is, they reduce the task complexity by limiting the

actions required, such as removing the need to perform the actions on the run or in response to a moving target. In addition, static drills often serve to reduce the cognitive processing demands such as decision making and the need to respond to external stimuli such as defensive pressure from opponents. Therefore, the athlete can selectively focus on learning the defined motor skills (Figure 5.24).



Figure 5.24: *Static drill practice of passing and trapping in hockey to reduce the task complexity and cognitive processing demands*

Consider a golfer learning how to perform a backswing, maintaining an appropriate elbow position. The golfer will benefit from performing a static drill where the coach can also provide proprioceptive cues by physically moving the golfer into the correct position (Figure 5.25).

When a coach is explaining and demonstrating a motor skill they will have approximately three key points that they want the learner to concentrate on during practice. A static drill can reinforce the three teaching points by allowing the learner to hold (and exaggerate) the technique points that the coach was referring to.



Figure 5.25: *Static drill practice to emphasise an appropriate elbow position during the backswing*

In a sport such as gymnastics where many of the skills have a risk of injury when they are first practiced, a coach may use static drills to familiarise the gymnast with key positions that are experienced throughout a skill, before progressing to a dynamic performance that incorporates these positions. (Figure 5.26 a & b).

Key point summary:

- Complex skills have a large number of components and demand a lot of attention.
- Simple skills have few components and low demand on attention.
- Strategies to simplify a motor skill include reducing the difficulty of the objects used, reducing attention demands, performing the skill in slow motion, adding auditory cues, sequencing skill progressions, and using simulators or virtual reality.
- Shaping involves simplified or incomplete versions of a skill being rehearsed initially before missing components are gradually added.
- Chaining involves the skill being broken down into components that are rehearsed separately, as if they were isolated skills. Over time, the components of the skill are then put together to perform the whole skill.
 - Forward chaining – skill components are rehearsed in the order that the whole skill is performed.
 - Backward chaining – last component is practised first and the whole skill is built by working backwards.
- The decision about whether to break down a motor skill for chaining or shaping is based on the complexity and organisation of the skill.
- Static drill – the athlete will stay on the same spot and perform the skill. They reduce the attention demands.
- Dynamic drill – performed while the athlete is in some form of locomotion.

Revision questions:

Test yourself on revision questions 13–17 located at the end of this chapter.

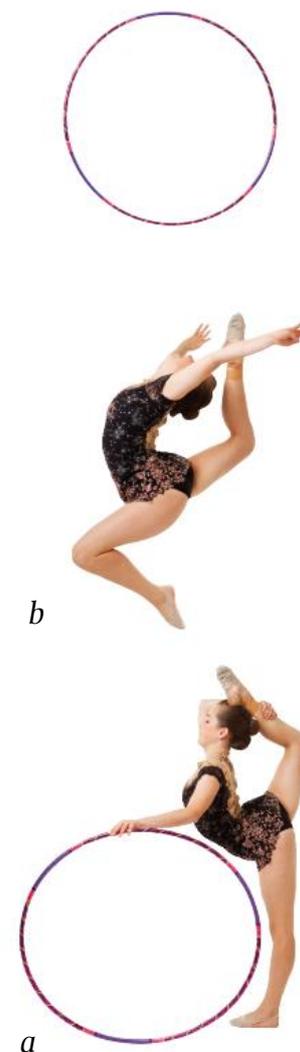


Figure 5.26: Employing a static drill in gymnastics (a) before progressing to a more challenging performance that incorporates these positions (b)

Leadership Styles

Text outcomes: *Leadership styles (Units 3)*

- *Evaluate the use of different leadership styles to suit audience needs.*

Content that follows: *Leadership styles (Unit 3)*

- *Using different leadership styles to suit audience needs*
- *Autocratic*
- *Democratic*
- *Laissez-faire*
- *Leadership groups in team sport*

Using different leadership styles to suit audience needs

Different situations call for different leadership styles. For example, in an emergency when there is little time to come together on an agreement and where a designated authority has significantly more experience or expertise than the rest of the team, an autocratic leadership style may be most effective. However, in a highly motivated team with comparable levels of expertise, similar goals and ideas about how to attain those goals, a more democratic or laissez-faire style may be more effective. The style adopted by a coach should be that which most effectively achieves the objectives of

the group while balancing the interests of its individual members.

It is important to remember that a single coach can adopt different leadership styles for different teams or even for individuals within the one team. Leadership styles can be placed along a continuum (see Figure 5.27). At one end of the scale is the autocratic leadership style – where the coach makes all of the decisions. The mid-point of the continuum is an inclusive style of leadership that seeks contributions from team members (democratic). The other end of the spectrum is the laissez-faire style where athletes are encouraged to do what they want. In real terms, coaches tend to move along the continuum and represent all of the three styles identified. It may be that a coach predominately uses one style; however, in order to best meet the needs of specific athletes or situations, good coaches may adopt more than one leadership style.

While discussing each style, it is important not to try and identify one coach or sport that fits a particular style (although some appear to fit styles), but to identify athlete needs that can be best met by a particular leadership style.

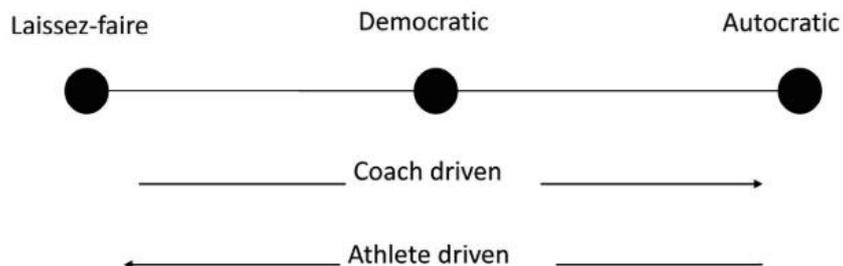


Figure 5.27: *Leadership styles can be viewed as a continuum and a coach may be required to adapt their style to suit different audiences and situations*

Autocratic

An *autocratic leader* uses an authoritarian manner and dictates exactly what is going to occur on the field, and sometimes off the field, without consulting the athletes and others; that is, they make the decisions. The autocratic style of leadership meets some athlete needs and is inconsistent with the needs of others (Table 5.2).

There are occasions when an autocratic style of leadership is necessary. When an immediate decision needs to be made, the decision is unlikely to change whether the athletes had input or not and the athletes will not lose motivation as a result of not being involved in the decision. An example might arise when a drawn soccer match requires an immediate list of five players to be presented to execute the

penalty shoot-out. Clear-cut, decisive action is required so that players have no confusion as to their roles. The teacher or coach takes on that responsibility and allows players to concentrate on the task ahead.

As stated above, there are times when an autocratic style is required as athletes cannot discuss every decision and, in team sports, the individuals require organisation. However, the autocratic style of leadership often has the adverse effect of stifling the motivation of athletes. Instead of striving to win or play their role within the team, athletes can find themselves driven by the extrinsic motivation of either trying to please the coach, and perhaps more detrimentally, to avoid being told-off by the coach.

Table 5.2: *The autocratic leadership style – what needs will it, and will it not, meet?*

The Autocratic Leadership Style	
Meets the needs of:	Does <u>not</u> meet the needs of:
<p><i>Athletes who need support and answers</i></p> <ul style="list-style-type: none"> Eliminates distractions and provides answers. That is, athletes can get on with the core business of training and performing. Efficient – in that they do not waste time trying to get a consensus. Athletes who value extrinsic motivation. Business like and driven – provide an extrinsic motivation to athletes. Role model and set the tone for everyone's effort, intensity and performance. <p><i>Athletes who value extrinsic setting of benchmarks and are goal driven</i></p> <ul style="list-style-type: none"> Athletes who want to know where they stand. Clarity on performance indicators and selection criterion are established. Often consistent with professional athletes. 	<p><i>Athletes who want to contribute</i></p> <ul style="list-style-type: none"> Does not allow the athlete/s to contribute to the direction and answers. Athletes who are experienced and wish to make informed contributions may feel stifled and frustrated. Athletes who are creative performers or experiential may feel inhibited, trying to adhere to the defined game plan. <p><i>Athletes who have their own answers</i></p> <ul style="list-style-type: none"> Athletes, who do not agree with the coach, have no-where to go.

Democratic

With the limitations of exclusive use of an autocratic leadership style realised, there has been a shift towards modern teachers or coaches using greater inclusivity, athletes' views, assistant's input and they are more open to alternatives; that is, democratic. A **democratic leader** requires the group to be a part of any decision-making process. This style of leadership is characterised by a process of consultation between the teacher or coach and the athlete(s). The teacher or coach may ask questions or provide a number of alternatives, but he/she allows the team or athlete to make the decisions. This approach serves to empower the athletes and provides them with a sense of control over their current and future career. A teacher or coach also should be aware that a democratic style can have negative outcomes when there is no clear agreement within a group of athletes and should be prepared to cope with

this situation (Table 5.3).

Appropriate courses of action could include a brief trial of the most popular choice, followed by practising the next most popular and so on. Then, the group might have another discussion as to which they now preferred. Or, alternatively, the teacher or coach might decide the course of action by a combination of choices or his/her own preference. The best results for this style of leadership often are achieved when the coach provides the structure and rules that allow athletes to set their own goals and strive for them.

It is important to note that adopting a democratic style of leadership is not an abandonment of the coach's responsibilities. Instead the democratic leader will carefully create the optimal learning environment by providing instruction and feedback when needed but also allow the athletes to make decisions and assume responsibility.

Table 5.3: *The democratic leadership style – what needs will it, and will it not, meet?*

The Democratic Leadership Style	
Meets the needs of:	Does <u>not</u> meet the needs of:
<p><i>Athletes who have their own answers</i></p> <ul style="list-style-type: none"> • Athletes, who do not agree with the coach, have scope for discussion and experimentation. They get a chance to create their own solutions or prove their point. <p><i>Athletes who are intrinsically motivated</i></p> <ul style="list-style-type: none"> • Athletes who do not rely on the coach for motivation. <p><i>Athletes who want to contribute</i></p> <ul style="list-style-type: none"> • Allow the athlete/s to contribute to the direction and answers. Athletes who are experienced and wish to make informed contributions have opportunity. • Athletes who want to feel valued and included. • Athletes who are creative performers or experiential can discuss their needs and desires. 	<p><i>Athletes who need support and answers</i></p> <ul style="list-style-type: none"> • Athletes who are susceptible to distractions can be confused or frustrated when asked to contribute. Sometimes early career professionals, intensely focused, or immature athletes do not benefit from the opportunity to contribute. • Athletes who want an immediate singular answer, and want it from the one source that matters – the coach. <p><i>Athletes who value extrinsic motivation</i></p> <ul style="list-style-type: none"> • Some athletes benefit from being immersed in a motivating and intense environment. They want to grow from the role modelling of others.

Laissez-faire

Laissez-faire is a French term that describes a leadership style where the teacher or coach will ‘let people do as they choose’. In this style of leadership, the teacher or coach’s role is minimised and he/she minimally interferes in athlete or team decisions. The athlete or team will generally learn from their own mistakes. Many coaches would argue that the laissez-faire style of leadership is not leadership at all. This approach is effective with athletes performing at a self-defined standard where the athletes are self-motivated and capable of making their own decisions (Table 5.4).

Table 5.4: *The laissez-faire leadership style – what needs will it, and will it not, meet?*

Class task: *Determining the best style of leadership for audience needs*

In pairs, discuss what style of leadership would generally be best suited to the following examples?

- A talented athlete who lacks motivation and is immature.
- An athlete who is highly experienced and goal focused.
- An experienced/Masters water polo player who is seeking friendship, fun and general participation.
- A squad of Olympic-level gymnasts preparing for team selection trials.
- A six year old playing Auskick football for the first time.

The Laissez-Faire Leadership Style	
Meets the needs of:	Does <u>not</u> meet the needs of:
<p><i>Athletes who want to focus on participation, socialisation and enjoyment</i></p> <ul style="list-style-type: none"> • Casual and relaxed. • Get encouraged. • Be included. <p><i>Athletes who are intrinsically motivated</i></p> <ul style="list-style-type: none"> • Athletes who simply enjoy the physical experience and participate for the inherent pleasure of the activity will enjoy the opportunity to do so without being coached to win. <p><i>Athletes who are experienced or Masters level</i></p> <ul style="list-style-type: none"> • Allows and encourages participation. • Everyone is valued. • Personal effort is valued. 	<p><i>Athletes, who want to learn, improve performance and win.</i></p> <ul style="list-style-type: none"> • Athletes who desire coaching for learning, enhanced performance and an opportunity to compete and win may be frustrated by the lack of direction and common team goal for success. <p><i>Athletes who value extrinsic motivation</i></p> <ul style="list-style-type: none"> • Athletes who seek extrinsic motivation to encourage them may become lost in the casual atmosphere.

Leadership groups in team sport

A recent feature of team sports is the appointment of leadership groups from amongst the players. A high profile example of this is in Australian Rules Football where, in the past, a team had a captain and a vice captain who would be the on and off-field leaders of the team. More recently it is common for an AFL team to have approximately eight players in a 'leadership group' that is headed by the team's captain.

Matthew Pavlich (Figure 5.28), All-Australian Footballer and Captain of the Fremantle Football Club, explained the important role that a leader plays during a game.

“On game day I need to play my role for the team as well as demand the best out of my team mates and be able to change and adapt our game plan in the moment if necessary.”

Matthew Pavlich, All-Australian Footballer and Fremantle Captain.

In this example we can see that one of the advantages of having leadership responsibilities designated to the players is that decisions can be made during a game by the on-field leaders rather than having to wait for the coach to relay information at game-breaks.

Pavlich also explained some of the off-field responsibilities of the leaders within the Fremantle Football Club including:

"...ensuring that all players adhere to team values and behavioural standards, provide input and recommendations into the physical training program with strength and conditioning coaches, input into specific training drills to the coaches if I see necessary, at times discussions and thoughts with selection, facilitation of honest and open feedback between players as well as



Figure 5.28: Matthew Pavlich; part of the Fremantle Football Club 'leadership group' addressing his teammates

to the coaches, player mentoring, crisis management and decision making when necessary...”

Matthew Pavlich, All-Australian Footballer and Fremantle Captain.

These comments by Matthew Pavlich highlight a number of advantages of having players nominated as leaders within a team, rather than all of the leadership being imposed by the coach, these include:

- communication from the athletes to the coaches is enhanced
- empowerment of the athletes to be involved in important decisions
- gives the players a voice so that if they have a problem there is a means by which they can be heard and know that it can make a difference (not be ignored)
- decisions can be made during a game by the on-field leaders rather than having to wait for the coach to relay information at game-breaks.

Key point summary:

- An autocratic leader makes the decisions. Suits athletes who: need support and answers; value extrinsic motivation; and value extrinsic setting of benchmarks and are goal driven.
- A democratic leader consults, asking the group to be a part of any decision-making process. Suits athletes who: have their own answers; are intrinsically motivated; and want to contribute.
- Laissez-faire describes a leadership style where the teacher or coach will 'let people do as they choose'. Suits athletes who: want to focus on participation, socialisation and enjoyment; are intrinsically motivated; and are experienced or Masters level.

Revision questions:

Test yourself on revision questions 18–20 located at the end of this chapter.

Technique Evaluation and Performance Analysis**Text outcomes: *Analysing performance (Unit 4)***

- *Explain the process of using tools such as checklists and video to analyse and reflect on self and others' performance in physical activity e.g. strengths and weaknesses, mental verses physical performance, error correction.*

This chapter has reinforced that feedback concerning performance in physical activities is fundamentally important for the successful acquisition of motor skills. Two common and very important tools that a coach and athlete can utilise to analyse performance are checklists and video. The level of technology available will largely dictate how sophisticated the analysis will be.

In the remainder of this section we will investigate how both checklists and video recordings can be employed for traditional *movement technique evaluation* or for evaluating the tactics of an individual or entire team (*notational analysis*).

Content that follows: *Using checklists, video and notational analysis (Unit 4)***Movement Technique Evaluation**

- *Using checklists and video to analyse:*
 - *strengths and weaknesses*
 - *mental verses physical performance*
 - *errors for correction.*

Notational Analysis

- *Notational analysis for:*
 - *tactical evaluation*
 - *analysis of movement on the field*

Movement technique evaluation

Checklists and video

Checklists are a record of performance in relation to a set of predetermined criteria and clearly communicate to the athlete what the performance expectations are in terms of the criteria and standard of those criteria. Checklists also provide a mechanism for feedback as part of the important ongoing process of performance evaluation and error correction. For examples of checklists see Table 5.5 and Table 5.6.

An observer, who watches your performance, can use a checklist to assess how well you achieved each of the established criteria. As part of a strategy to educate an athlete, a coach can ask their athlete to analyse their own performance

from **video** recordings. It is often an interesting exercise to see whether there is a difference between a coach and an athlete's assessment of the same performance from a video recording. When athletes view themselves performing a motor skill from video replay, they often comment to their coach that: 'I thought I was doing it, but now I understand what you want me to do'.

Video feedback can be useful for performers at all stages of learning. Viewing your own performance on video and analysing performance with a checklist is also an effective way to develop the capacity to correct your own errors. Checklists and video can be specifically used by coaches to:

- supplement visual, verbal and written feedback
- improve the breadth, detail and accuracy of performance analyses
- provide a more objective review
- de-personalise feedback by focusing on the actual movement or performance ensuring that the athlete does not feel like their personality is being attacked.

AFL Kicking Performance Analysis Checklist – Drop Punt		
<i>Phase of Skill</i>	<i>Performance Criteria</i>	<i>Performed Optimally?</i>
<i>Preparation</i>	Align body to target	
	Head over ball	
	Fingers evenly spread	
	Support foot to target	
<i>Back Swing and Ball Release</i>	Guide ball with one hand	
	Knee flexed maximally	
<i>Forward Swing to Impact</i>	Ball hits laces	
	J-kick	
<i>Follow Through</i>	Point toe to target	
	Keep moving towards target	
	Land on kicking foot	

Table 5.5: A checklist designed to be used in the field to assess the drop punt kick in Australian Rules Football

The benefits of using checklists and video to analyse performance is that an athlete can:

- access accurate visual feedback that serves to improve understanding
- be more involved in detecting and correcting their own errors, strengths and weakness
- determine if the strengths and weaknesses were the result of mental or physical performance
- engage in reflective learning by monitoring their own improvements over time and compare their performance to any goals that they have set.

Table 5.6: A checklist designed to be used to assess Taekwondo fighting performance from a video replay

Taekwondo Fighting Performance Analysis Checklist			
<i>Performance Focus</i>	<i>Weakness in Performance</i>	<i>Some Development Needed</i>	<i>Area of Strength</i>
<i>Avoiding Attack</i>	Avoids some of the opponent's attack	Able to avoid and block some of the opponents attack	Able to consistently avoid and block the opponents attack
<i>Balance</i>	Maintains some balance during the performance	Generally maintains balance during the performance	Maintains balance during the performance
<i>Kicking</i>	Performs a variety of basic kicks without stumbling	Performs a variety of advanced kicks without stumbling	Performs a variety of advanced kicks with good and balanced technique
<i>Counter Moves</i>	Some counter moves are attempted	Able to employ some appropriate counter moves	Able to regularly employ the appropriate counter moves
<i>Protection</i>	Attempts to maintain upper body and head protection with some use of high hands	Attempts to maintain upper body and head protection with the use of high hands	Maintains upper body and head protection with the maintenance of high hands
<i>Range (close, moderate and long)</i>	Employs some of the 3 fighting ranges	Employs the 3 fighting ranges	Uses the 3 fighting ranges to advantage with the appropriate punch, kick, step, kick
<i>Motion</i>	Uses some motion	Uses forward and back motion	Uses lateral and forward and back motion
<i>Intensity</i>	Assertive performance	Aggressive and assertive performance	Uses aggressive and assertive performance to advantage

Using checklists and video to analyse strengths and weaknesses

A checklist can be used to highlight both strengths and weaknesses in performance. A good practice for any coach is to ensure that feedback is provided in what is sometimes called a ‘*positive sandwich*’. While the evidence suggests that the best way to improve performance is to provide feedback concerning the errors in performance, it is also important to understand that feedback plays an important role in maintaining the motivation of the athlete or learner. The positive sandwich, therefore, refers to sandwiching the feedback concerning errors between feedback of performance aspects that are well executed. Providing feedback in this manner serves to maintain motivation and also allows focus on correcting aspects that need to be changed.

An excellent means of identifying strengths and weaknesses of your own or someone else’s performance is to make a comparison between your own skill execution and that of an expert. Using technology such as Silicon Coach™ it is relatively simple to examine split screen comparisons of your performance with another performer (Figure 5.30).

A checklist should, therefore, be designed such that the sole purpose is not to highlight errors but to also emphasise positive aspects of performance. One way to achieve this is to have a checklist that reflects the level of performance and the age of the athletes that are being coached. For example, there is little to be gained by assessing the performance of a squad of 8–10 year old swimmers with the same criteria that you would use for a National level squad of 16 year olds. This would potentially only highlight the errors being made.



Figure 5.29: Examples of video-based software that can be used to analyse movement technique



Figure 5.30: Comparison of learner’s and an expert’s technique in Silicon Coach™

Class task: Designing a checklist

Design a checklist for assessing a tennis serve for a group of 8 year old children and another for a high performance 18 year old about to turn professional.

Using checklists and video to analyse mental versus physical performance

An athlete and coach can often become very frustrated when the athlete performs all of their motor skills perfectly at training but fails to replicate that high standard during competition. It is possible that there is little wrong with the physical performance of the athlete but the problem may be related to their mental performance. In skills such as golf putting (Figure 5.31), there can be immense pressure on the performance of a relatively simple and closed motor skill, particularly if there is a title and/or millions of dollars riding on whether performance is successful or not.



Figure 5.31: *Mental performance can significantly influence putting in golf*

Checklists and video analysis that allow performance in training to be compared with performance during competition are important in determining the influence of mental processes. The mental toughness and the resilience of the athlete are two mental performance characteristics that researchers have attempted to assess. Table 5.7 displays the characteristics, along with a

Table 5.7: *Attributes of mental toughness in order of importance (Adapted: Cox, 2007)*

Having an unshakable self-belief to achieve your goals.
Bouncing back from performance setbacks as a result of increased determination to succeed.
Having an unshakable self-belief that you possess unique qualities and abilities that make you better than others.
Possessing an insatiable desire and internalised motive to succeed.
Remaining fully focused on the task in the face of competition-based distractions.
Regaining psychological control following unexpected, uncontrollable events.
Pushing back the boundaries of physical and emotional pain, while still executing skilfully.
Accepting competition anxiety is inevitable and knowing that you can cope with it.
Not being adversely affected by others' good or bad performances.
Thriving on pressure and competition.

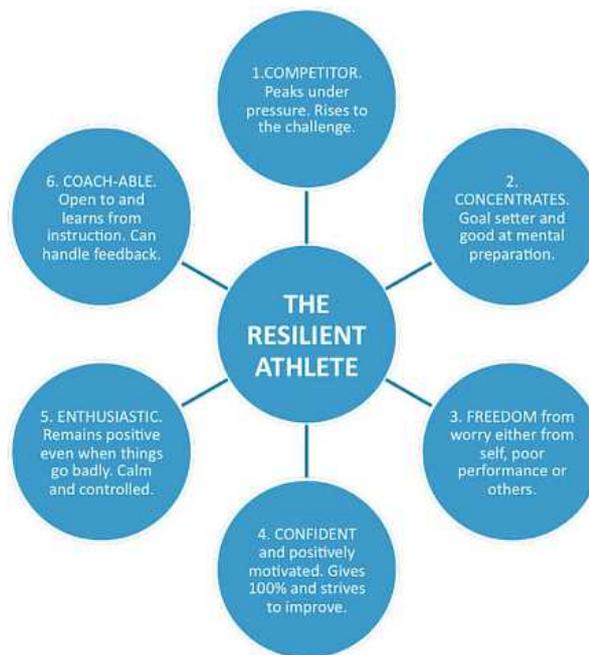


Figure 5.32: The characteristics of a resilient athlete. These characteristics can be used in a checklist to assess mental performance before, during and after a game.

description of each, of the attributes of mental toughness that could be assessed in a checklist to examine mental performance. An athlete can assess their own perception of their mental toughness compared with how the coach views the same attributes. Related to mental toughness is the idea of a resilient athlete who is able to overcome adversities and maintain their performance (see Figure 5.32). Once again, the attributes of the resilient athlete as described by Pengelley, Whipp, and Debowksi (2010) could be included in a checklist to assess mental performance.

Depending on the sport, there may be a number of criteria that a coach may include in a checklist to examine mental performance (including those related to mental toughness and resilience). While the previous section has discussed checklists used primarily for evaluating physical performance, some examples of criteria that could be used to

determine whether skill errors are related to mental performance include those listed below.

- **Concentration:** The same skill is performed with a different technique in different circumstances.
- **Concentration:** Failing to see cues that are important to successful performance.
- **Concentration:** External factors such as crowd noise affect performance.
- **Anxiety:** Inability to concentrate in competition and better performance is recorded in non-competitive situations.
- **Anxiety:** Skill errors occur when under physical pressure.
- **Stress:** Skill errors occur during important times of a game.
- **Self-confidence:** Failure to persist in the face of adversity or failure.
- **Decision Making:** The skill is executed well but the wrong decision is made.

The addition of these criteria to a more traditional motor skill checklist will enable a coach to determine whether or not mental performance is hindering the successful execution of the skill. If mental performance is identified as the problem then a coach may need to consult the expertise of a Sport Psychologist to rectify the problem and adopt some of the appropriate mental skills discussed in this textbook.

As stated previously, watching video replays of performance can allow the player to assess some of the suggested criteria relating to mental rather than physical performance. When a coach and athlete sit down together to watch a video of training or competition-related performance, it also allows the coach to ask questions of the player such as:

- ‘what were you intending to achieve with that pass?’
- ‘did you feel anxious or nervous when you were executing that skill?’
- ‘why do you think you made a mistake there?’

The information gathered from watching the video together and asking similar questions may provide more useful information than that obtained from just a checklist.

Using checklists and video for error correction

An important aspect of correcting errors in the performance of learners or elite level performers is obtaining feedback. In an earlier section ‘movement analysis for identifying errors’ it was stated that obtaining feedback about errors in motor skills is the best way to improve performance. Checklists serve to provide a record of the errors in performance that both a coach and an athlete can utilise.

Because a checklist is a record of performance relative to a list of criteria, regular assessments will provide a record of changes (hopefully positive changes) that have taken place over

time. If, for example, there is one criterion of performance that is not being achieved (an error), the checklist will give the coach information that can then be used to direct their feedback, develop training activities and instructions. Furthermore, the coach can also use the checklist to assess whether the feedback and training that they are providing actually results in any improvements.

An excellent means of correcting errors is to make a comparison between your skill execution prior to a coach’s feedback and with your technique after the feedback. Video-based technology such as Silicon Coach™ has made it quick and easy to make comparisons within a practice session that can highlight whether an error has been corrected. Overlaid images of a performer before and after feedback from a coach during the one session is a powerful visual aid that allows the performer to view any changes they have made (see Figure 5.33). Also, the split screen comparison of your performance with that of an expert provides a visual aid for correcting movement technique.



Figure 5.33: *Overlaid comparison of a performer’s movement technique before and after feedback from a coach using Silicon Coach™*

While video feedback is an excellent example of non-verbal feedback, it is important to note that the best error correction occurs when the viewing of the video is accompanied by verbal extrinsic (augmented) feedback, as the teacher or coach directs the learner's attention to

important characteristics of the performance. Higher level performers who have reached the autonomous stage of learning should be able to analyse their own performance from video with a checklist.

Key point summary:

- Checklists and video provide a mechanism for feedback as part of the important ongoing process of performance evaluation and error correction.
- Checklists are a record of performance in relation to a set of predetermined criteria.
- Coaches use checklists and video to:
 - supplement visual, verbal and written feedback
 - improve the quality of performance analyses
 - provide a more objective review
 - de-personalise feedback.
- Athletes use checklists and video to:
 - improve understanding
 - be more involved in correcting their own performance
 - determine the impact of mental or physical performance
 - engage in reflective learning.
- To maintain motivation, feedback should be provided as a positive sandwich (positive feedback – corrective feedback – positive feedback).
- The performance impact of mental functioning can be assessed by comparisons with performance successes and errors, quality and consistency recorded in checklists and by video from training and past performances. Also, athletes can undertake self-reflection using checklists and video, or use the checklists and video to evaluate performance through discussion with the coach.
- Obtaining feedback about errors in motor skill is the best way to improve performance.

Revision questions:

Test yourself on revision question 21a, b, c and d located at the end of this chapter.

Performance and Notational Analysis

A *notational analysis* is an objective way of recording performance so that key elements of that performance can be quantified in a valid and consistent manner (Hughes 2005). Notational analysis is a relatively new method of analysing performance that assesses how individuals and teams (as a whole) perform. In the previous section, we discussed the use of checklists and video to analyse movement technique; however, checklists and video can also be used to analyse the tactics and strategies employed by teams and individuals.

During notational analysis, play within a match is analysed by annotating (keeping records or statistics) players for tactics and techniques. The focus is on collecting information concerning how a player moves around the field/court/oval, the skills performed, and the success or failure of the skills performed in team and individual sports. Patterns of play which lead and did not lead to scoring against specific opponents can then be identified and exploited in subsequent matches. A ‘game analysis’ or ‘notational analysis’ can be performed live or from video and utilises a checklist of criteria that can be used to analyse the performance of an individual, a team or a number of teams.

Notational analysis has become common because of our limited ability to process information during the game and the limitations of our memory. Coaches are aware of the importance of providing accurate feedback to their athletes; however, human memory is limited so that it is almost impossible to remember all of the events that take place within a game or match. For example, high performance junior tennis players (U12–U16 years of age) are only able to accurately recall, on average, 48% of serve and return of serve patterns of play in the immediate time after a

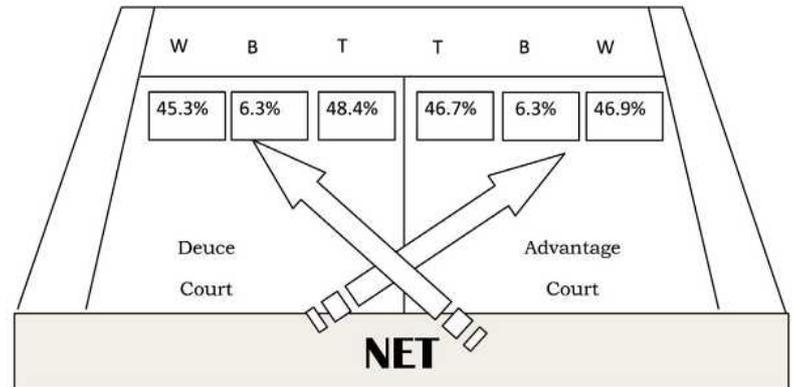


Figure 5.34: Notational analyses of first serve locations for men at the Australian Open (2008). Note: All numbers are percentages. W= Wide, B= Body, T= T of the service box. A coach can provide this information to a tennis player to help them with their return of serve. (Source: Hizan, Whipp & Reid 2010b)

match (Hizan, Whipp & Reid 2010a). Franks and Miller (1986) showed that soccer coaches are less than 45% accurate in their post-game assessment of what occurred during a game. Furthermore, coaches’ observations are biased by their own motives and beliefs and as a result they selectively remember aspects of a performance they have just observed. This highlights the need for objective methods of performance analysis that are not subject to memory limitation or personal bias.

An example of notational analysis of the first serve in tennis is provided in Figure 5.34. A tennis coach may want to know where the first serve is most likely to be directed so that they can inform their player where the best position to receive the serve is and how to prepare for the return in an optimal manner. Information can be specific to a single opponent, a group of players or a whole tournament. Importantly, this analysis is not going to be limited by the coach’s memory or biases.

Notational analysis can be used to analyse and reflect on a number of aspects of performance, including:

- analysis of success or failure of skills performed
- tactical evaluation and patterns of play
- player movements on the field.

Analysis of success or failure of skill execution

A notational analysis is more than just a checklist. Relatively new computer software has allowed notational analysis to be used quickly and efficiently and combined with video analysis in many sports. For example, SportsCode™ can be used to notate all of the required game actions such as effective kicks, effective handballs, tackles etc. that you may want to record for Australian Football. In addition, if this notation is combined with a video feed of the game when the notational analyst records a kick, it records not only the kick but links this to the video 5 seconds before the skill is performed and 5 seconds after. Shortly after a game, a coach can then easily review all of the kicks that a particular individual performed by just looking at these 10 second video snapshots. Players can also use the snapshots to efficiently review every direct involvement they had in a game.

Most notational analysis criteria that a coach will want to know during and after a game will take into account the success or failure of each skill executed. For example, in AFL a kick can be notated under a number of headings including: effective long kick, ineffective long kick, effective short kick, ineffective short kick, kick inside the forward 50 m. By notating the success or failure and description of the type of kick (long or short) a coach can start to examine the impact that a player is having on the game with their possessions rather than simply the number of possessions.

In addition, notational analyses are used to assess KPI's (key performance indicators)

for successful/unsuccessful performance and fatigue-related criterion. Coaches of elite athletes and teams, particularly AFL teams in Western Australia, can be regularly seen accessing and evaluating such criterion. An example of the notational analysis output from an Australian Rules Football game is shown in Figure 5.35.

Tactical evaluation

Conventional statistics recorded during any sport can inform you how many kicks, passes or goals have been scored during a game. This information provides very little concerning how a team or individual has played the game and will not assist the coach to organise training to reduce performance errors. Most coaches are interested in not only how many goals were scored but how the goals were scored. That is, a coach will want more detailed tactical information about the way their team played and probably about the tactics of the team that they are playing next week to help prepare.

An example of how notational analysis can be used for tactical evaluation comes from soccer where the pattern of play that led to a goal being scored can be recorded. Every time a team moves the ball into an attacking formation and creates a scoring opportunity (regardless of whether they actually score the goal) the pattern of ball and player movement can be recorded. If a team has a particular strength such as a tall striker that often scores goals by heading the ball through the goal, then a preferred method of scoring goals may be found via a notational analysis. For example, the majority of the teams scoring chances or shots on goal may come from passes wide on the right of the field to the middle of the penalty box where the strikers can then score.

Game Action	Weighting
Goal assist	+4
Hit out 2 adv	+0.5
Hit out sharked	-0.5
Kick long advantage	+2.5
Kick short advantage	+1.5
Kick long clanger	-1.5
Kick short clanger	-2.5
Bounces	+1
Handball clanger	-1
Dropped mark	-1.5
Dispossessed	-0.5
50m penalty=shot	-6
Infringement = Goal disallowed	-6
Chase	+1
Tackles effective	+1
Spoils	+1
Goals	+6
Behinds	-1
Free Against	-2
Hard Ball Get	+4
Loose Ball Get	+1
Kick ineffective	-1
Handball ineffective	-0.5
Smothers	+1
Shepherds	+1
Contested marks	+3
50m penalty	-2
50m penalty	+1.5
Kick Short	+1.5
Uncontested marks	+0.5
Handballs effective	+1

Figure 5.35: Notational analysis from an Australian Rules Football match

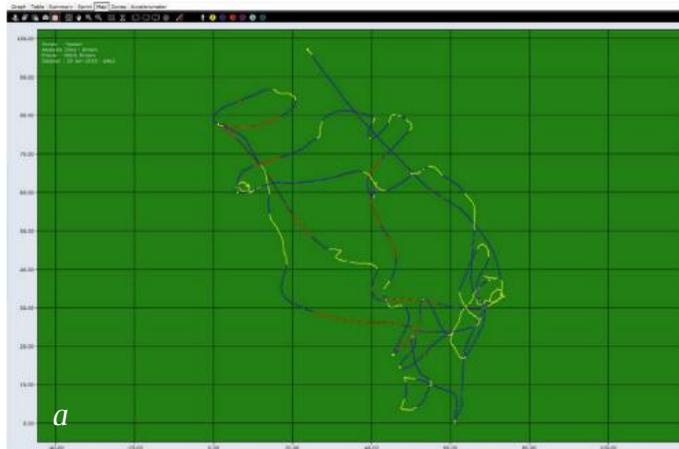


Figure 5.36: Global Positioning System (GPS) data from an AFL footballer (a) and a player wearing a GPS unit and heart rate monitor (b). The different colour lines represent different movement speeds of the player; from walking slowly to sprinting.

UWA research snapshot: *Performance analysis in Rugby Super 14s (Lim et.al., 2009)*

Researchers within Motor Learning and Exercise Physiology at the School of Sport Science, Exercise and Health at The University of Western Australia have been interested in using notational analysis data to objectively rate a player's impact on team performance in a range of sports. One such example came from Super 14 Rugby Union where the frequency of game actions are notated and assigned positive and negative weightings that reflect their importance to winning. By adding together the impact of all of the game actions and their relative importance, the notational analysis system was shown to be highly predictive of winning performance. This research was published in the International Journal of Performance Analysis in Sport.

Analysis of player movement on the field

It is important to note that, in the context of notational analysis, the analysis of movement is concerned with how a player, or players, move around the field, oval and court during a game or match. Initially, the tracking of player movements and measurements during a game were recorded by hand; however, modern tracking technology has taken much of the chore out of gathering movement data. Most elite sporting teams, in particular all of the football codes, use tracking systems such as Global Positioning Systems (GPS) to track how far and how fast players are moving throughout a game. The movement data can then be immediately (real time) represented for coaches. An example of this data can be seen in Figure 5.36a where the

GPS data from an Australian Rules footballer is displayed with different coloured lines representing different speeds that the footballer is travelling.

Key point summary:

- Observations made by coaches during the game are limited to what they see and remember. They can be biased by their own motives and beliefs.
- A notational analysis of performance using checklists, live observation and video is an analysis of data for players:
 - success or failure of skills performed
 - tactical evaluation and patterns of play
 - player movements on the field.

Revision questions:

Test yourself on revision question 22 located at the end of this chapter.

Analysis of Learning for Improved Performance

Text outcomes: *Analyse learning and skill development (Unit 4)*

- *Analyse learning and skill development in relation to correction and improvement of self and others e.g. use video analysis, reflective journals, peer/mentor/coach feedback, and questionnaire.*

Thus far we have spoken about analysing performance, in this section we are going to consider how to analyse learning.

Performance is an observable behaviour (for example, a skill performed) at a specific time and location; whereas, **learning** is the change in the capability to perform a skill (usually an improvement) that is derived from a relatively permanent improvement in performance as a result of practice or experience. The key point is that motor learning involves a semi-permanent retention of the capacity to perform a motor skill rather than a one-off performance that could be a stroke of luck or not repeatable.

Therefore, when we analyse learning and skill development we should focus on assessing a number of performances over a period of time, rather than one or two performances on the same day.

One way to analyse learning is to apply all of the methods that we have considered already such as checklists and video analysis and simply repeat the process over a period of time to measure how a skill has developed. During this section we are going to consider a

reflective learning process where the learner is not simply a passive receiver of information but rather, is actively involved in gaining and examining feedback and other information to improve performance and ultimately retention of that performance; learning.

The motion analysis model that was introduced in the Biomechanics section and also presented in Figure 5.13 of this chapter is primarily designed to be used by a coach or an expert in movement analysis. In this section we are going to more specifically focus on the athlete or learner's role in reflecting on their own performance to increase motor learning.

Athletes who have attained performance of a motor skill consistent with an autonomous (or final) phase of learning (Fitts & Posner 1967) have the capacity to self-correct and analyse their own performance. While it is important for a coach to provide feedback to an athlete, it is also essential that as the athlete increases their understanding of the skills required to perform at a high level, they take more responsibility for their own training methods, important tactical decisions and also assessing their own performance. This process of self-responsibility for learning can take place not only at training, but also during a game or competition as it is unfolding and post-performance. In sports such as tennis and many team sports there may be little or no instruction or augmented feedback during a performance and, it is important that an athlete can take responsibility for making decisions. Figure 5.37 outlines the learning process model whereby after performing the motor skill, the athlete should reflect on their performance, recognise the correct and incorrect aspects of that performance, plan a strategy to overcome any problems and then repeat the cycle.

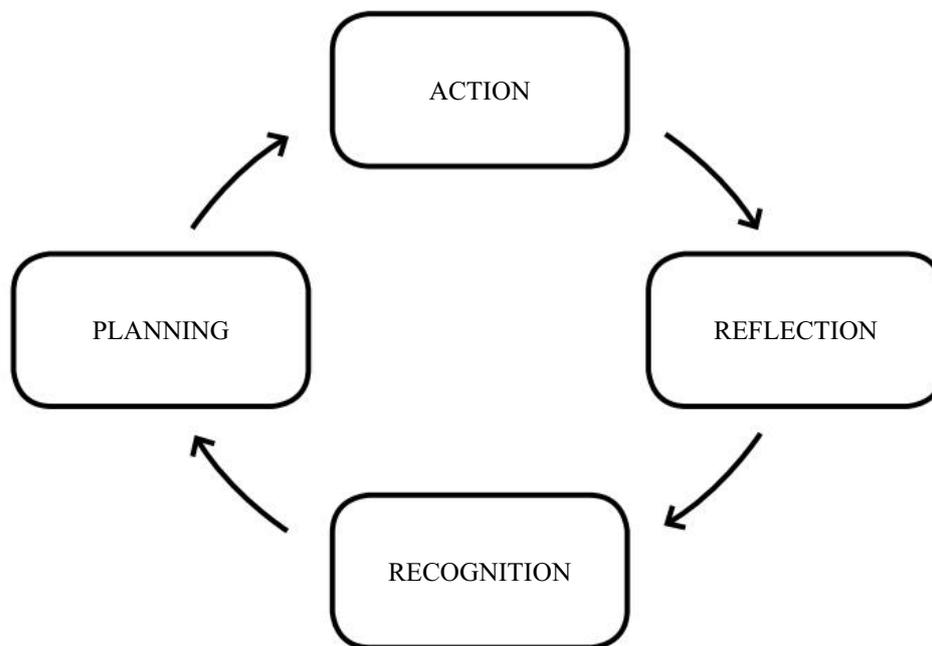


Figure 5.37: A learning process model to involve athletes in self-instruction and self-responsibility as a part of reflective learning

Content that follows: *Reflective learning (Unit 4)*

- *Reflective learning*
- *Methods of reflection:*
 - *video analysis*
 - *reflective journals*
 - *peer/mentor/coach feedback*
 - *questionnaires.*

Reflective learning

Reflective learning within a sporting environment involves making comparisons between the goals that have been set previously and what is actually occurring, planning for improvement and also monitoring any improvement.

A reflective learner will reflect on:

- What and how they are learning – including any aspect of the skill that they do not understand.
- Strengths and challenges – reflecting on the strengths can help to maintain motivation and enthusiasm, while examining the challenges or weaknesses will aid skill development.
- How to improve – reflecting on strategies in the short-term and training interventions in the long-term that will improve learning and skill development.
- Working towards goals – reflecting on how close performance is to any pre-established goals and re-setting goals as appropriate.

Methods of reflection

There are a number of methods of reflection that an athlete can use to analyse their own or someone else's learning and skill development.

Video analysis

Previously we examined how video analysis is used to analyse performance. When used frequently throughout practice and performance, video is invaluable in assessing learning and skill development. As one method of reflecting on learning, video analysis provides the following opportunities for reflection:

- visual feedback of your own performance in comparison to others and an expert
- visual feedback of current performance against previous performances to monitor progress
- allows self-evaluation and correction.

Video analysis at high-levels of performance is often performed with the aid of biomechanical or notational analysis software. Both the West Coast Eagles and the Fremantle Dockers football clubs utilise SportsCode™ software to analyse player performance on video from games and Silicon Coach™ for technique evaluation.

Reflective journal

A reflective journal allows an athlete to record aspects of the reflective learning process. The advantage of a written record is that at any time an athlete can look back on previous journal entries to assist the reflection process. Matthew Pavlich utilises a "...notebook of thoughts about performance during a game, how skills were executed during the game and training and also psychological aspects of performance..." as part of his process of analysing his own learning and skill development.

A reflective journal should include the following:

- documentation of progress in relation to strengths and deficiencies; which may relate to physical fitness, technical skill execution or strategies and tactics employed
- information for long-term monitoring
- athlete's or coach's suggestions about how to improve.

Peer/mentor/coach feedback

Critical feedback that is provided by a knowledgeable and trusted source such as a coach or a mentor is valuable for learning and skill development. Reflecting on and discussing performances with a coach or mentor is an important process to gain an understanding of how to improve. As part of his role as a leader within the Fremantle Football Club, Matthew Pavlich (Figure 5.38) watches the performances of players' that he mentors, so that he can provide advice to the new and developing players within the team. Young players often find it easier to trust and to seek advice from a fellow player rather than a coach. More experienced players are usually more comfortable seeking the critical feedback from the coaching staff.



Figure 5.38: Matthew Pavlich mentors teammates with feedback about their performance

Questionnaires

Questionnaires have recently been used by elite sporting teams to evaluate more than just mental and physical performance skills. Indeed, the ability for coaches and players to display quality leadership skills has realised the use of specific questionnaires. When answered by the individual coach/player concerned and the players they interact with, they provide a valuable insight into the leadership qualities they display and their impact on others.

One of the authors of this Chapter, and colleagues from The University of Western Australia (Pengelley, Whipp & Debowski 2010), have worked with a high-profile

sporting team to enhance the leadership skills and mentoring outcomes of all players. This program is not only informed by the results of questionnaires, but the questionnaires serve to identify the individual's psychosocial skills (such as resilience, decision making and emotional intelligence) and target behaviours that impact positively and negatively on other team members. Examples of some of the questions used are included in Table 5.8. Leadership players are then better placed to enhance understanding of their own personal skills and interpersonal capacities, group cohesion, and quality leadership and mentoring behaviours.

Table 5.8: Examples of questions used to evaluate and improve player's leadership skills

The next group of questions focus again on confidence, but this time they relate to your confidence as a leader at this point in time right now.					
1. No confidence at all, 2. Low confidence, 3. Moderate confidence, 4. High confidence, 5. Complete confidence					
So, how confident are you in your leadership ability right now that you can...					
<i>use your voice to set the tone of the group</i>	1	2	3	4	5
<i>hold the focus on a topic, an activity, or a person</i>	1	2	3	4	5
<i>impart information</i>	1	2	3	4	5
<i>draw out quiet team members</i>	1	2	3	4	5
<i>encourage expression of differences</i>	1	2	3	4	5
<i>provide coping strategies to members of your team members</i>	1	2	3	4	5
<i>give positive feedback</i>	1	2	3	4	5
<i>give corrective feedback</i>	1	2	3	4	5
<i>engage in appropriate self-disclosure</i>	1	2	3	4	5
<i>provide clear directions to the group</i>	1	2	3	4	5
<i>provide an atmosphere of support and care</i>	1	2	3	4	5
<i>help the team set productive norms</i>	1	2	3	4	5
<i>respond constructively when team members challenge your personal values</i>	1	2	3	4	5
<i>respond constructively to an attack from a player in your team</i>	1	2	3	4	5
<i>respond to a deep disclosure by a team member</i>	1	2	3	4	5
<i>help your team members process the meaning of the coach's instructions</i>	1	2	3	4	5
<i>help your team members integrate and apply the coaching principles</i>	1	2	3	4	5
<i>apply ethical and professional standards in team work</i>	1	2	3	4	5
<i>help your team players to relate effectively to others of different gender, race, age at all times</i>	1	2	3	4	5
<i>inspire your team players to meet team goals</i>	1	2	3	4	5

Key point summary:

- Learning is the change in the capability to perform a skill that is derived from a relatively permanent improvement in performance as a result of practice or experience.
- Performance is an observable behaviour at a specific time and location.
- To analyse learning and skill development focus on assessing a number of performances over a period of time.
- Reflective learning sees the athlete actively involved in gaining and examining feedback to improve performance. They make comparisons between the goals that have been set previously and what is actually occurring, planning for improvement and also monitoring improvement, by considering:
 - what and how they are learning
 - strengths and challenges
 - how to improve
 - working towards goals.
- The learning process model: Action, Reflection, Recognition and Planning encourages the athlete to engage in self-reflective learning.
- Methods to support self-reflective learning include video analysis, reflective journals, peer/mentor/coach feedback, and questionnaires.

Practical investigation

'Ultimate' game performance analysis of self and others

See Appendix B2 for a practical investigation, along with questions and report-writing format recommendations.

Revision questions:

Test yourself on revision questions 23–26 located at the end of this chapter.

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Appendix A: Writing the practical investigation report

Writing the report

If you are required to write a report as part of your practical investigation, you may choose to use the following format.

Title: Title of the practical investigation.

Aim: State what you hope to achieve in the experiments (~30–50 words).

Introduction: Define and discuss the sport science principles being investigated (~200 words).

Hypotheses: Identify the expected results or anticipated outcomes (*statements*).

Method: Identify the steps taken to complete the experiments (~100 words).

Results: Present the data and findings in the appropriate format (*for example, graphs, diagrams and tables*).

Response to the questions: Write the questions out and respond.

Discussion: Provide a detailed discussion of the results. Apply the sport science principles under investigation to other sporting contexts (~400 words).

Conclusion: Summarise the discoveries made. Make links to each hypothesis and include limitations of the experiment (~100 words).

Appendix B1

Practical Investigation and Report: Motor Learning and Coaching Transfer of learning

Weighting: Unit 3

Type: Investigation

Content:

To evaluate the effects of transfer of learning and its application to selected activities and sports.

Total marks = /30

Task outline

When completing the experiment outlined below you are to record, describe and evaluate

the effects of ‘skill-to-skill’ and ‘theory-to-practice’ transfer of learning.

Experiment: Task one

AFL kicking activity

Condition A: Pre-intervention – AFL kicking

- In groups of three, each participant will be required to kick an AFL football on three separate occasions with the non-preferred foot. The participant must use a run-up (not a standing kick) and attempt to kick for maximum distance.
- The two partners observe the kicking action and use the AFL Kicking Evaluation Rubric presented below to determine one agreed score for the kicking performance (Table 5.9).
- Measure the distance the ball travels in the air for the longest kick achieved in three attempts, from the point of kicking to the point of landing on the ground.

Table 5.9: AFL kicking evaluation rubric

Action	AFL Kicking Evaluation Rubric – Points Scoring			Pre-intervention points scored	Post-intervention points scored
	1 point	2 points	4 points		
Run-up	Motion is running (not walking or standing).	Fluent running.	Fluent running. Accelerates toward target.		
Ball release	Evidence of controlled release.	Controlled release of the ball with one hand (same hand as kicking foot) guiding the ball.	Controlled release of the ball with one hand (same hand as kicking foot) guiding the ball. Drops the ball in an appropriate position relative to the kicking foot.		
Impact	Makes solid contact with the ball.	Makes solid contact with the ball whilst remaining balanced.	Makes solid contact with the ball whilst remaining balanced. Accelerated leg extension.		
Pre-intervention - Total points					
Post-intervention - Total points					
Pre-intervention - Distance the best kick travelled					
Post-intervention - Distance the best kick travelled					

Condition B: Intervention – transfer of learning task

- In groups of three, each participant will be required to practice kicking a soccer ball that is in a stationary position on the ground, using the non-preferred foot. The participant must use a run-up (not a standing kick) and attempt to kick for maximum distance.
- Practice consistently for a period of 5 minutes.
- The participant is required to engage in skill-based self-reflection and evaluation with the goal of improving kicking performance. Partners are required to provide skill-related evaluation and feedback to the kicker. Both the kicker and the partners are encouraged to use the AFL kicking evaluation rubric (Run-up and Impact) to assist with the focus of feedback.

Condition C: Post-intervention – AFL kicking

- Repeat all of the requirements of ‘Condition A: Pre-intervention – AFL kicking’ and record data using the AFL Kicking Evaluation Rubric (Table 5.9).

Chop sticks activity

Condition D: Pre-intervention – chop sticks

NB: All participants must undertake the following tasks with their non-preferred hand.

- In groups of three, each participant will be required to use chop sticks, in their non-preferred hand, to pick-up a raspberry lolly in the ends of the sticks (not balancing on top of the sticks).
- Only one smooth action is permitted. Failure to execute in one smooth action means that you must move to the next lolly.
- Having collected a lolly from one circle,

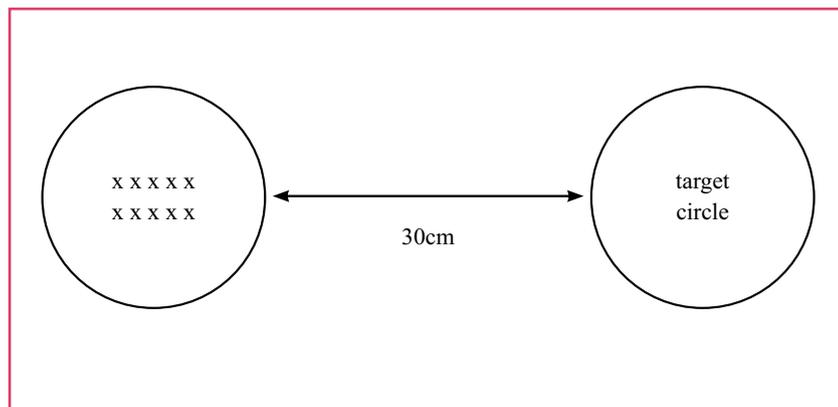


Figure 5.39: Ten raspberry lollies and the target circle

the participant must, without dropping it, place it in the target circle (Figure 5.39).

- Continue until the participant has moved (or made one smooth attempt to move) all ten lollies.
- Record the number of lollies that have been successfully placed in the target circle for each participant.

Condition E: Intervention – transfer of learning tasks

NB: Each member of the group (three per group) must undertake only one of the prescribed interventions. That is, each member of the group must undertake a different intervention.

- Intervention i: The participant is to engage in non-related casual play for a period of 5 minutes – for example, shooting a basketball at a hoop.
- Intervention ii: The participant is to collect three large paper-clips. One at a time, using only one hand (the same hand that you use the chop sticks in) try and unravel the paper clip into one long line. After successfully unravelling one

paper clip, undertake a rest and stretch your fingers and hands for a period of 30 seconds, before trying to unravel the second and third paper clip, or until 5 minutes has elapsed.

- iii. Intervention iii: The participant is to read the following instructions – ‘How to use chop sticks’ Figure 5.40. Note, the participant is not allowed to physically practice with chop sticks, just read and look at the diagrams. Continue this task for 5 minutes.

Condition F: Post-intervention – chop sticks

- After 5 minutes of intervention activity, all three participants are to repeat all of the requirements of ‘Condition D: Pre-intervention – chop sticks’ and record the number of successful transfer of lollies into the target circle for each participant (Figure 5.40).

Questions: Task one

In presenting your findings to Task one: Condition A, B, C, D, E, and F respond to the following:

- Describe and account for any differences between performance in Condition A (Pre-intervention – AFL kicking) when compared with Condition C (Post-intervention – AFL kicking), discuss how undertaking Condition B (kicking a soccer ball) may have impacted on the post-intervention performance (2 marks).
- Describe and account for any differences between performance in Condition D (Pre-intervention – chop sticks) when compared with Condition F (Post-intervention – chop sticks), discuss how undertaking the three different intervention tasks in

Condition E (i. non-related casual play; ii. unravelling a paper clip, and iii. Reading instructions on how to use chop sticks) may have impacted on the post-intervention performance (6 marks).

Questions: Task two

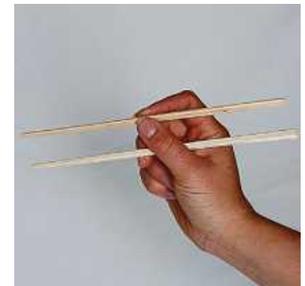
- Research, identify and review an athlete of your choice (it could be you or someone more famous!) who exemplifies a skill-to-skill positive transfer of learning. Explain how the athlete may have benefited from previous learning to achieve successful performance (3 marks).
- Discuss in detail, using a sporting example, the transfer of learning for the situation: Training to competition. Include a review of the important qualities that training must provide to facilitate a successful transfer (4 marks).

Equipment:

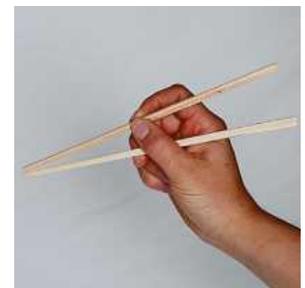
- AFL footballs.
- Soccer balls.
- Tape measure (approximately 50 metres).
- Pairs of chop sticks.
- Raspberry lollies.
- Paper with circles drawn on.
- AFL scoring rubric.
- Large paper clips.
- Area and equipment for non-related casual play.
- Pen.
- Markers.
- Chop sticks instructions



Hold the chop stick between your thumb and middle finger. The chopstick should not touch the forefinger.



Place the other chop stick between your thumb and forefinger. The side of the chopstick should rest against the tip of your thumb



Move only the second (top) chop stick.

Figure 5.40: How to use chop sticks

Task: Transfer of learning: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to the effects of transfer of learning (skill-to-skill and theory-to-practice) to enhance learning and performance.	1 mark
Provides clear statements of the expected results or anticipated outcomes in relation to the effects of positive and neutral transfer of learning (skill-to-skill and theory-to-practice) to enhance learning and performance.	2 marks
Introduction (3 marks)	
Identifies and defines the aspects associated with transfer of learning and how it can/cannot enhance learning and performance.	1 mark
Shows an understanding of positive, negative and neutral transfer of learning (skill-to-skill, theory-to-practice, and training to competition) and how transfer of learning can/cannot enhance learning and performance.	2 marks
Shows a comprehensive understanding of positive, negative and neutral transfer of learning (skill-to-skill, theory-to-practice, and training to competition) and how transfer of learning can/cannot enhance learning and performance.	3 marks
Results (2 marks)	
Satisfactory presentation of data.	1 mark
Accurate and relevant presentation of data.	2 marks
Response to Questions (15 marks)	
<i>Task one: Question a: 2 marks, Question b: 6 marks (8 marks).</i>	
<i>Task two: Question a: 3 marks, Question b: 4 marks (7 marks).</i>	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	1 mark
Limited discussion of the results found and few links made to the variables associated with the transfer of learning and its impact on performance.	2 marks
Uses other sporting contexts to discuss the results found and identifies skilled performance. Discusses other sporting examples in relation to positive, negative and neutral transfer of learning and how transfer of learning can impact on learning and performance.	3 marks
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with positive, negative and neutral transfer of learning (skill-to-skill, theory-to-practice, and training to competition) and how transfer of learning can/cannot enhance learning and performance.	4 marks
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the characteristics of positive, negative and neutral transfer of learning (skill-to-skill, theory-to-practice, and training to competition) and how transfer of learning can/cannot enhance learning and performance.	5 marks
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the characteristics of positive, negative and neutral transfer of learning (skill-to-skill, theory-to-practice, and training to competition) and how transfer of learning can/cannot enhance learning and performance.	6 marks
Conclusion (2 marks)	
Summarises some of the factors associated with transfer of learning in relation to learning and performance and the hypotheses.	1 mark
Fully summarises the impact of the factors affecting transfer of learning in relation to learning and performance and the hypotheses. Limitations discussed.	2 marks
Comment:	Total
	/30

Appendix B2

Practical Investigation and Report: Motor Learning and Coaching

'Ultimate' game performance analysis of self and others

Weighting: Unit 4

Type: Investigation

Content:

- Design a game notational analysis system.
- Collect notational performance data from an actual performance.
- Analyse performance using the notational data collected, reflecting on skill and strategically-related strengths and weaknesses of performance.
- Create training activities that are designed to improve performance of self and others.

Total marks = /30

Task outline

When completing the experiment outlined below you are to determine the important performance elements of Ultimate, create a game notational analysis system to describe and evaluate performance and create a skill and/or strategy-based intervention that would potentially address your own and others weaknesses and improve performance. Three games of 10 minutes duration will be played.

The first game is to experience and determine the requirements of the game of Ultimate, permitting a notational analysis system for data to be collected on 'skill execution' and 'strategical performance'.

The second game, is to be played with the participant using their non-preferred hand to throw and catch and will allow 'skill execution' data to be collected. The use of the non-preferred hand will potentially permit greater errors in performance to be observed and therefore create more detailed discussion opportunities.

The third game, is to be played with the participant using their preferred hand to throw and catch and will allow 'strategical performance' data to be collected. The use of the preferred hand will potentially permit participants to focus on strategical performance, rather than skill execution.

Experiment: Task one

Condition A: Experiencing the game of Ultimate (using the preferred hand to throw and catch the Disc)

- Using the instructions 'Introduction to Ultimate', develop an understanding of the rules and demands of playing a game of Ultimate.
- Determine four teams of equal number and ability. Identify them as Team 1, 2, 3 and 4.
- Play games of 10 minutes duration where Team 1 is to play Team 2; and, Team 3 is to play Team 4. Experience and evaluate

the successful performance requirements of playing a competitive game of Ultimate.

- Option: Consider a video recording of the game for the purposes of supplementing post-performance analysis.

Condition B: Creating a ‘Notational Analysis System’ for the game of Ultimate

- At the conclusion of the game, each player is to use their game experiences to create a ‘notational game analysis system’ that allows game-based data to be collected, that reflects the demands of the game and quality of performance. Ensure that all of the criterion that you create can be accurately defined, observed and have data recorded during a game of Ultimate. Your notational analysis could include, but may not be limited to, the following:
 - i. Skill execution (number of times, relative success and quality of execution during performance):
 - a. Throwing (recording number of throws made; and consider accuracy of throw, length of throw, type of throw, action evaluation – including preparation phase, delivery phase and follow through along with biomechanical qualities such as velocity development and balance).
 - b. Catching (recording number of catches made and the field position in which they were received; and consider success of catch, type of catch, action evaluation – including preparation phase, and contact/absorption phase along with biomechanical qualities such as force absorption and balance).
 - ii. Strategical performance (number of times and relative success of execution

during performance):

- a. Offensive contribution (number of offensive uncontested and contested possessions, the number of times when their team is in possession a player makes space, number of offensive scoring assists and number of successful or unsuccessful scoring efforts etc).
- b. Defensive contribution (number of defensive contested actions, number of successful or unsuccessful intercepts, number of defensive contested possessions, and number of times successfully or unsuccessfully defended scoring efforts etc).

Condition C: Part 1 – Notational analysis collection of ‘*skill execution*’ whilst playing the game of Ultimate (10 minute game – using the non-preferred hand to throw and catch the Disc)

- Determine player-performance observation buddy’s by the pairing of players from different teams using the following instructions. Players from Team 1, will be paired with a player from Team 3. Players from Team 2, are to be paired with a player from Team 4. All players must have an observation buddy.
- Whilst working in the allocated pair, each participant is to explain and discuss their ‘*skill execution*’ component of the notational analysis system, identifying the criterion that will be used to assess ‘*skill execution*’ during the game.
- Play games of 10 minutes duration where all participants are to use only their non-preferred hand to throw and catch. Team 1 is to play Team 2, Team 3 and Team 4 are to undertake a ‘*skill execution*’ analysis on their buddy; then Team 3 is to play

Team 4 whilst Team 1 and 2 members are to undertake a '*skill execution*' notational analysis on their buddy.

- Participants are to use the notational analysis system that they designed to collect performance data on their buddy.
- Option: Consider a video recording of the game for the purposes of supplementing post-performance analysis.

Condition C: Part 2 – Notational analysis collection of '*Strategical performance*' whilst playing the game of Ultimate (10 minute game – using the preferred hand to throw and catch the Disc)

- Determine player-performance observation buddy's by the pairing of players from different teams using the following instructions. Players from Team 1 will be paired with a player from Team 3. Players from Team 2 are to be paired with a player from Team 4. All players must have an observation buddy.
- Whilst working in the allocated pair, each participant is to explain and discuss their '*Strategical performance*' component of the notational analysis system, identifying the criterion that will be used to assess '*Strategical performance*' during the game.
- Play games of 10 minutes duration where Team 1 is to play Team 2 whilst Team 3 and Team 4 are to undertake a '*Strategical performance*' analysis on their buddy; then, Team 3 is to play Team 4 whilst Team 1 and 2 members are to undertake a '*Strategical performance*' notational analysis on their buddy.
- Participants are to use the notational analysis system that they designed to collect performance data on their buddy.
- Option: Consider a video recording of the

game for the purposes of supplementing post-performance analysis.

Condition D: Collect a copy of your buddy's notational analysis data

- Option: If video recordings were made, supplement the analysis where appropriate and ensure that the notational analysis is accurate.
- Ensure that each pair has a copy of the notational analysis undertaken by their buddy on them, and one they did on their buddy.

Questions: Task one

In presenting your findings to Task one, Condition A, B, C, and D respond to the following:

- Discuss the effectiveness and critically analyse, with suggestions for improvement, the notational analysis that you designed (2 marks).
- Using the data collected by your buddy as evidence, evaluate your own game-performance strengths and weaknesses (3 marks).
- Using the data collected by you as evidence, evaluate your buddy's game-performance strengths and weaknesses (3 marks).
- For one of the above listed weaknesses identified for your performance, using 'Motor Learning and Coaching principles', describe and justify a training-based intervention to improve that specific element of performance (2 marks).
- For one of the above listed weaknesses identified for the performance of your buddy, using 'Motor Learning and Coaching principles', describe and justify a training-based intervention to improve that specific element of performance (2 marks).

Questions: Task two

- a. Discuss the tools and processes that would be used to analyse and reflect on performance in a sport of your choice to explicitly evaluate the contribution of the 'mental or psychological aspects' (mental processes) to performance (3 marks).

Equipment:

- 'Introduction to Ultimate' document.
- Discs.
- Coloured ribbons or bibs.
- Paper.
- Pen.
- Markers.
- Clock.
- Option: Video recorder.

Introduction to Ultimate

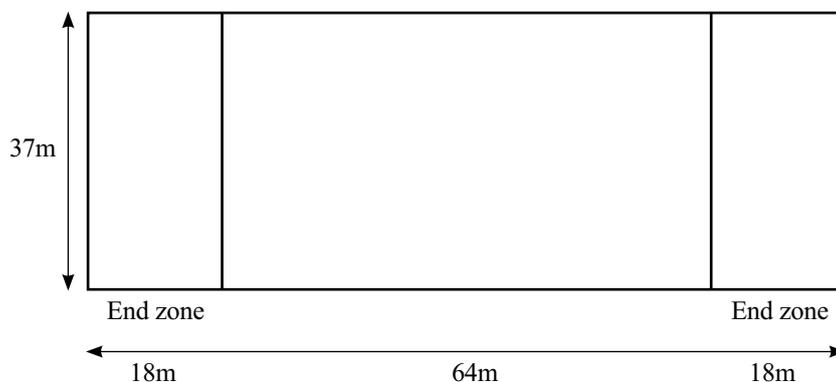
Teams: Minimum number of 4 players and a maximum number of 7 players per team.

Playing field: Suggested dimensions should be adapted in accordance with the number of participants allocated to each team.

Game aim: To move the Disc up the field, without dropping it, using the action of passing (throwing and catching) and for one of your team-mates to catch it whilst standing in the end-zone to score a point. The non-possessing team is to attempt to intercept the Disc without making physical contact.

Game rules:

1. Refereeing is undertaken by the game players on the field. Players resolve differences of opinion. When a resolution is not found, the Disc is returned to the position that it was thrown and re-played.
2. No running when in possession of the Disc. Use a pivot foot (as with the rules of netball).



3. No physical contact, although small incidental contact may occur without penalty. There is no screening or blocking of players permitted.
4. Players have 10 seconds to dispose of the Disc. Opponents are permitted to count 1, 2, 3... out loud to define the time in possession.
5. One defender or marker is permitted. They are to be no closer than 1 metre to the player with the Disc. No other player is permitted within 3 metres of the player holding the Disc.
6. Turnovers occur when the Disc hits the ground, is dropped, crosses a boundary line or is intercepted by an opponent.
7. Intercepts do not need to be caught, that is, if the Disc hits the ground during an intercept, a turnover is recorded and the offensive team will lose possession. It does not matter who was the last to touch the Disc, an intercept will result in the defending team taking possession.
8. When an offensive team catches the Disc in the end-zone, a point is scored. Teams change ends after each point is scored. Play is to be re-started when players are in position with the non-scoring team taking possession.

Task: Task: 'Ultimate' game performance analysis of self and others: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to using notational analysis to provide feedback to improve learning and performance.	1 mark
Provides clear statements of the expected results or anticipated outcomes in relation to using notational analysis to provide feedback to improve learning and performance.	2 marks
Introduction (3 marks)	
Identifies and defines some of the tools used to analyse performance and the role of feedback to improve learning and performance.	1 mark
Shows an understanding of performance analysis using checklists, video, notational analysis, reflective journals, peer/mentor/coach feedback, and questionnaires to provide feedback and the impact of feedback on learning skills and improving performance.	2 marks
Shows a comprehensive understanding of performance analysis using checklists, video, notational analysis, reflective journals, peer/mentor/coach feedback, and questionnaires to provide feedback and the impact of feedback on learning skills and improving performance.	3 marks
Results (2 marks)	
Satisfactory presentation of data.	1 mark
Accurate and relevant presentation of data.	2 marks
Response to Questions (15 marks)	
<i>Task one: Question a: 2 marks, Question b: 3 marks, Question c: 3 marks, Question d: 2 marks, Question e: 2 marks (12 marks).</i>	
<i>Task two: Question a: 3 marks.</i>	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	1 mark
Limited discussion of the results found and few links made to the variables associated with performance analysis, learning and improving performance.	2 marks
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with performance analysis to provide feedback and the impact of feedback on learning skills and improving performance.	3 marks
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with using checklists, video, notational analysis, reflective journals, peer/mentor/coach feedback, and questionnaires to provide feedback and the impact of feedback on learning skills and improving performance.	4 marks
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to using checklists, video, notational analysis, reflective journals, peer/mentor/coach feedback, and questionnaires to provide feedback and the impact of feedback on learning skills and improving performance.	5 marks
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to using checklists, video, notational analysis, reflective journals, peer/mentor/coach feedback, and questionnaires to provide feedback and the impact of feedback on learning skills and improving performance.	6 marks
Conclusion (2 marks)	
Summarises some of the factors associated with performance analysis in relation to feedback for learning and improved performance and the hypotheses.	1 mark
Fully summarises the impact of the factors associated with performance analysis in relation to feedback for learning and improved performance and the hypotheses. Limitations discussed.	2 marks
Comment:	Total
	/30

Appendix C (I)

Revision questions

1. Give two reasons to account for why transfer of learning occurs.
2. How could something that was learned previously impact negatively on our current sporting performance?
3. Why is it that some superstar athletes like basketballer, Michael Jordan, struggle when they change sports?
4. Explain the difference between ‘proactive’ positive skill-to-skill transfer of learning and ‘retroactive’ positive skill-to-skill transfer of learning.
5. When PE teachers introduce a new skill to a class, they describe and demonstrate the skill, reinforcing three key teaching points. This is an example of using the concept of which type of transfer of learning?
6. Briefly explain the qualities of training that are important to transferring learning to competition.
7. A tennis coach meets someone who is new to tennis, and they ask them; “what other sports have you played”? The player confirms that they have extensive experience as a recreational sailor. This situation is likely to represent a
 - a. positive practice-to-competition transfer of learning.
 - b. theory-to-practice transfer of learning.
 - c. zero transfer of learning.
 - d. negative pro-active transfer of learning.
8. If a motion analysis model has five steps, which one of the following represents the fifth step?
 - a. Re-observation after an intervention
 - b. Preparation and identifying key variables
 - c. Evaluation and prioritising weaknesses
 - d. Providing feedback
9. Whilst acknowledging the feedback that summarises the good aspects of performance and errors made during performance is important, which of the two is more essential for learning?
10. Augmented feedback should be used with some caution. Explain the possible limitations of using augmented feedback.
11. Why is prescriptive augmented feedback more appropriate for a beginner than descriptive augmented feedback?
12. Describe the differences when feedback is provided as visual, verbal and proprioceptive cues.
13. Using your understanding of the strategies that can simplify a complex skill, explain how someone learning to juggle three balls may benefit from practising with silk scarves.
14. The decision about whether a motor skill should be practised as a whole or broken down into parts is based upon the complexity and organisation of the skill. Use two different sporting examples to explain the first sentence.
15. While the decision to teach a skill through shaping or chaining is influenced by complexity and organisation, it is also based on two other aspects. Identify these aspects.
16. Static drills have been said to have the advantage of allowing the coach to ‘reduce attention demands’ or ‘close the learner’s environment down’. What could be reduced or closed down for a learner by employing a static drill for developing passing and trapping skills in soccer?
17. A dynamic drill is best represented by which one of the following statements?
 - a. Performance of the skill with no motion
 - b. Performance of the skill with the motion that is consistent with the environment that replicates competition

- c. Forward chaining a skill
d. Shaping a skill
18. Justify a leadership style that is best suited to a triathlete who is highly experienced and motivated?
19. Identify a time/circumstance where an autocratic leadership style is more appropriate.
20. Why is it that the laissez-faire style of leadership style has a limited role in sport?
21. How does performance analysis using checklists and video enhance the:
- Objectivity of performance analysis.
 - Understanding of mental influences on performance.
 - Opportunity for the performer to engage in reflective learning.
 - Design of future training programs.
22. Describe what a notational analysis of performance is and how it might differ from the observations a coach makes during a game.
23. The learning process model that defines a 4-step process for self-reflective learning, asks the athlete to perform (action) and then to reflect. Briefly describe what the third phase (recognition) requires the athlete to do.
24. The fourth component of the learning process model is best represented by which one of the following options?
- Planning
 - Performing
 - Video analysis
 - Answering a questionnaire
25. For each of the sentences that describes what a reflective learner should reflect on, fill in the missing word/s. Note, the first letter of the word/s is provided and bolded.
- What and how they are
L _____ – including any aspect of the skill that they do not understand
 - Strengths and challenges – reflecting on the strengths can help to maintain motivation and enthusiasm, while examining the challenges or weaknesses will aid **S** _____
D _____
 - H** _____ to improve – reflecting on strategies in the short-term and training interventions in the long-term that will improve learning and skill development
 - Working towards **G** _____ – reflecting on how close performance is to any pre-established goals and re-setting goals as appropriate
26. An athlete is seeking answers from the coach to assist future learning, but the coach said that they will be a better athlete in the long term if they firstly try reflective learning strategies to sort it out for themselves. Justify the position taken by the coach and identify two self-reflective methods that the athlete could use.

Appendix C (II)

Revision answers

1. Transfer of learning occurs when very similar physical skills learned when performing a skill are used to physically execute a new, but similar skill. The second reason to explain why transfer of learning occurs, relates to skills that require similar cognitive processing transfer to other skills with similar needs.
2. Negative transfer of learning occurs when previous experience inhibits or negatively affects performance of a skill in a new context or the learning of a new skill. Negative transfer of learning occurs more commonly when you are performing a skill in a familiar environment that requires a different response or skill than what you would normally provide. Negative transfer can also occur when an individual has to unlearn a well-learned skill.
3. The problem for some superstar athletes who change sports is that there are very few similarities, in the motor skills, the context in which the skills are performed and the information processing requirements of the sports. Therefore for athletes like Jordan, there was little or neutral (zero) transfer of learning from basketball that would allow him to be a superstar baseballer.
4. Positive skill-to-skill transfer of learning occurs when previous experience or practice of a skill facilitates the skill in a new context or improves performance of another skill. Proactive transfer occurs when skills practiced in the past have an impact on motor skills that you will learn in the future. When a skill that you have learned previously is altered by a new skill that you learn, that is retroactive transfer of learning.
5. Theory-to-practice transfer of learning.
6. To increase the positive transfer between practice and competition, the practice should imitate the competitive situation, by incorporating into the training session:
 - the aspects of the skill
 - the context of the skill
 - the perceptual stimuli (visual, proprioceptive and auditory cues)
 - the time critical nature of making decisions and responding to those stimuli.
7. c. Zero transfer of learning.
8. a. Re-observation after an intervention
9. Movement analysis that identifies errors is essential for learning. Error information directs the athlete to change the incorrect aspects of performance, whereas feedback concerning correct performance encourages the athlete to continue performing in that manner.
10. Coaches need to be careful when providing augmented feedback because when provided, even if the feedback is wrong (erroneous) or inappropriate to the learners needs, learners will generally use it instead of their own task-intrinsic feedback. If augmented feedback is provided too often, the learner will possibly become dependent on the augmented feedback and will not utilise task-intrinsic feedback to improve. For augmented feedback to be most effective, it is important to allow learners to try to problem-solve for themselves and to utilise task-intrinsic error detection following the completion of the skill. Providing augmented feedback too early will possibly compromise learning as these processes will not occur.
11. Prescriptive augmented feedback describes the performance and then prescribes a solution to the problem. In general, beginners require more prescriptive feedback because they are unaware of how

to correct their mistakes, whereas more advanced performers may only require descriptive feedback because they have sufficient knowledge of the skill to correct it themselves.

12. Visual cues give the learner an opportunity to see what the movement requires and are often provided through the demonstration of a skill. A verbal cue is a short, concise phrase that directs attention to the most important feature(s) in the environment, or prompts performers to attend to key components of the skill.

Proprioceptive cues (kinaesthesia) refer to the internal sensory information that informs us about our own joints, muscles and orientation of our bodies in space. Proprioceptive feedback often involves the coach physically moving the athlete through the required action.

13. Silk scarfs (reducing the difficulty of the objects used) are good to simplify the skill of three-ball juggling because they move more slowly through the air (slow the motion down) and do not bounce out of the hand (reducing the difficulty).
14. The response must identify, with an example such as a volleyball spike or basketball lay-up, that tasks that are high in complexity and low in organisation are more appropriately broken down into parts, with one part learned before another part is learned. Ultimately, when all parts are learned they are combined. Motor skills that are low in complexity and high in organisation, such as an AFL kick or basketball free-throw or set shot, are best practised where the incomplete or modified versions of the whole performance are undertaken.
15. Chaining is best suited to skills that are firstly, easily broken into component parts. Secondly, the order of the skill is important

in chaining, whereas, the order is not as important for shaping the skill.

16. Using static drills to practice trapping and passing in soccer helps learners by reducing the task complexity through limiting actions such as the need to dribble and run, and cognitive processing required such as decision making and the need to respond to external stimuli. Therefore, the athlete can selectively focus their attention on learning the skills of passing and trapping.
17. b. Performance of the skill with the motion that is consistent with the environment that replicates competition
18. A democratic style of leadership, which is characterised by a process of consultation between the teacher or coach and the athlete. This approach serves to empower the athlete and provides them with a sense of control over their current and future career. This style respects and benefits from their experience. In addition, the athlete is already highly motivated and not solely reliant on the coach.
19. An autocratic leadership style is more appropriate when an immediate decision needs to be made, or particularly in team sports, when the individuals require organisation. This style of leadership also suits athletes who need support and answers, who need extrinsic motivation, or athletes who value the extrinsic setting of benchmarks and are goal driven.
20. The laissez-faire style of leadership is effective with athletes performing at a self-defined standard where the athletes are self-motivated and capable of making their own decisions. As a result of a general lack of direction, this style does not meet the needs of athletes who aim to learn and improve performance.
- 21.
- a. The objectivity of performance analysis is enhanced by checklists and

video because performance criteria are defined and predetermined. Video replay provides the opportunity to quantify performance by measuring/counting performance criteria, such that comparisons can be made with others and with self from training and performance, and over time in repeat performances.

- b. In addition to physical performance the impact of mental and cognitive functioning, such as concentration, anxiety, stress, self-confidence and decision making on current performance can be assessed by comparisons with performance successes and errors, quality and consistency recorded in checklists and by video from training and past performances. Also athletes can undertake self-reflection using checklists and video, or use the checklists and video to evaluate performance through discussion with the coach.
- c. Reflective learning is enhanced by the additional evidence (augmented feedback) that checklists and video provide during post-performance analysis. During the performance, athletes are primarily focused on performance and the opportunities to self-assess through intrinsic/inherent feedback are limited. This is particularly so for those who are not in the autonomous phase of learning or who are unable to use intrinsic feedback to analyse performance.
- d. A checklist and video provides a record of changes (hopefully positive changes) that have taken place over time. If, for example, there is one criterion of performance that is not being achieved

(an error), the checklist will give the coach information that can then be used to direct their feedback, develop training activities and instructions.

Furthermore, the coach can also use the checklist to assess whether the feedback and training that they are providing actually results in any improvements.

22. The observations that the coach makes during the game are limited to what they see and remember. They can be by biased by their own motives and beliefs. However, a notational analysis of performance using checklists, live observation and video is an analysis of data for players:
 - Movements (including distance and intensity),
 - The success or failure of:
 - a. the skills performed
 - b. techniques employed
 - c. patterns of play
 - d. tactics and strategies
23. The third phase requires the athlete to recognise correct and incorrect aspects of that performance.
24. a. Planning
25.
 - a. learning
 - b. skill development
 - c. how
 - d. goals
26. Sometimes learners become dependent on the augmented feedback from the coach and will not utilise task-intrinsic feedback or reflective learning to improve. For augmented feedback to be most effective, it is important to allow learners to try to problem-solve for themselves and to utilise task-intrinsic error detection and self-reflective methods such as video analysis, reflective journals, peer/mentor feedback, and questionnaires.

Appendix D

Personalised project – Units 3 and 4: Teaching or coaching a new complex skill(s)

This assessment task is framed by the principles of Bloom’s taxonomy. The mark allocations respect the level of complexity of individual task requirements. The following table differentiates for the complexity of each task, beginning with Level 1 (for example, label) to Level 6 (for example, create) (adapted from O’Brien & White 2001).

This project would be best initiated at the end of the sport psychology unit, before commencing the motor learning and coaching unit.

1	2	3	4	5	6
REMEMBERING	UNDERSTANDING	APPLYING	ANALYSING	EVALUATING	CREATING
	Summarise	Measure	Identify	Justify	Create
		Undertake	Compare & contrast	Evaluate	Imaging
			Discuss		Hypothesise
					Forecast

Weighting:

- Unit 3 – 25 marks
- Unit 4 – 25 marks

Type: Investigation

Content:

- Sport Psychology
- Motor Learning and Coaching

Total marks = /50

Instruction

Choose a complex skill or series of skills that you will teach or coach to another person (learner) who currently cannot successfully complete the task(s). The activity and the learner may be linked to your Physical Education Studies course (a classmate), or the skill and the learner may be independent of your current studies (for example, three-ball juggling or controlling a hacky-sack and a family member, friend or younger student). The learner must be prepared to practise this activity for a minimum of three times per week (minimum of twenty minutes per session), during a period of three weeks.

Content

1. *Create and justify* a comprehensive performance analysis portfolio (series of measurement tools) for the chosen skill(s). Ensure that the analyses access:
 - ‘physical skill’ analysis (Unit 4: 7 marks), and
 - ‘mental or psychological aspects’ (mental processes) of the performance (Unit 4: 7 marks)
 Consider the use of video, checklists, notational analysis, pre- and post-performance interview, and questionnaire.
2. Base-line data collection and performance (pre-intervention phase). Without having practised the skill(s), have the learner, as best they can, perform the skill(s) in front of you. Use the comprehensive performance analysis measurement tools that you created to assess the learner’s physical and mental performance state. Collect this information (0 marks).
3. Interview the learner to *identify* and *summarise* any transfer of learning that may have impacted (positively or negatively) on the initial performance of the skill(s) (Unit 3: 2 marks).
4. Use the base-line data collection performance as evidence to *evaluate, create and justify* an appropriate physical skills training program for the learner to undertake (each session is to be planned for a minimum of three times per week (minimum of twenty minutes per session), during a period of three weeks. Consider the explicit use of shaping and/or chaining activities, static and/or dynamic activities, and simple and/or complex activities (Unit 3: 10 marks).
5. Use the base-line data collection performance as evidence to *evaluate, create and justify* an appropriate mental skills pre-, during- and post-performance procedure for the learner to implement in subsequent training sessions and performances. Consider their levels of stress, motivation, concentration, self-confidence, and arousal, and the use of self-talk, relaxation, routines, goal setting and imagery (Unit 3: 8 marks).
6. Present the physical skills training program with instructions to the learner and seek the learner’s understanding (0 marks).
7. Present the mental skills program with instructions to the learner and allocate a training session in the first week and teach the learner to use the mental skills (0 marks).
8. Attend each/some of the training sessions and provide feedback to the learner. Journal the feedback that you provide and *compare and contrast* your feedback with the ‘suggested feedback strategies’ documented in this textbook (Units 3 and 4: 4 marks)
9. Repeat this process of evaluation and provide feedback using the comprehensive performance analysis measurement tools that you created after one week (mid-intervention phase) of practice and at the end of the three weeks (post-intervention phase) (0 marks).
10. *Evaluate* and *discuss* the intervention outcomes. In doing so, consider the impact of sport psychology and motor learning and coaching principles on the learning outcomes and the learner’s performance (Units 3 and 4: 6 marks).
11. *Imagine* that your learner was not an individual performer, but was a member of a team of performers (n=10) who were preparing for a competition that required expert performance of the skill/s that you are teaching. You are the coach. Your learner, as a beginner is the weakest in the team, while others have a range of abilities. *Forecast* team cohesion issues that may have arisen. *Hypothesise* strategies that would

minimise the chance of social loafing and the forecasted team cohesion issues (Unit 4: 6 marks).

Process or support

- Design performance analysis tools assisted by the teacher.
- Review texts or scientific journals and, in a small group, hold a teacher-facilitated debate and discussion of the evidence at hand.
- Review video material.

Product or outcome

Verbal or written explanation

- Variables that contribute to or impact on learning and performance.

Written

- Comprehensive performance analysis portfolio.
- Variables that contribute to or impact on a personal performance.
- Create a training program.
- Evaluate the impact of training on learning and performance.
- Predict and hypothesise to account for potential team cohesion issues.

Tabulate or graph

- Diagrams and label.
- Measure and record personal performance.
- Tabulate and identify learning.

Appendix E

Glossary of key terms

Augmented feedback: Extra feedback that enhances inherent feedback and can be provided via visual, verbal, kinaesthetic, or written cues.

Autocratic leader: Makes all of the decisions.

Backward chaining skills: The last component is practised first and the whole skill is built by working backwards.

Chaining skills: Involves the skill being broken down into components that are rehearsed separately, as if they were isolated skills.

Checklists: Are a record of performance in relation to a set of predetermined criteria and clearly communicate to the athlete what the performance expectations are in terms of the criteria and standard of those criteria.

Complex skill: Has a large number of components and demand a lot of attentional resources.

Democratic leader: Consults, asking the group to be a part of any decision-making process.

Descriptive augmented feedback: Identifies the errors.

Dynamic drill: Performed while the athlete is in some form of locomotion.

Forward chaining skills: Skill components are rehearsed in the order that the whole skill is performed.

Laissez-faire leader: The teacher or coach will ‘let people do as they choose’.

Learning: The change in the capability to

perform a skill that is derived from a relatively permanent improvement in performance as a result of practice or experience.

Negative transfer of learning: Occurs when previous experience inhibits or negatively affects performance of a skill in a new context or the learning of a new skill.

Notational analysis: An objective way of recording performance so that key elements of that performance can be quantified in a valid and consistent manner. Assesses how individuals and teams (as a whole) perform.

Performance: An observable behaviour at a specific time and location.

Positive feedback sandwich: Positive feedback – corrective feedback – positive feedback.

Positive transfer of learning: Occurs when previous experience facilitates performance of a skill in a new context or the learning of a new skill.

Prescriptive augmented feedback: Identifies the errors and a means to correct them. Visual cues used to improve performance include demonstrations, visual aids, and enhancement of the visual environment.

Proactive transfer of learning: Occurs when skills practiced in the past have an effect on motor skills that you will learn in the future.

Proprioceptive feedback: Refers to internal sensory information that informs us about our own joints, muscles and the orientation of our bodies in space (kinaesthesia).

Reflective learning process: Where the learner is actively involved in gaining and examining feedback and other information to improve performance and ultimately retention of that performance.

Retroactive transfer of learning: Occurs when a skill that you have learned previously is altered by a new skill that you learn.

Shaping skills: Involves simplified or incomplete versions of a skill being rehearsed initially before missing components are gradually added.

Simple skill: Has few components and low demand on attention.

Skill-to-skill transfer of learning: Occurs when previous experience or practice of a skill impacts on the execution of the skill in a new context or performance of another skill.

Static drill: The athlete will stay on the same spot and perform the skill.

Theory-to-practice transfer of learning: Refers to transferring knowledge of sport or skill into the actual performance.

Transfer of learning: Is the gain (or loss) in proficiency in one skill as a result of practice on another skill.

Verbal cue: Is a concise phrase that directs attention to the most important feature(s) in the environment, or prompts performers to attend to key components of the skill.

Zero transfer of learning: Occurs when previous experience has no influence on the performance of a skill in a new context or the learning of a new skill.

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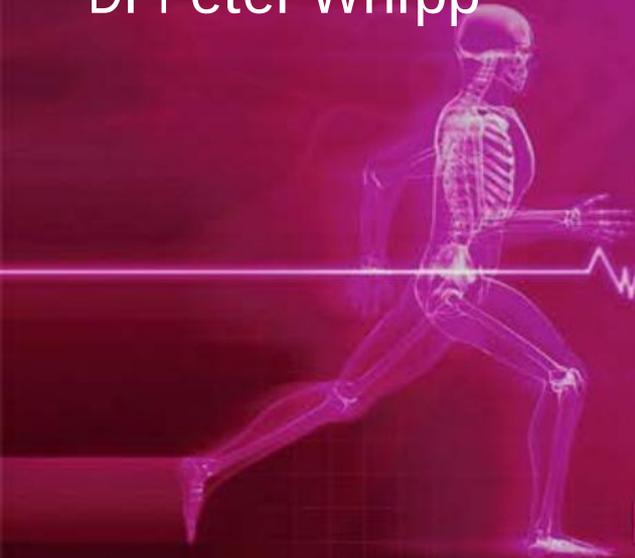


THE UNIVERSITY OF
**WESTERN
AUSTRALIA**

BIOMECHANICS

Dr Bruce Elliott,
Dr Jacqueline
Alderson and
Dr Peter Whipp

This chapter provides an insight into the biomechanical mechanisms that cause and alter motion. This approach, which begins with an expansion of linear kinetics from Units 1 and 2, then explores the topic of angular kinetics, an area critical to the understanding of the mechanics of movement. A number of issues associated with fluid mechanics are then presented from an applied perspective.



PHYSICAL EDUCATION STUDIES ATAR UNITS 3 AND 4
A TEXTBOOK FOR TEACHERS AND STUDENTS

The 5-step Analysis Framework

Students are challenged to re-visit the biomechanical analysis approach presented in Units 1 and 2, such that it can be applied to movement commonly seen in sport and exercise.

Step 1: Preparation

Understand the skill to be analysed, identifying the critical variables associated with 'ideal performance'.

Step 2: Observation

Decide on the number of observations needed to 'make a decision' on critical variables. Remember, you will need to observe the action from different locations to assess different variables. Also observe performance under varied situations (fatigued vs non-fatigued).

Step 3: Evaluation

Compare critical variables of your 'ideal performance' with observed performance. Prioritise practice time with regards to strengths in performance and observed weaknesses.

Step 4: Intervention

Select the appropriate intervention to rectify weakness in performance. Provide feedback on the mechanical variables being practised.

Step 5: Re-observe

Check that intervention strategies have been successful in modifying the movement.

Linear Momentum ($m \cdot v$)

This is the product of mass (m) and velocity (v). Remember velocity is a vector that has size (for example, $10 \text{ m} \cdot \text{s}^{-1}$ (m/s)) and direction (for example, 45° to the horizontal, either forward or back). Let's consider animals that build linear momentum primarily through their mass or velocity.

Mass: The elephant has a mass of $\sim 5,000 \text{ Kg}$, which when combined with the ability to run at moderate speed (e.g. $10 \text{ m} \cdot \text{s}^{-1}$ directly toward the person taking the picture), produces a huge linear momentum ($50,000 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1}$).



Velocity: The cartoon character Sonic the Hedgehog with a mass of $\sim 20 \text{ kg}$ is able to build linear momentum based on 'blistering' velocity (for example, $100 \text{ m} \cdot \text{s}^{-1}$).

$$\begin{aligned}\text{Linear momentum (p)} &= \text{mass} \cdot \text{velocity} \\ &= 20 \text{ kg} \times 100 \text{ m} \cdot \text{s}^{-1} \\ &= 2,000 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1}\end{aligned}$$



Conservation of Linear Momentum

Newton's 2nd Law ($F = m \cdot a$) relates to the behaviour of objects when all forces are unbalanced, resulting in the development of acceleration. That is, to potentially increase acceleration of a ball more force must be applied, assuming the mass of the bat and ball is held constant. Conversely, applying less force but increasing the mass of a bat (e.g. using a heavier bat in cricket) may also result in an increase in the ball's acceleration.



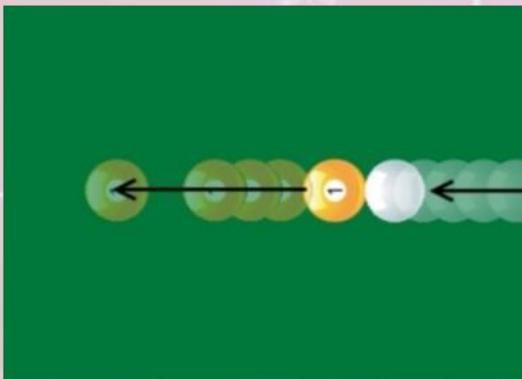
To create a **change in momentum** ($m \cdot v$) force must be applied. Consider hitting the ball from the tee in tee-ball. In this situation, force is provided by the swinging bat. The momentum of the stationary ball, which is initially zero, as it sits on the tee, is increased following impact.

Force and Linear Momentum

Force is equivalent to *the time rate of change of linear momentum*.

The collisions between two objects may be 'perfectly elastic', in which case the total momentum of the 'system' (all objects combined) remains constant – *it is conserved*. This is the Law of Conservation of (Linear) Momentum. ***When two bodies collide, the momentum before the collision remains the same as the momentum after the collision and therefore, momentum is conserved.***

The cue ball impacting another ball in a game of pool is a situation where momentum post-impact is conserved.



Conversely, attempting to bounce a ball in a sand pit is an example of a 'perfectly inelastic' collision – there is no bounce and therefore linear momentum is not conserved.



Conservation of Linear Momentum: When both objects are moving

Now let's first consider the situation where both objects are moving in a straight line both pre- and post-impact. Remember, this is just a basis for understanding the concept as these are NOT elastic collisions and some energy will be lost during the collision ('imperfect elastic collision'). In a baseball drive, where linear momentum is conserved, the velocity of the ball post-impact may be calculated when you know the:

- Mass of the bat and ball
- Linear velocity of impact point on the bat both pre- and post-impact
- Linear velocity of the pitched ball



<i>Momentum (Kg·m·s⁻¹)</i>	<i>Pre-impact</i>	<i>Post-impact</i>
<i>Ball</i>	Linear momentum: $m_1 \cdot v_1$ Remember, velocity is a vector, so direction would be critical if calculations were to be performed	Linear momentum: $m_1 \cdot v_3$ v_3 = Velocity of the ball post-impact
<i>Bat</i>	Linear momentum: $m_2 \cdot v_2$ v_2 = Velocity of the bat pre-impact	Linear momentum: $m_2 \cdot v_4$ v_4 = Velocity of the bat post-impact

Pre-impact linear momentum (bat + ball) = Post-impact linear momentum (bat + ball)

Linear Momentum

Exam style question

For the last over of a one day cricket innings, with the scores close and the match in the balance, the fielding captain decides to ask the spin bowler, rather than a fast bowler, to bowl. Use the biomechanical principle related to 'conservation of linear momentum' to justify this decision.

(3 marks)



Linear Momentum

Answer

For the last over of a one day cricket innings, with the scores close and the match in the balance, the fielding captain decides to ask the spin bowler, rather than a fast bowler, to bowl. Use the biomechanical principle related to 'conservation of linear momentum' to justify this decision. (3 marks)

When two moving objects collide (cricket bat and ball) the linear momentum is conserved (1 mark). By using a relatively slow delivery, when compared with a fast bowler, the momentum of the ball before impact is reduced (1 mark). Therefore, the bat must be swung with greater velocity to generate maximum momentum after impact (1 mark).



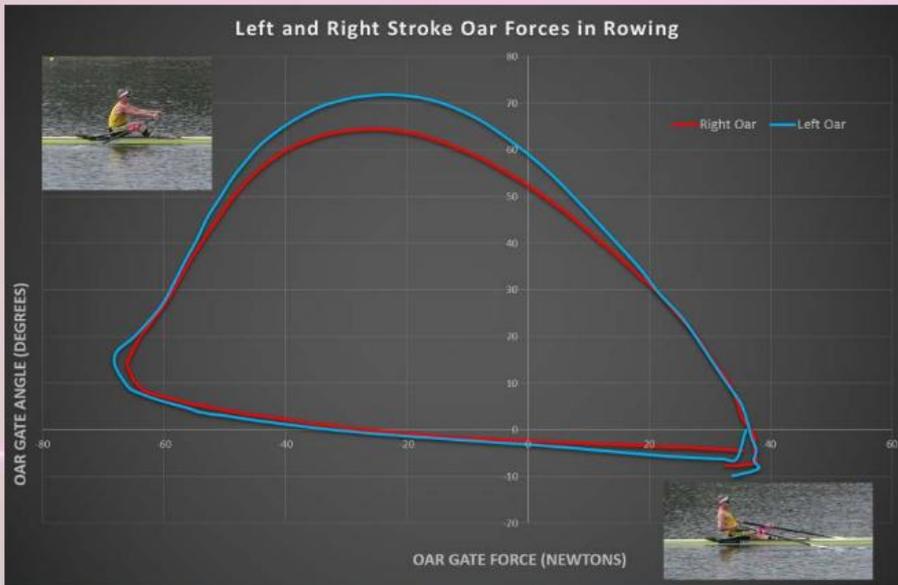
Impulse and Change in Momentum

The concepts of conservation of linear momentum and impulse are linked in Newton's 2nd Law, as shown in the formula $F = m [v_2 - v_1]/t$. If both sides of the equation are multiplied by t you get:

$$F \cdot t = m (v_2 - v_1)$$

Impulse = change in momentum ($m \cdot v$)

Impulse curve: Applying Force



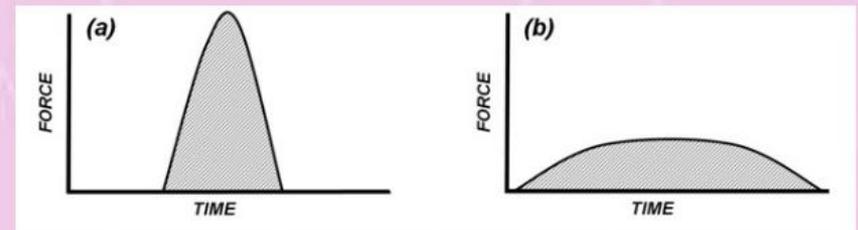
Oar gate left and right force traces plotted against gate angle during a complete rowing cycle (in and out of water phases). Photos and data courtesy of Matt Doyle, the Western Australian Institute of Sport.

Impulse curve: Absorbing force

Catching a ball

(a) With a short time period

(b) With a longer time period – give with the hands



Impulse and Change in Momentum

Exam style question

Explain, using diagrams, the resultant impulse for the netballer landing with:

- (a) a straight leg (little knee flexion).
- (b) the same action with considerable knee flexion.

In your diagrams, show the approximate peak force recorded during foot contact.

(8 marks)



Impulse and Change in Momentum

Answer

Explain, using diagrams, the resultant impulse for the netballer landing with:

- (a) a straight leg (little knee flexion).
- (b) the same action with considerable knee flexion.

In your diagrams, show the approximate peak force recorded during foot contact. (8 marks)

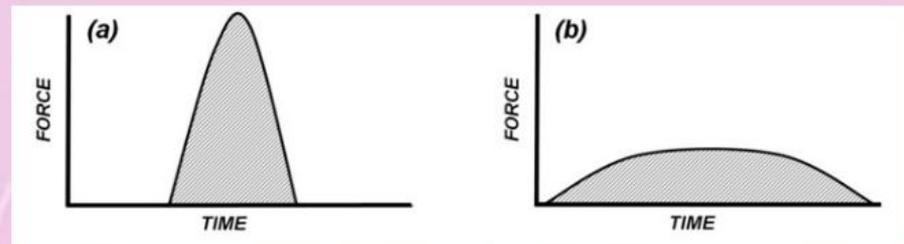
(a) The peak force would be relatively high. The force of foot contact with the ground has been absorbed over a relatively small amount of time. (2 marks)

(b) Although the impulse under each curve is the same - the peak force would be relatively low when the force is absorbed over a longer period of time. (2 marks)



2 marks

2 marks



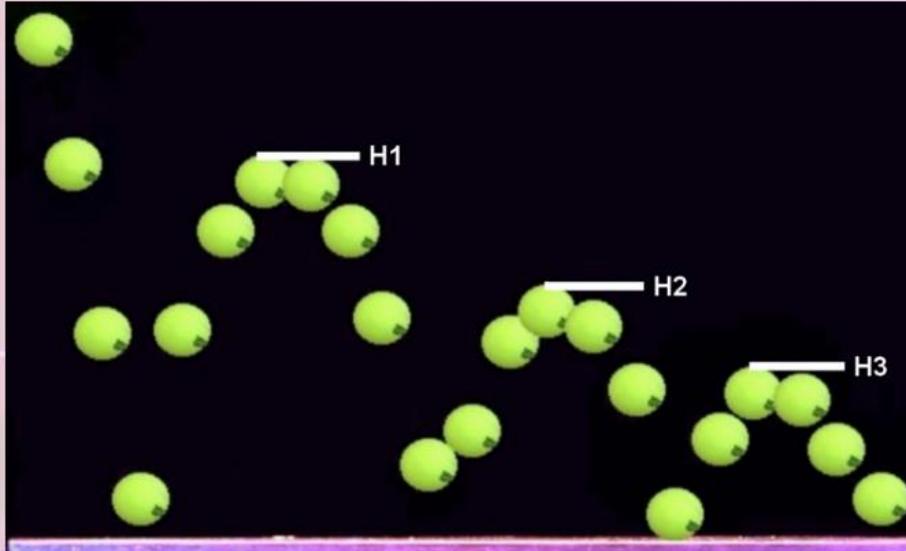
The Coefficient of Restitution (COR)

The coefficient of restitution (COR), or bounciness of an object is a value representing the ratio of the velocity after an impact compared with the velocity before the impact.

An object with a COR of 1 collides perfectly elastically (linear momentum fully conserved).

An object with a COR < 1 experiences an imperfectly elastic collision.

For a COR = 0, the object does not bounce at all perfectly inelastic collision.



A bouncing ball is an example of an imperfectly elastic collision.

The Coefficient of Restitution

COR is influenced by 3 main factors:

The materials of the interacting bodies: New tennis balls will have a higher coefficient than old and different surfaces (clay vs grass tennis courts) will also influence bounce height.

The velocity of the collision: The velocity between the oncoming ball and the swinging implement will also alter the COR – higher velocities will reduce the COR because of the greater compression of the ball.

The temperature of the materials involved: As the temperature of a ball increases so does the COR (think of the bounce height of a cold and hot squash ball).

How do you think COR is influenced by the materials used in a baseball bat and the speed of the pitched ball?



Angular Kinetics/ Moment of Inertia

In angular motion, while the mass of an object (bat, stick, or body) is important the critical factor in being able to swing this object is the ***distribution of the object's mass about the point that is used to rotate the object*** (the grip or centre of rotation). In angular motion this is termed the ***moment of inertia*** of the object (I).

$$\text{Moment of inertia (I)} = \sum(\text{Sum}) \text{ mass} \cdot r^2$$

r = distance from mass concentration (e.g. head of hammer) to the axis of rotation (e.g. grip hand position on handle of hammer).

Moment of inertia

This is higher when a hammer is swung by the handle than when swung with the metal end in the hand.



Moment of Inertia in Sport

Moment of inertia of sporting equipment

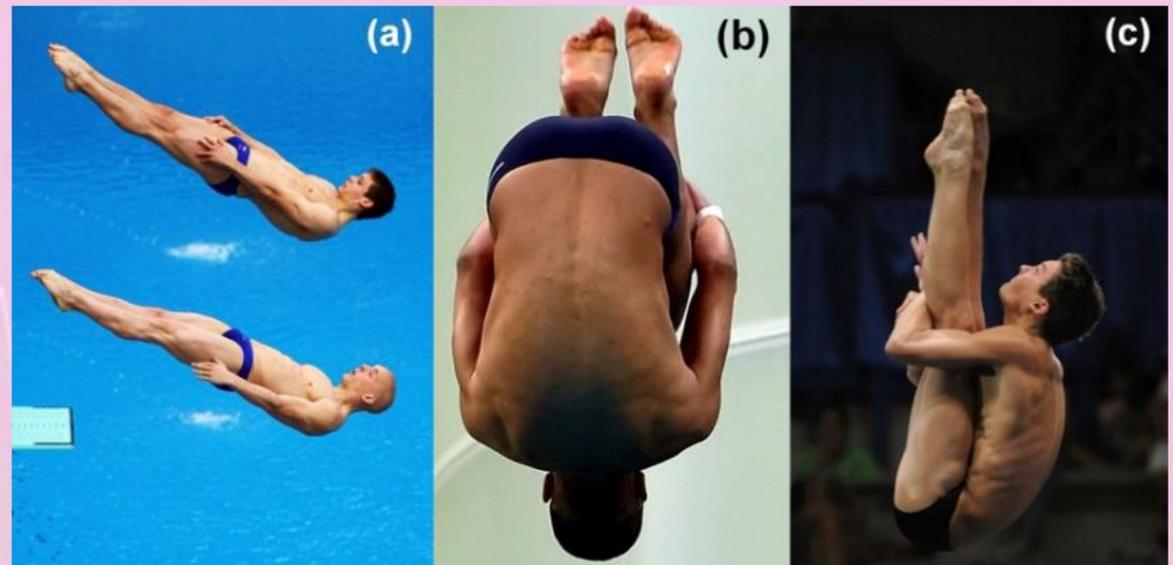
The shorter handle used by the young tennis player (d), compared with the adult player (D) assists in manoeuvrability of the racquet.



Moment of inertia of the human body during sporting activities

The diver is able to change his moment of inertia by changing his body shape. He varies the distribution of mass from the axis of rotation for a somersault.

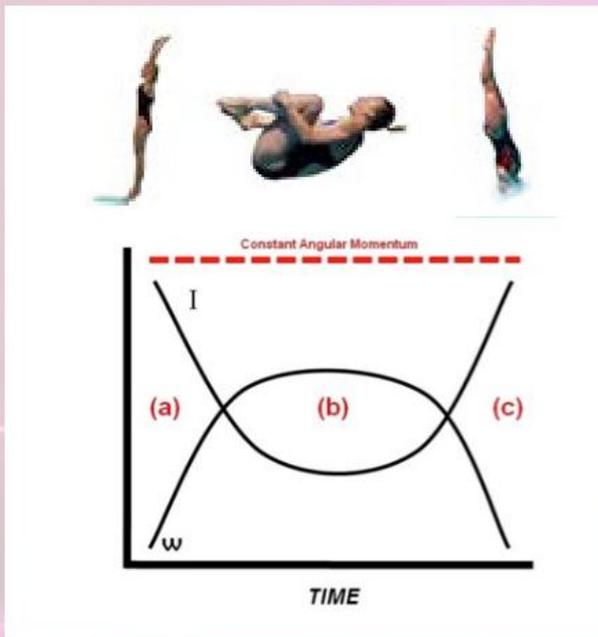
- (a) Layout position - Highest moment of inertia
- (b) Tucked position - Lowest moment of inertia
- (c) Piked position - Intermediate level moment of inertia



Angular Momentum

Angular momentum ($I \cdot \omega$) is the angular equivalent of linear momentum ($m \cdot v$)

Linear motion	Angular motion
Mass (m)	Moment of inertia (I)
Velocity (v)	Angular velocity (ω)
Momentum ($m \cdot v$)	Angular momentum ($I \cdot \omega$)



Conservation of Angular Momentum

When in the air your angular momentum is constant.

However, moment of inertia and angular velocity may change depending on the shape of the body.

- (a) On leaving the board the moment of inertia is high and the angular velocity low.
- (b) In midflight the body is tucked reducing the moment of inertia and increasing the angular velocity.
- (c) At water entry the diver again increases the moment of inertia to reduce the angular velocity for water-entry.

Angular Momentum

Angular momentum ($I \cdot \omega$)

Conservation of angular momentum also occurs about the long axis of the body when one rotates in dancing or ice-skating. The contact with the floor or rink is considered almost frictionless – so it is like you are in the air.

Arms close to the body =
high angular velocity - rotation



Arms away from the body =
lower angular velocity - rotation



Conservation of Angular Momentum



Exam style question

Using your understanding of biomechanical principles, explain why a child's bat is shorter and lighter than that used by an adult.

(2 marks)

Conservation of Angular Momentum

Answer

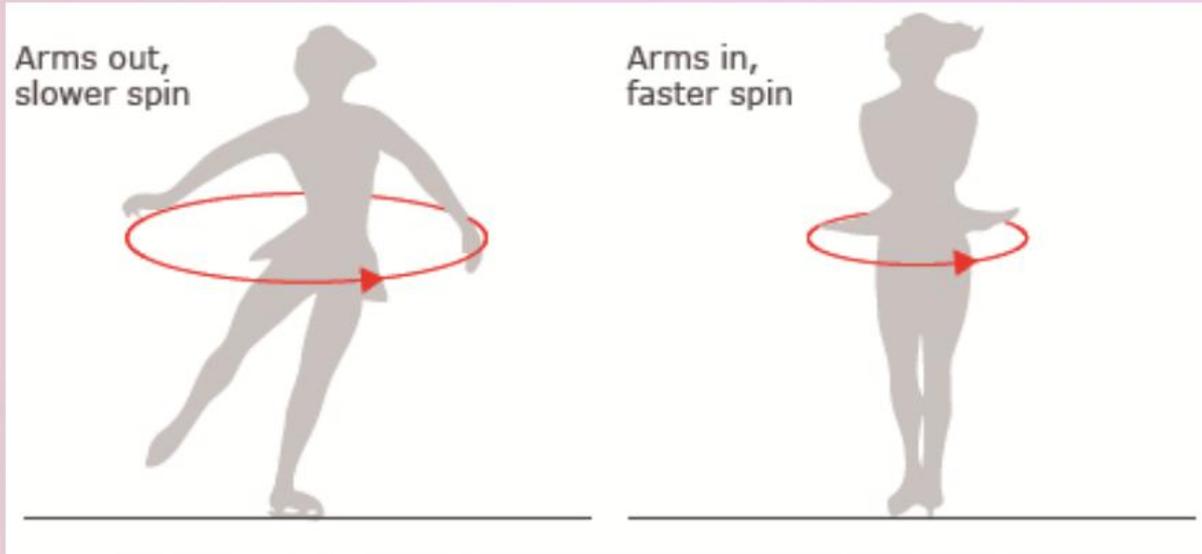


Using your understanding of biomechanical principles, explain why a child's bat is shorter and lighter than that used by an adult. (2 marks)

By using a relatively shorter and lighter bat, the child's bat has a lower moment of inertia (1 mark) and therefore is easier for the child to accelerate. (1 mark)

Conservation of Angular Momentum

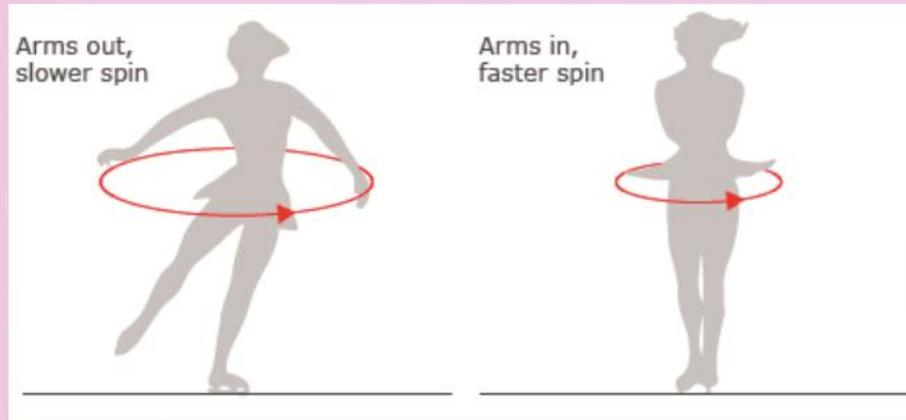
Exam style question



Using your understanding of biomechanical principles, explain how the position adopted by the ice skater impacts on their rate of spin.

(4 marks)

Conservation of Angular Momentum



Answer

Using your understanding of biomechanical principles, explain how the position adopted by the ice skater impacts on their rate of spin. (4 marks)

When the arms and legs are moved close to the trunk, the mass is distributed closest to the axis of rotation, thereby reducing the moment of inertia (1 mark), with a resultant increase in angular velocity. (1 mark)

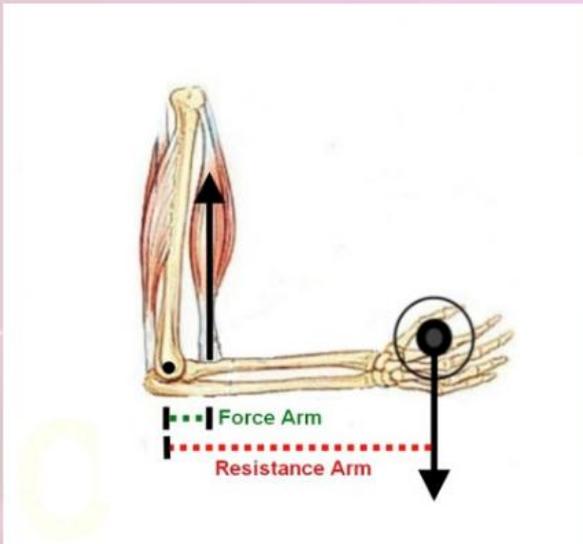
When the arms and legs are extended, the mass is distributed further away from the axis of rotation and the moment of inertia is highest (1 mark), and the angular velocity is reduced. (1 mark)

Levers in the Body

Components of a lever

To fully understand how levers benefit movement requires an understanding of the three components that make up a lever.

- A pivot point or axis: This is the point about which the two lever arms (force and resistance – discussed below) operate.
- A weight/load/resistance to be moved.
- The applied force required to move the weight/load/resistance.



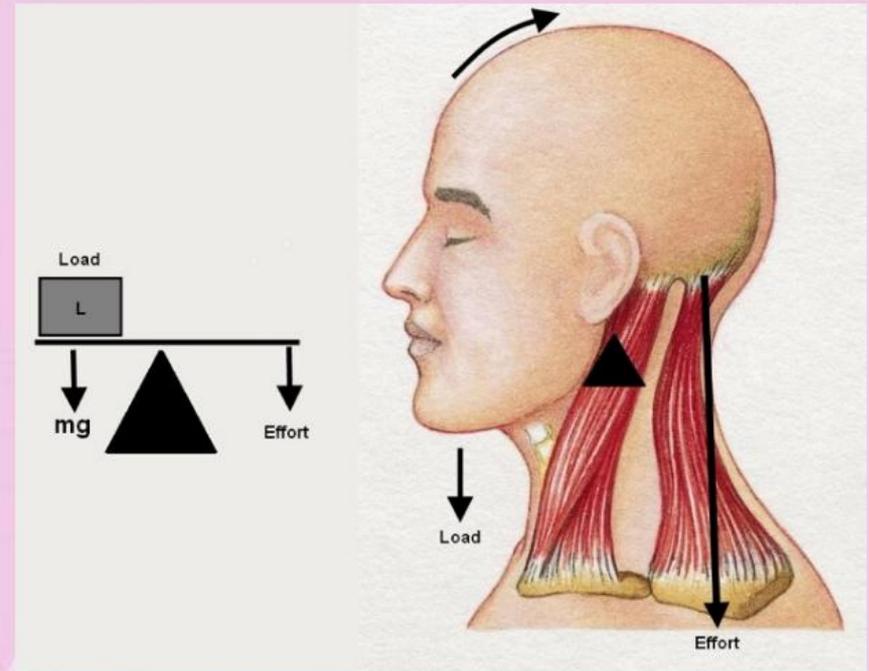
The distance between the force and the pivot point or axis of rotation is termed the *force arm*, whereas the distance between the weight/load/resistance and the axis of rotation is termed the *resistance arm*.

Types of Levers in the Body

1st Class

The axis of rotation (the fulcrum) is between the force (effort) and the load (for example, a seesaw).

Functionally, not many examples exist in the body; however, holding one's head erect is an example of this type of lever. The fulcrum, in the centre, is the connection between the head and the spine, while the load is the weight of the head acting through its centre of gravity, with the force being the muscle force pulling on the back of the skull.

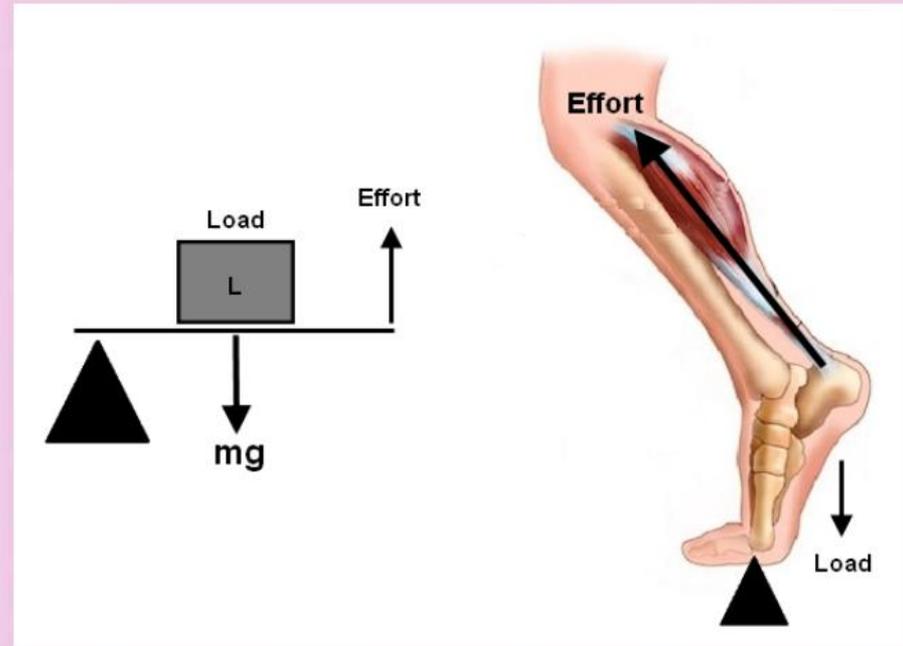


Types of Levers in the Body

2nd Class

For this type of lever the weight/load/resistance is located between the fulcrum and applied force, such as in a wheelbarrow.

Again this lever type is not common in the body though a good example is a when an individual takes a walking step. The toes act as the fulcrum and the body weight (for part of the walking cycle) is positioned centrally, as the gastrocnemius muscle contracts and pulls upward – ‘effort’. As the weight of the body (line of the centre of gravity) moves forward of the toes (fulcrum) in walking, this 2nd class lever then becomes a 1st class lever.

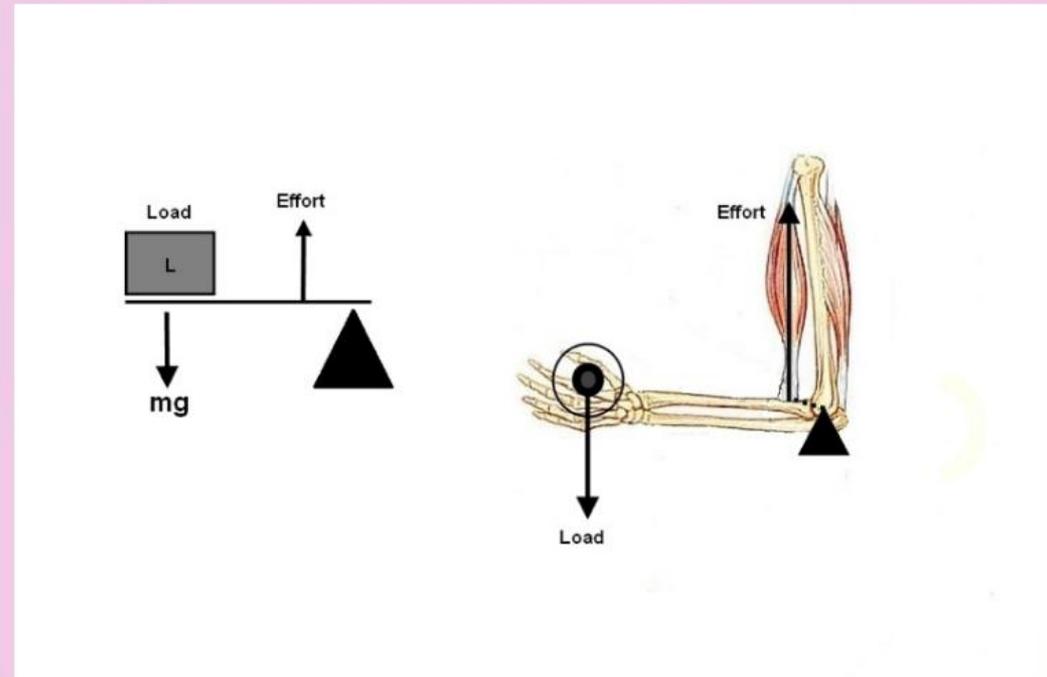


Types of Levers in the Body

3rd Class

This is the most common type of lever in the body, with the applied force (the muscle attachment - effort), somewhere between the axis of rotation (e.g. the elbow) and the weight/load/resistance (for example, a dumbbell in the hand).

A biceps curl is an excellent example of a 3rd class lever. Think of throwing a softball for distance. The ball represents the resistance in the hand, the shoulder acts as the fulcrum and the muscle(s) attachment needed to create the motion is between these two ends.



Modification of Lever Lengths during Sporting Activities

If the body comprises primarily 3rd class levers then humans are typically not mechanically efficient – the force arm is always going to be shorter than the resistance arm.

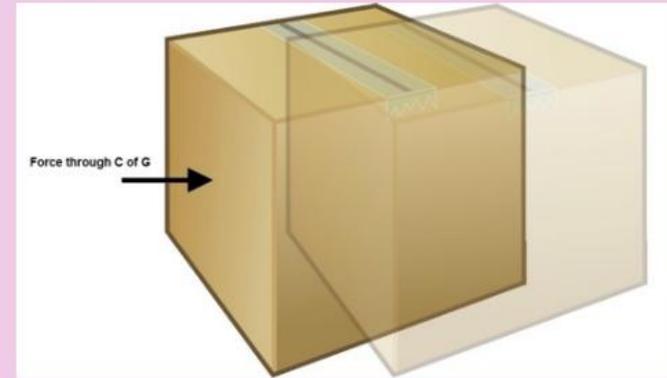
In an attempt to overcome this deficiency we try to reduce the length of the resistance arm as much as possible when performing ‘force related activities’, such as in weight/power lifting or when attempting to increase the force on an object (for example, the water – as shown in picture during the pull in freestyle swimming). This reduction in the effective length of the resistance arm is our attempt to increase the effectiveness of the force arm.

However, where speed of an end point such as in tennis or cricket bowling is required, we extend the length of the lever to increase speed of the hand/foot or racquet.

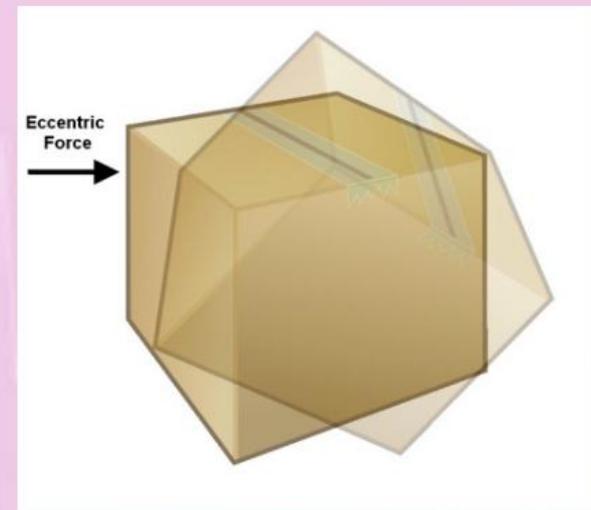


Moment of Force (Torque) – Turning Forces

If a force is applied directly through the centre of gravity of an object no rotation will occur and the object moves in a straight line (it translates).



However, if a force is applied away from this point (off-centre) you get a combination of linear and angular motion, unless one end is fixed where in that case, you only produce a turning effect.



Creating Turning Forces

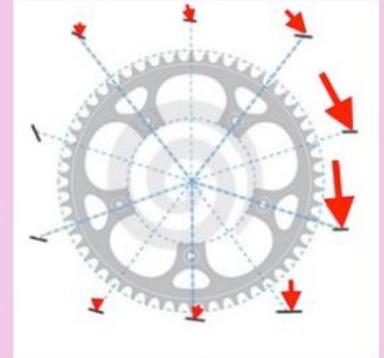
Moment of force (N·m) = Applied force (N) x perpendicular distance (m) between the line of the force and the axis of rotation.

This turning effect occurs during all sporting activities.

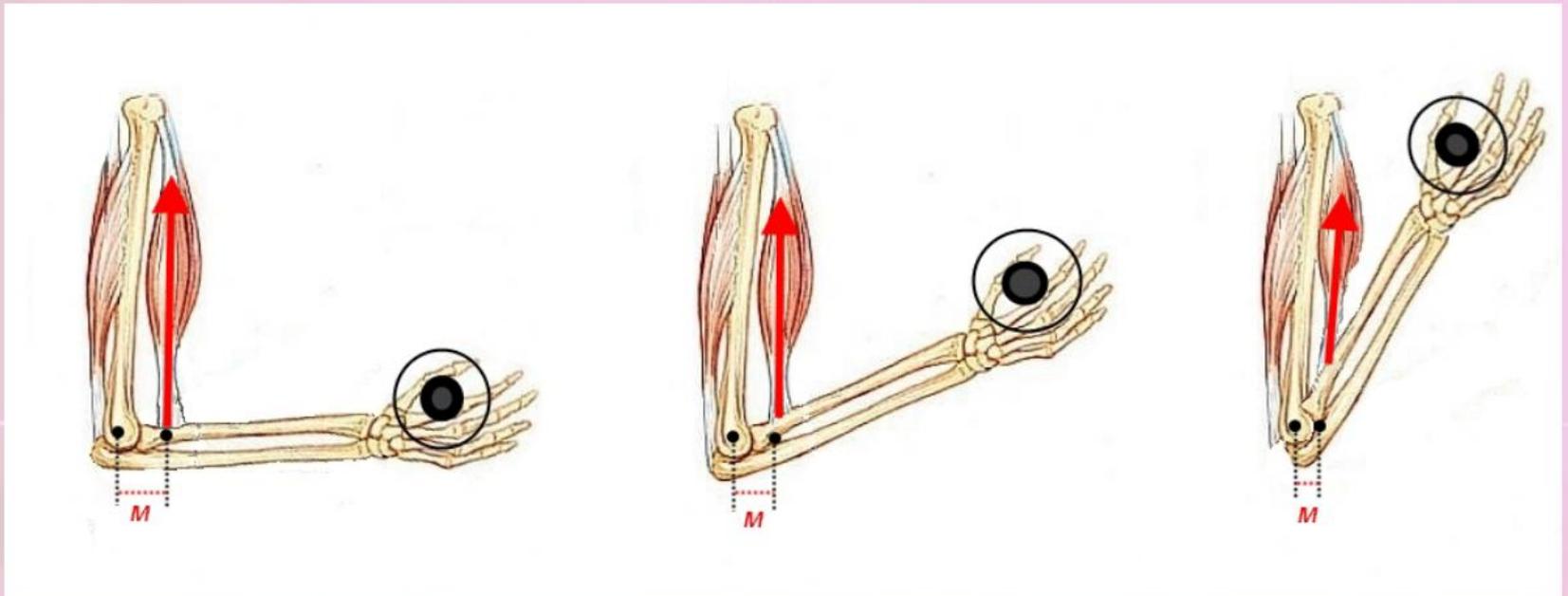


Creating Turning Forces: Changes in moment arm length

Moment of force (N·m) = Applied force (N) x perpendicular distance (m) between the line of the force and the axis of rotation.



The ability to apply force will alter as the moment arm (M) changes in length.



Fluid Mechanics: Drag

In an endeavour to enhance performance by 'shaving' fractions of a second from a race time athletes attempt to reduce the affect of air resistance or drag in the following ways.

Reduce air resistance by modifying equipment such that the athlete is more 'streamlined'.



Reducing the influence of air resistance through modification to technique – e.g. 'drafting'.

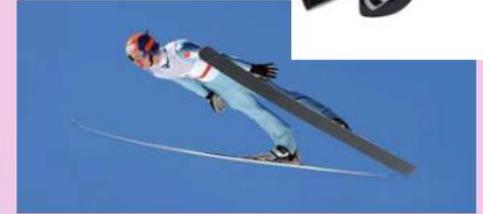
Fluid Mechanics: Drag

There are three types of drag to consider:

Pressure drag (or form drag) – a combination of eddy and frontal resistance is related to the shape and includes streamlining

Surface drag (skin friction) – is related to the surface of the objects and reducing the turbulence

Wave drag – relates to the energy lost due to the creation of waves



Fluid Mechanics: A focus on air

A fluid is a substance that has no fixed shape, such as air and water, although in this section we will focus on air.

A ball deviates in air during various sporting activities (e.g. tennis, golf, cricket, football, baseball and soccer) because of uneven pressures created around the ball.



The 'boundary' layer of air around the ball is particularly susceptible to both the type of

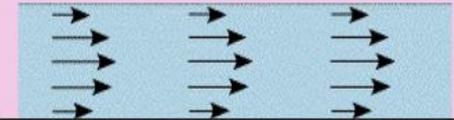
- air flow (laminar and turbulent), and
- spin of the ball (Bernoulli principle and Magnus effect).

One must also study the speed, orientation, shape and skin of an object to fully understand the influence of air.

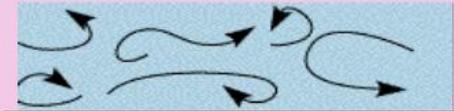
Fluid Mechanics: A focus on air

In 'laminar flow', the air flows in parallel layers, with no disruption between the layers (Figure a)
In 'turbulent flow' the air mixes and is irregular in flow (Figure b).

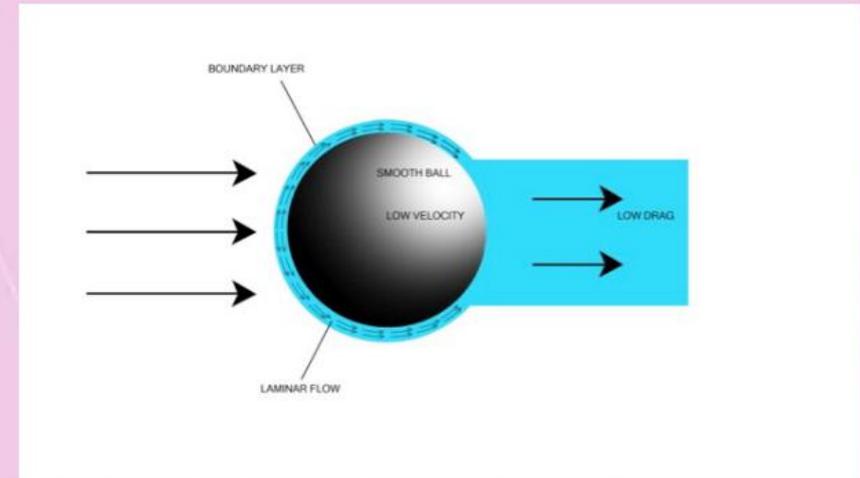
When an object moves through the air, the air which is closest to the ball interacts with the surface ('sticks to the surface') creating what is termed a 'boundary layer'



a. Laminar airflow



b. Turbulent airflow

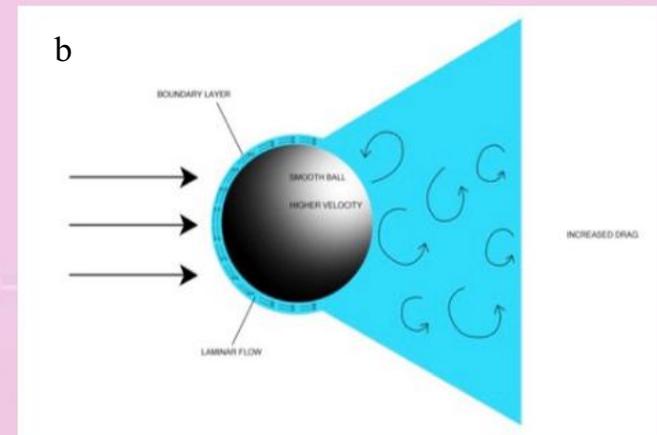
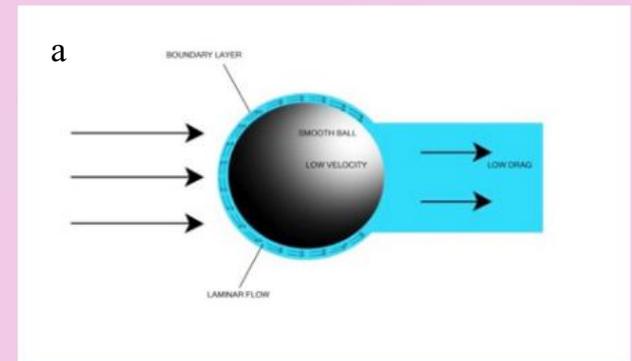


Fluid Mechanics: A focus on air

The type of airflow around the ball, combined with the velocity of the ball determines how quickly the boundary layer separates from the ball's surface (i.e. the separation point changes position).

For a smooth ball at low velocity (Figure a), where the airflow is laminar this separation point is near the back of the ball and the drag is minimal.

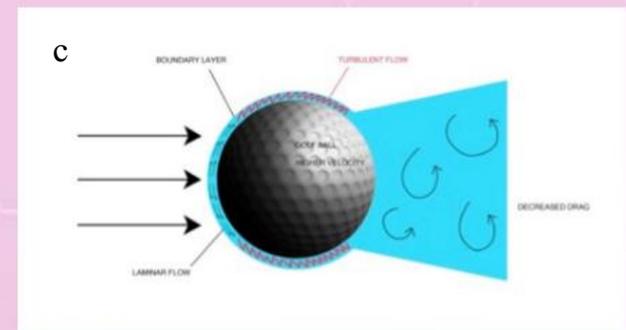
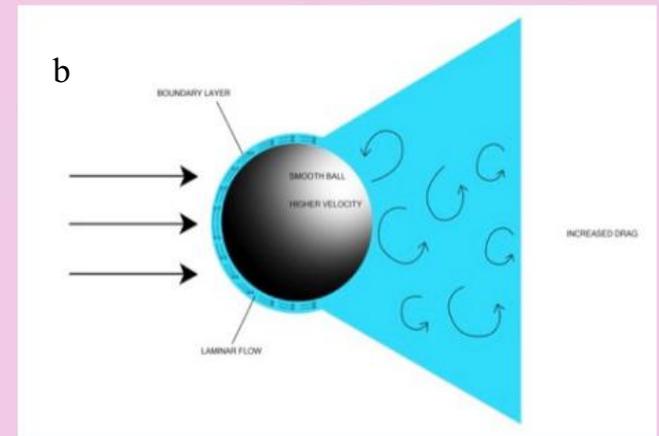
Whereas at a higher velocity it separates earlier (Figure b) and the drag increases.



Fluid Mechanics: A focus on air

However, for an object such as a golf ball with dimples (Figure c) the initial laminar airflow becomes turbulent as the dimples help the boundary layer 'stick' to the surface of the ball.

This means that the separation point occurs later, ultimately leading to a decrease in drag (smaller wake) compared with that recorded for the smooth ball in Figure b.

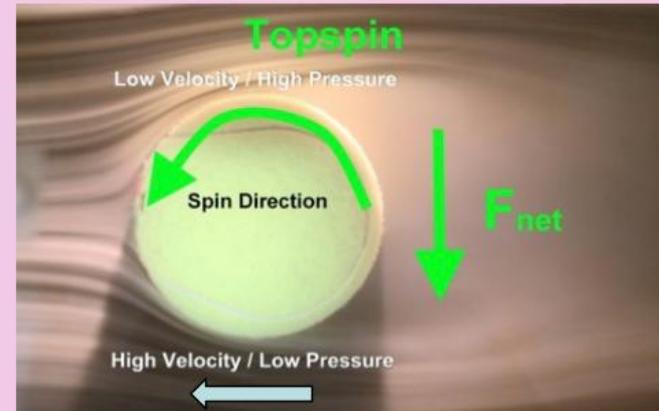


Bernoulli's Principle

Bernoulli's principle states that an increase in the speed of fluid occurs simultaneously with a decrease in pressure.

For a topspin shot, hit from right to left, as the boundary layer rotates with the ball, the particles on top of the ball decrease in speed (crash into the particles of air that the ball is moving through). Conversely the particles under the ball increase in speed, as they are moving in the same direction as the general airflow, producing a decrease in pressure.

For a backspin shot the reverse is true.

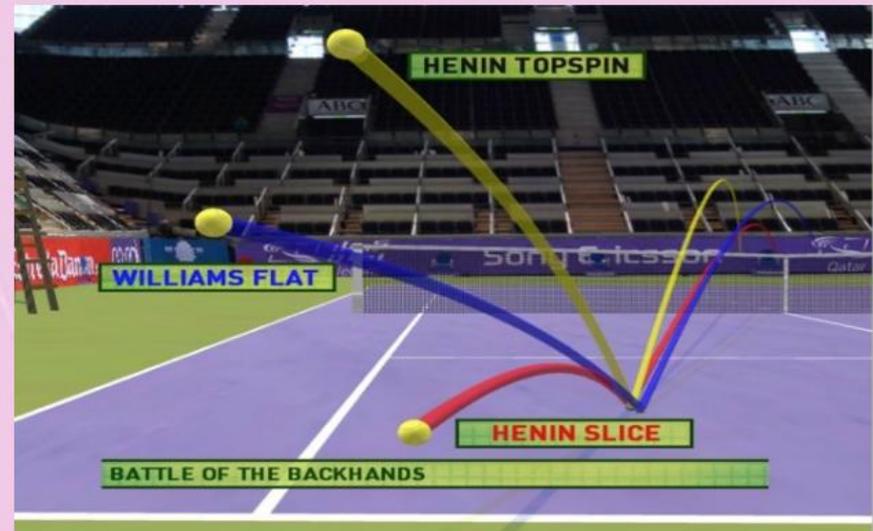
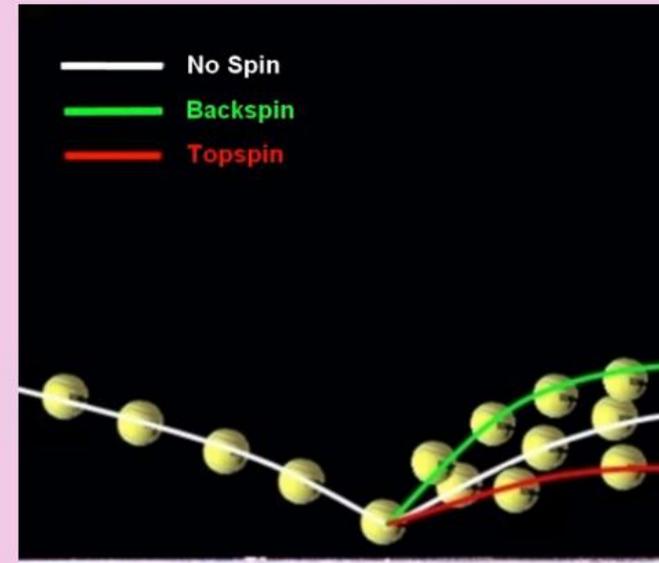


Magnus Effect and Spin

If the ball was to come in at the same approach angle then the type of spin the ball possesses will influence the rebound angle. If one compares the topspin and backspin rebound with the no spin situation you find that the ball bounces with a steeper rebound for the ball with backspin and lower for the ball hit with topspin.

In tennis, where the ball will approach at varying angles you typically get rebounds as can be observed for topspin, flat and slice (backspin) rebounds.

Remember, the curving effect of spin on the flight of a ball is termed the Magnus effect.



Spin

Exam style question

Use your knowledge of forces, spin, horizontal and vertical displacement in the air and after landing, to respond to and explain the following. Use diagrams where possible to assist your answer.

(15 Marks)

- (a) In tennis, you want to hit a ball deep into the opponent's court with a large 'error margin' at the net.
- (b) Your volleyball serve is hit with backspin.
- (c) You slice the golf ball off the tee. As a right handed golfer the ball curves to the right.

Spin

Answer: Answers are provided with different foci to assist student learning.

Use your knowledge of forces, spin, horizontal and vertical displacement in the air and after landing, to respond to and explain the following. Use diagrams where possible to assist your answer.

- (a) In tennis, you want to hit a ball deep into the opponent's court with a large 'error margin' at the net. (5 marks)
- (b) Your volleyball serve is hit with backspin. (5 marks)
- (c) You slice the golf ball off the tee. As a right handed golfer the ball curves to the right. (5 marks)

(a) Hit the ball with topspin – an eccentric force (1 mark), which will allow the ball to be hit high over the net, but the greater force 'on top of the ball' will assist to drop the ball back into court inside the baseline. (1 mark) – plus a correctly labelled diagram of the flight path and spin (pressure, velocity and net Magnus force) (3 marks)

(b) Back spin – the ball has been hit off-centre – an eccentric force. It will travel with linear and angular motion. (1 mark) The ball will have a high velocity on top with low pressure and on the bottom of the ball – the velocity will be low and the pressure high. (see diagram for marks) Therefore, the ball will experience lift and have a greater horizontal component than a ball hit with no spin. That is, it will float. (1 mark) – plus a correctly labelled diagram of the flight path and spin (pressure, velocity and net Magnus force) (3 marks)

(c) Sidespin, eccentric force (off-centre) is applied to the ball (1 mark)– low velocity and high pressure on the side of the ball that is closer to the golfer, therefore, the ball moves to the right. (1 mark) – plus a correctly labelled diagram of the flight path and spin (pressure, velocity and net Magnus force) (3 marks)

Biomechanical Analysis

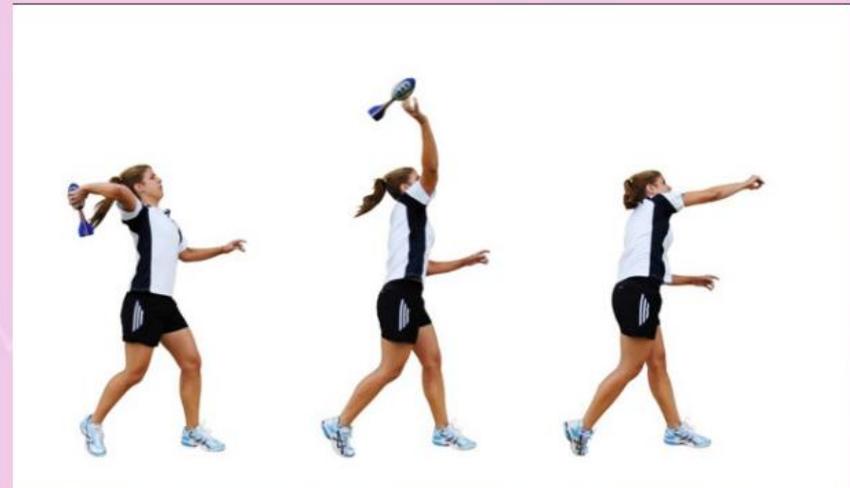
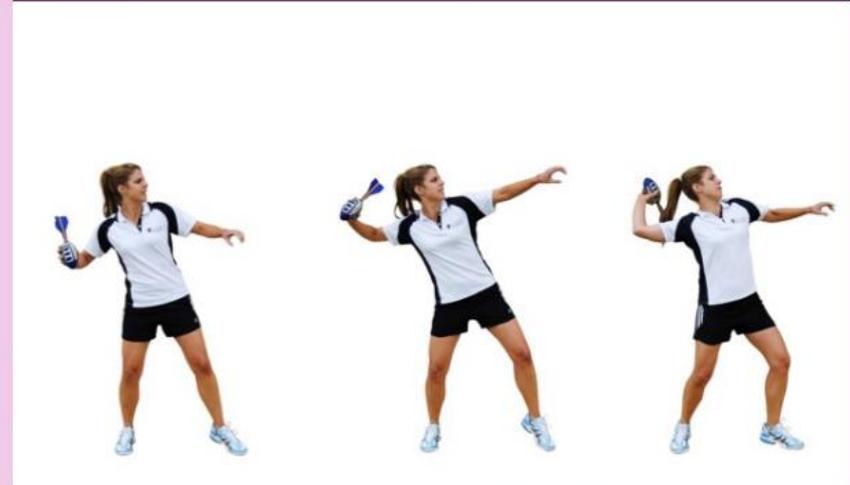
Discuss the variables as they apply to throwing

Moment of inertia (**I**) – The distribution of mass.

Angular momentum: Combination of moment of inertia and angular velocity (rotational speed).

Levers: Three levers in the body - mostly, 3rd class.

Torque: A product of force and a moment arm (perpendicular distance to line of the force).



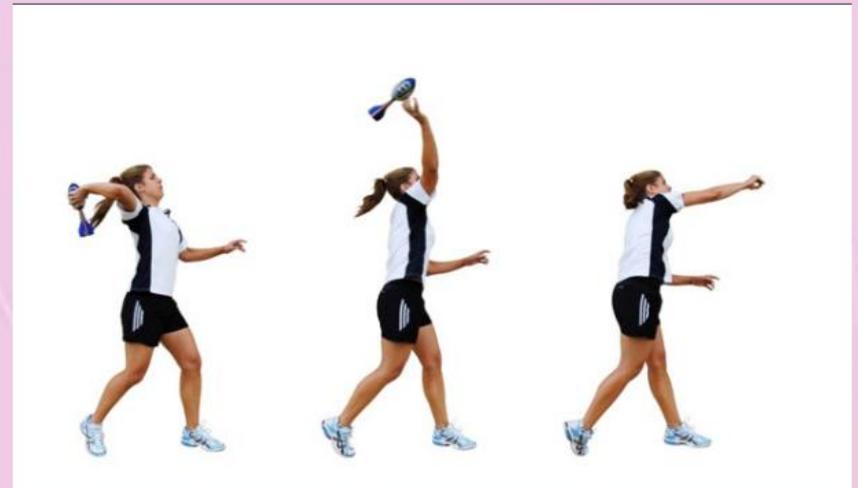
Biomechanical Analysis

Discuss the variables as they apply to throwing

Balance: May be static or dynamic (position of C of G to base of support).

Coordinated movement: Either velocity (sequential) or accuracy (as one) based.

Force-time: Impulse - the application of force over time (Impulse: force x time).



Biomechanical Analysis

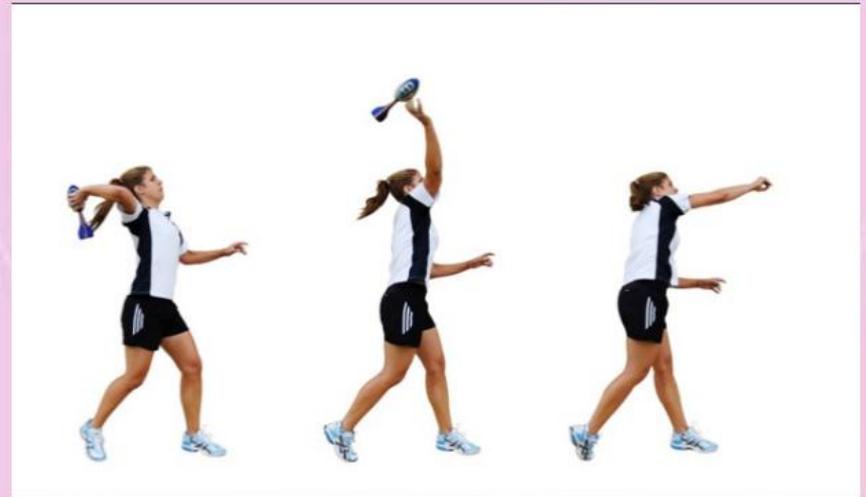
Discuss the variables as they apply to throwing

Inertia: The reluctance of a body to move.

Optimal projection: Related to height of release and landing.

Range of motion: Total range of movement at key joints related to the activity.

Spin: If possible consider spin in the air and bounce following landing.



Biomechanical Analysis

Discuss the variables as they apply to running

Moment of inertia (I): The distribution of mass.

Angular momentum: Combination of moment of inertia and angular velocity (rotational speed).

Levers: Three levers in the body - mostly, 3rd class.

Torque: A product of force and a moment arm (perpendicular distance to line of the force).



Biomechanical Analysis

Discuss the variables as they apply to running

Balance: May be static or dynamic (position of C of G to base of support).

Coordinated movement: Either velocity (sequential) or accuracy (as one) based.

Force-time: Impulse - the application of force over time (Impulse: force x time).



Biomechanical Analysis

Discuss the variables as they apply to running

Inertia: The reluctance of a body to move.

Range of motion: Total range of movement at key joints related to the activity.





THE UNIVERSITY OF
**WESTERN
AUSTRALIA**

FUNCTIONAL ANATOMY

Dr Grant Landers , Dr Peter Whipp and
Dr Kym Guelfi



PHYSICAL EDUCATION STUDIES ATAR UNITS 3 AND 4
A TEXTBOOK FOR TEACHERS AND STUDENTS

Skeletal Muscle Structure

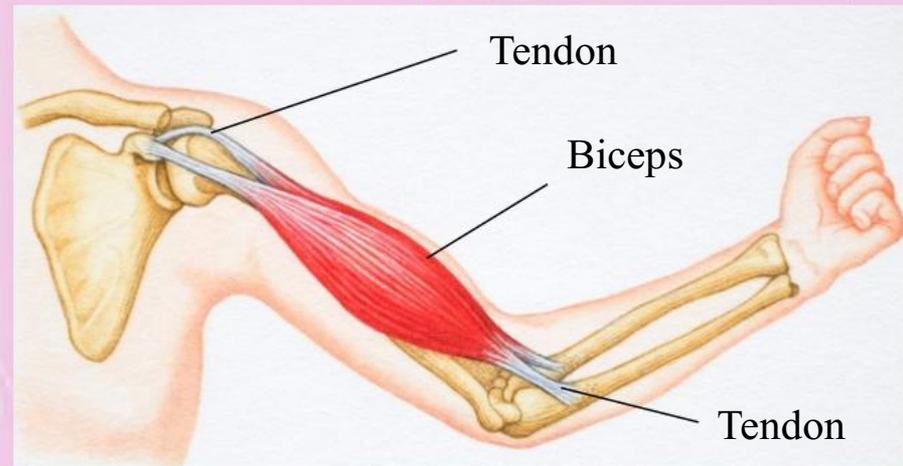
Skeletal muscles create movement or assists maintaining posture when they contract.

They are connected to bones via tendons.

Contraction is voluntary, that is you must think about the movement for it to happen.

Skeletal muscles only pull, they do not push.

During contraction the muscle shortens as tension develops and the muscle appears to get bigger.



Skeletal Muscle Structure

Muscle Components

The smallest units in the muscle are the *actin* & *myosin*.

Actin is a thin protein whereas myosin is a thick protein.

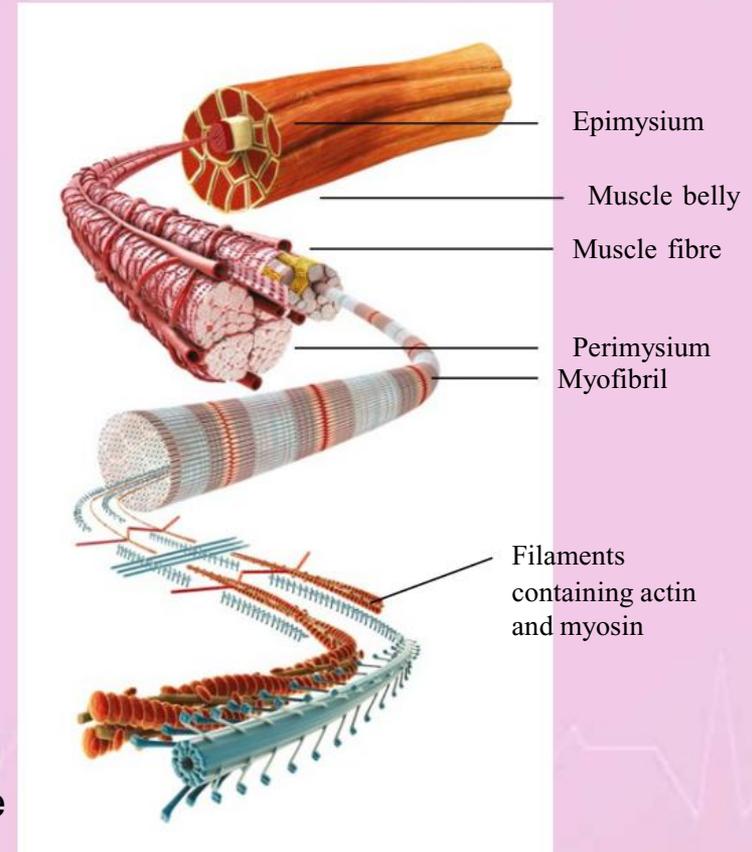
The *myofibrils* are a combination of the actin & myosin.

A group of myofibrils make up the *muscle fibres*.

Muscle fibres are surrounded by the *perimysium*.

Skeletal muscles are made up of long muscle fibres all bundled together forming the *muscle belly*.

The *epimysium* surrounds the muscle belly holding all the muscle fibres together.



Skeletal Muscle Structure

Shopping Bags – an example

The structure of the muscles similar to filling shopping bags.

Each bag represents the outer layer – *epimysium* of a muscle and separates your shopping (muscles) and holds it all together.

Inside the shopping bag we have a number of groceries (*fascicle* – bundles of muscle fibres).

Each with their own external packaging – or *perimysium* which keeps each item (or bundle of muscle fibres) separated.

Each grocery item (fascicle) is comprised of number smaller components.

That is within the individual packaging (perimysium) we find the strands of spaghetti, slices of bread or a dozen eggs (*fibre*).

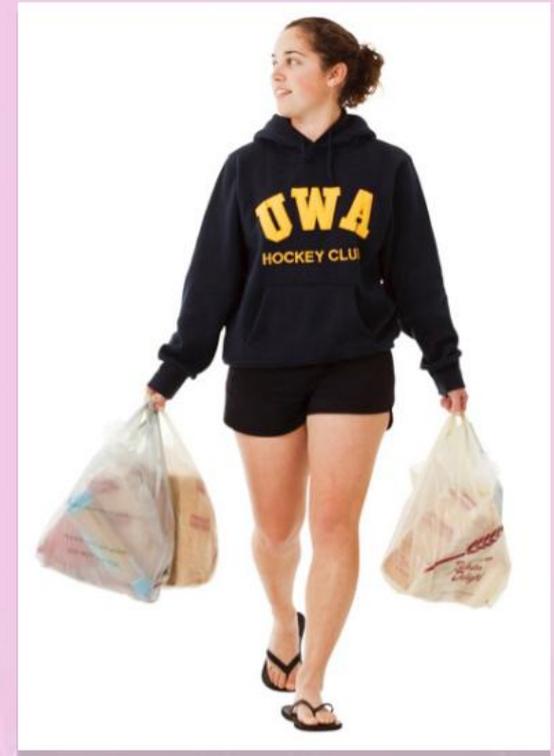


Skeletal Muscle Structure

Exam style question

Place in order, from the largest to the smallest component, the following terms related to skeletal muscle structure:
(1 mark)

- Muscle fibre
- Myofilament
- Muscle belly
- Myofibrils
- Fascicle



Skeletal Muscle Structure

Answer

Place in order, from the largest to the smallest component, the following terms related to skeletal muscle structure: (1 mark)

Muscle fibre, Myofilament, Muscle belly, Myofibrils, Fascicle.

Muscle belly

Fascicle

Muscle fibre

Myofibrils

Myofilament



Skeletal Muscle Contraction

Contractile Unit

The contractile unit of the muscle is the *sarcomere*.

A sarcomere is made up of overlapping *actin* & *myosin* proteins.

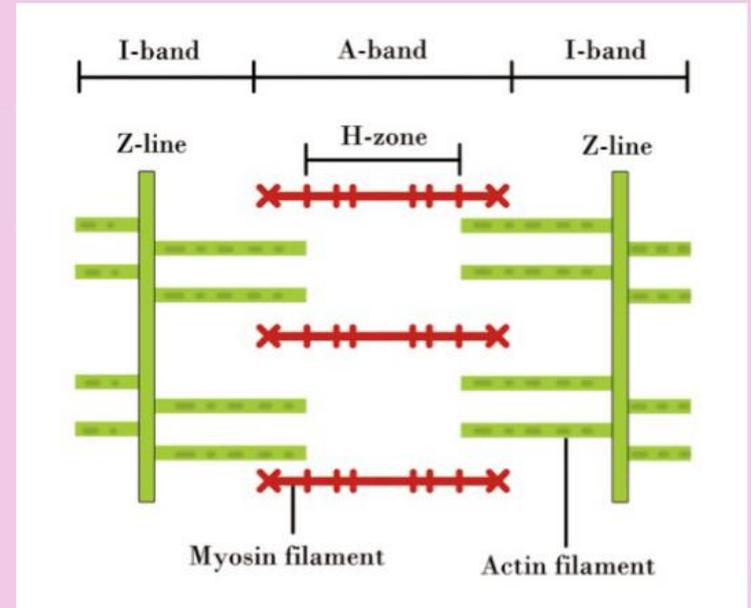
Z lines form the boundary of the sarcomere.

Actin is attached to the Z lines.

The myosin filaments run parallel to the actin and sit between each actin filament, in the middle of the sarcomere.

Myosin does not attach to the Z lines.

Myofibrils are made up of many sarcomeres.



Sarcomere

Skeletal Muscle Contraction

Sliding Filament Theory

The sliding filament theory explains the process of muscle contraction.

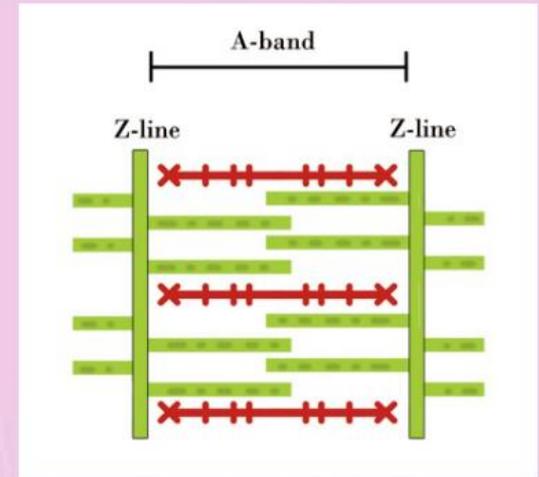
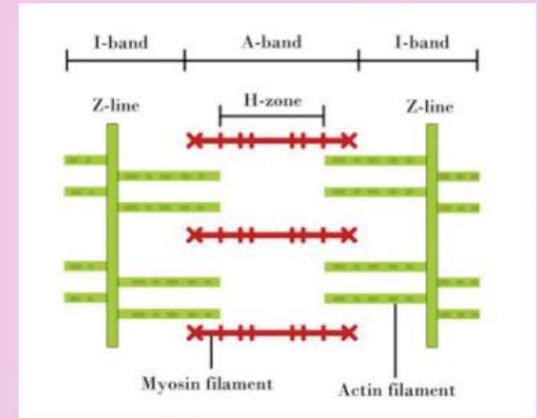
During contraction actin and myosin filaments slide past each other.

This brings the Z lines closer together, reducing the length of the sarcomere.

As more sarcomeres contract the length of the muscle belly is reduced.

Each sarcomere may shorten 20-50% of its resting length.

Millions of sarcomeres may contract at the same time creating a forceful contraction.



Skeletal Muscle Contraction

Exam style question

Using your understanding of the sliding filament theory, upon receiving a neural stimulus to contract a muscle, what happens first?

(2 marks)



Skeletal Muscle Contraction

Answer

Using your understanding of the sliding filament theory, upon receiving a neural stimulus to contract a muscle, what happens first? (2marks)

*The myosin cross-bridges reach out and grab-on to the actin (1 mark)
and begin to oscillate pulling the actin inwards. (1 mark)*



Developing Muscle Force

Force-Velocity Relationship

It takes time for sarcomeres to contract.

Rapid movements do not allow complete contraction of the sarcomere.

To develop greater force more time is required for all sarcomeres to contract fully thus movements may be slower e.g. pulling a truck.



The greatest amount of force can be developed during an isometric contraction, when there is no movement in the muscle.

When there is no resistance to the movement or no force exerted, the greatest velocity of that movement is achievable.

If you were to throw a table tennis ball you could move your arm much faster than if you were trying to throw a shot put.

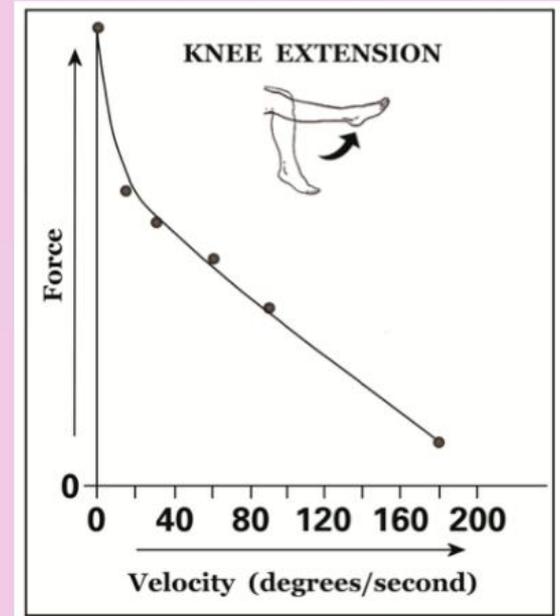
Force-Velocity Relationship

Maximum force is generated from an isometric contraction.

Power is a combination of strength and speed.

To achieve maximum power, the velocity and the resistance should be approximately one third of maximum values.

Most cyclists, choose a gear that maintains a cadence of between 75 and 90 rpm (30-40% of maximum). This offers the most efficient combination of resistance and velocity of leg turn over. Therefore, the greatest horizontal velocity can be produced.



Developing Muscle Force

Force-Length Relationship

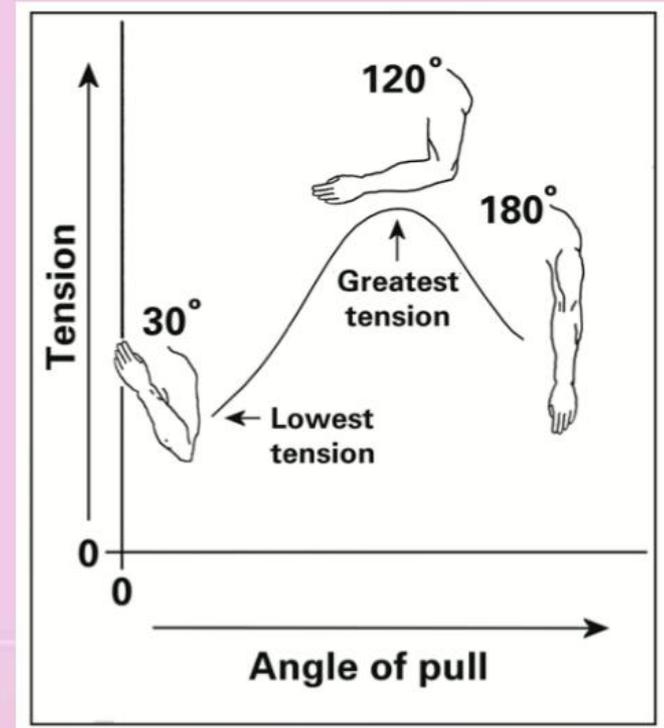
The length of a muscle and the angle at the joint has an impact on the force that can be generated.

The optimum muscle length and joint angle is different for each part of the body.

However, the optimal position is somewhere near the middle of a joints range, allowing maximum attachment of the myosin cross-bridges with the actin.

The longer muscles can create a greater range of motion at a joint.

A shorter wider muscle produces greater amounts of force.



Nervous System

The *nervous system* comprises two main parts, the CNS & PNS.

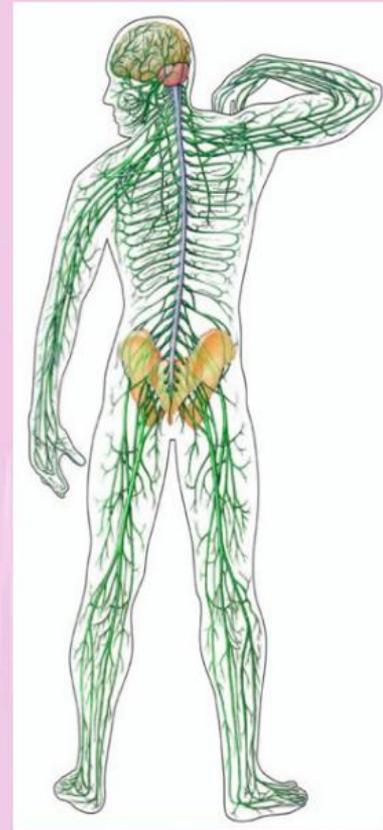
The *CNS* is comprised of the brain and spinal cord.

The *PNS* includes all the nerve branches that our outside the spinal cord.

Information must be sent from the brain down the spinal cord then to the target muscle for muscle contraction, and thus movement to occur.

The information is sent via an electrical impulse with the nerves acting as a conductor. These nerves act in the same manner as an electrical cable such as the power cord for a toaster.

When neural messages travel to the muscle from the CNS, they do so along *motor neurons* and when they send impulses back from receptors to the brain, they do so along *sensory neurons*.



Components of a Motor Neuron

A *motor neuron* is a nerve whose end point is a muscle.

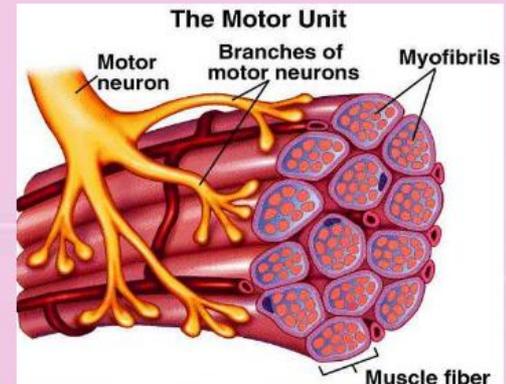
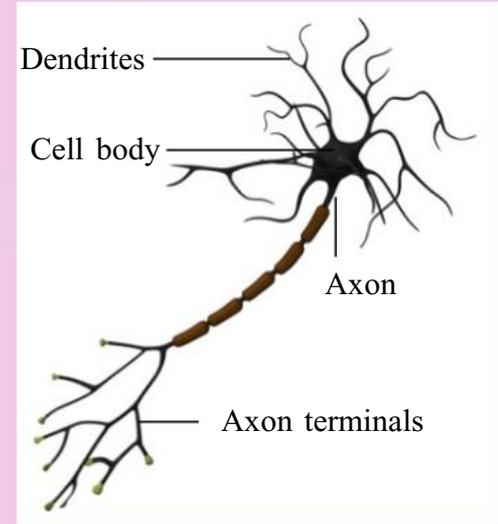
A motor neuron or nerve is made up of three main parts; the dendrite, cell body and axon.

The *dendrite* is like a TV antennae, it receives the signal or information from the CNS. It feeds this information to the cell body.

A *cell body* directs the activities of the neuron, so when it receives the signal it then transmits the information along the length of the axon.

The *axon* is responsible for transmitting messages away from the cell body.

The motor neuron and the muscle fibres that it innervates are collectively called a *motor unit*.



Neuromuscular Structure and Function

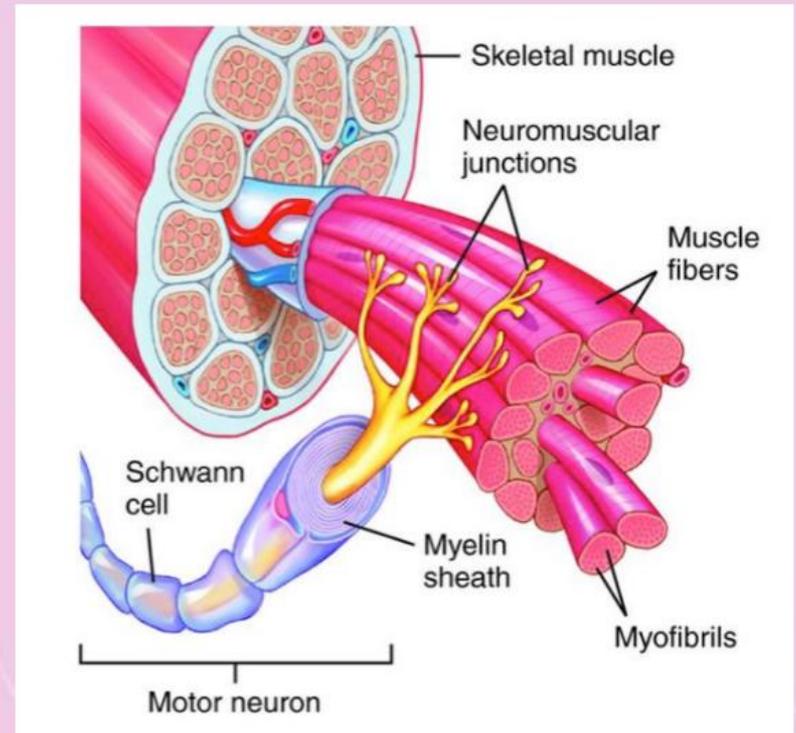
Motor Units

The *motor unit* refers to the muscle fibres which are influenced by each nerve.

The axons of the neurons can branch to one or many thousands of muscle fibres.

In large muscles, such as the quadriceps in the thigh, a motor unit may comprise 1000s of muscle fibres where big, powerful movements are required.

When precision is needed, such as movements of the eye, a motor unit may be 1–3 muscle fibres.



Developing Muscle Tension

The All-or-None Principle of Motor Neuron Stimulation

The *all-or-none principle* of a motor unit states:

If an electric stimulus reaches a threshold level, then all of the muscle fibres associated with that unit will contract to their maximum level and all at the same time.

The relationship between muscle contraction and nerve function is similar to turning on a light in a darkened area.

Each time you 'flick the switch' a light will come on.



Developing Muscle Tension

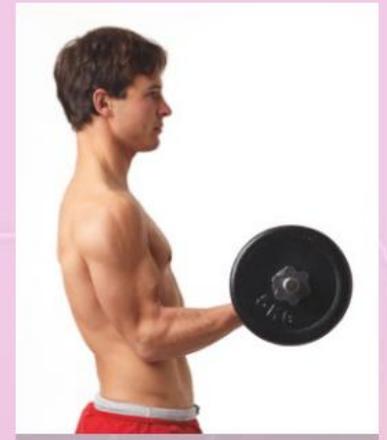
Neuromuscular Response to Strength Training

Improvements in muscular strength can occur in the first two to eight weeks of training without any changes in muscle size.

This is because the improvements first occur at the neuromuscular level, that is, the skill level of the movement improves.

There are four main responses to strength training without changes in muscle bulk:

1. improved technique
2. increased firing rate of motor units
3. more motor units are recruited, and
4. the firing pattern of the motor units are better coordinated.



Muscle Fibre Types

Comparing Fast & Slow Twitch Muscle Fibres

	Type I fibres	Type IIa fibres	Type IIb fibres
Speed of contraction	Slow	Fast - intermediate	Fast - explosive
Endurance qualities	High	Low	Very low
Predominant energy system used	Aerobic	Anaerobic	Anaerobic
Size	Small	Large	Large
Colour	Red	White	White

Muscles

Exam style question

Using your understanding of fibre types, explain how sprint athletes are born and not made.

(3 marks)



Muscles

Answer

Using your understanding of fibre types, explain how sprint athletes are born and not made.

Elite sprinters have relatively high percentages or predominance of Type II fibres (fast-twitch). (1 mark) You are born with and do not change your percentage of muscle fibre types. That is, they are determined by your genetic heritage (your parents) and do not change even with training. (1 mark) Therefore, the limits placed on your allocation of specific fibre types at birth, limits your ability to generate high levels of force in exceptionally short periods of time – as in sprinting. (1 mark)





THE UNIVERSITY OF
**WESTERN
AUSTRALIA**

EXERCISE PHYSIOLOGY

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PHYSICAL EDUCATION STUDIES ATAR UNITS 3 AND 4
A TEXTBOOK FOR TEACHERS AND STUDENTS

Nutritional Considerations for Exercise

A **balanced diet** is important not only for everyday health, but also for optimal athletic performance.

A balanced diet includes healthy amounts and proportions of the three macronutrients - **carbohydrate**, **fat** (lipid) and **protein** - as well as a variety of **minerals** and **vitamins**.

Fat



Carbohydrate

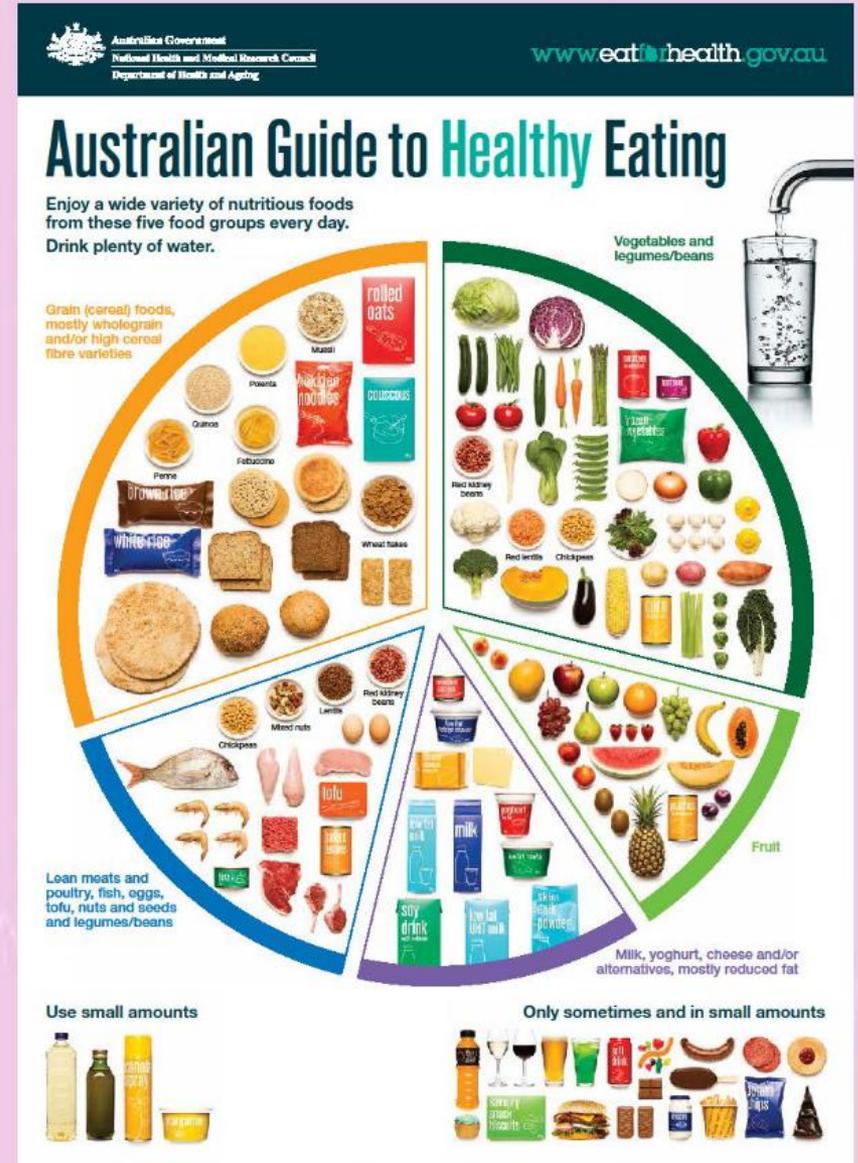


Protein



Nutritional Considerations for Exercise

The Australian Guide to Healthy Eating represents the types and proportions of different foods we should aim to consume each day for good health and well-being.



Carbohydrate

Carbohydrates account for ~55% of total energy intake.

The carbohydrate intake of an endurance athlete may account for up to 70% of total energy intake.

Carbohydrates include:

- simple sugars (such as honey, table sugar and fruit juice)
- complex carbohydrates (such as potatoes, bread, cereal, rice and pasta).



Carbohydrate

Carbohydrates are digested to a single small molecule called glucose.

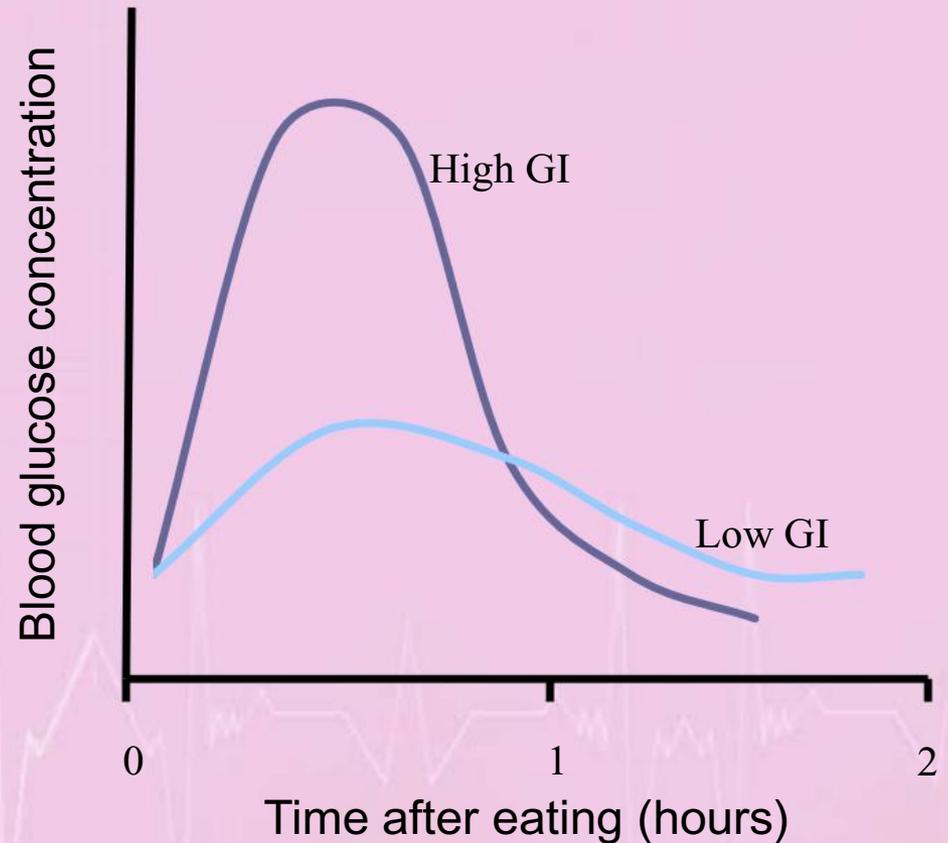
Glucose obtained from dietary carbohydrate is either:

- released into the bloodstream for circulation
- converted into glycogen for storage in the muscle and in the liver.

The amount of glycogen that can be stored in the body is limited to 600-800 g.

Glycaemic Index

The glycaemic index (GI) is a measure of the speed at which glucose is released into the bloodstream after eating carbohydrates.



Glycaemic Index

	Food	Glycaemic Index
High Glycaemic Index Foods (GI > 70)	Watermelon	72
	Jellybeans	76
	Coco Pops™ cereal	77
	Honey	87
Low Glycaemic Index Foods (GI < 55)	Banana	50
	Apples	40
	Egg Pasta	46
	All-Bran™ cereal	30

Fat

Dietary fat accounts for ~30% of total energy intake.

Saturated fatty acids (found in full cream milk, cheese and fatty meats) are considered unhealthy.

Unsaturated fatty acids (avocados, fish, nuts and olive oil) can be beneficial for health if consumed in moderation.



Fat

Dietary fats are broken down in the digestive system to free fatty acids.

Free fatty acids obtained from dietary fat are either:

- released into the bloodstream for circulation
- stored as triglycerides (a molecule resulting from the combination of three fatty acids) in adipose tissue.

Fat stored as triglycerides in the body provides a plentiful source of energy.



Protein

A protein intake of ~15% of total energy, or 0.8 g per kilogram of body mass is adequate for most active men and women.

Strength and endurance athletes may require a protein intake of up to 1.6 g per kilogram of body mass.

Protein consumed in the diet is digested into amino acids.



The primary role of protein is to maintain the body's structures, growth and repair of muscle tissue.

Fluid Intake

A balanced diet includes drinking plenty of water to ensure optimal health and performance.

The body loses about 2 L of fluid per day from general living.

Plain water is adequate to replace fluid lost due to normal daily activities.

Daily fluid requirements are impacted by exercise and the environmental conditions.



Nutritional Requirements for Physical Activity

It is typically recommended that the general population should obtain ~55% of energy intake from carbohydrates, less than 30% from fat, and ~15% from protein.

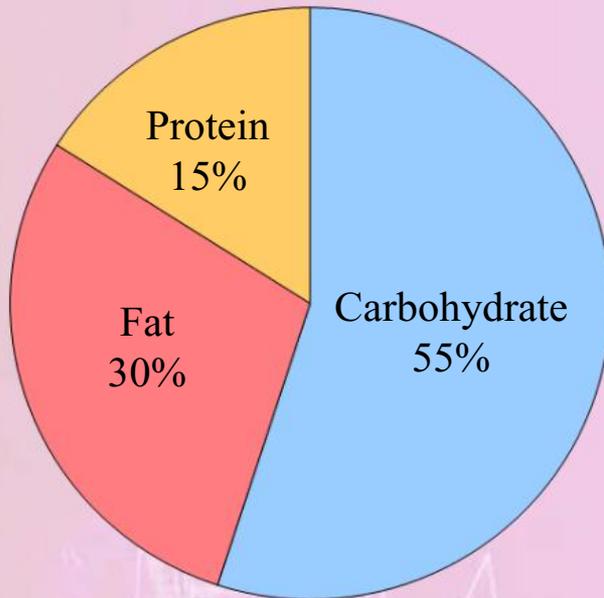
For an athlete, the optimal percentage of carbohydrate, fat and protein in the diet is dependent upon the specific sport of interest.

The total amount of energy (kJ) consumed is also highly variable depending upon the specific sport of interest.



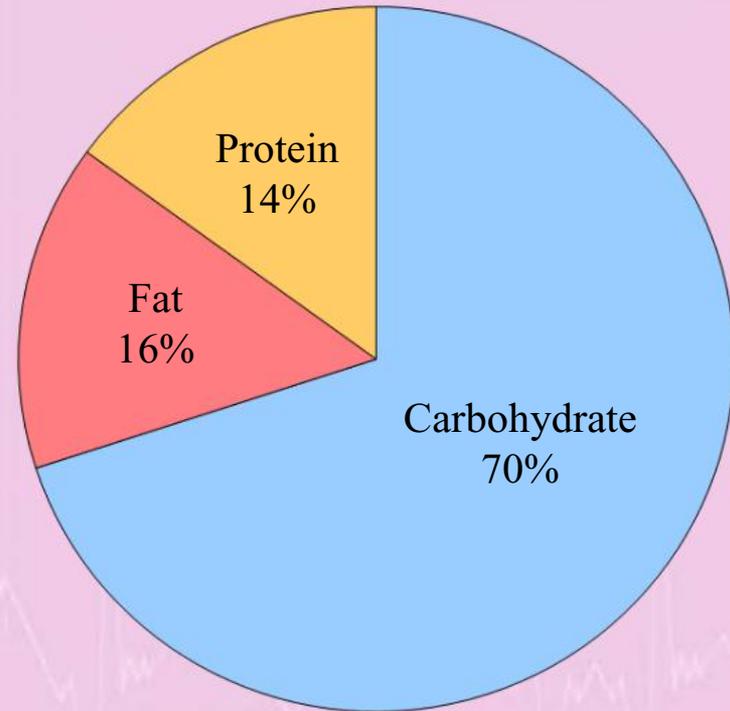
Nutritional Requirements for Physical Activity

Inactive individual



Total energy intake = 8,000 kJ

Endurance athlete



Total energy intake = 17,000 kJ

Nutrition

Exam style question

Using a specific sporting example for each of the following, identify and account for how an athlete's overall diet may vary from that recommended in the 'Australian Guidelines for Healthy Eating' for:

i. Carbohydrate

ii. Protein

iii. Total kilojoule intake

(6 marks)



Answer

Using a specific sporting example for each of the following, explain and account for how an athlete's overall diet may vary from that recommended in the 'Australian Guidelines for Healthy Eating' for:

i. Carbohydrate (2 marks)

Because carbohydrate is the primary fuel source for an endurance athlete (i.e. Olympic distance triathlete) (1 mark) the percentage of carbohydrate in the diet may increase from 55% up to 70%. (1 mark)

ii. Protein (2 marks)

Because protein plays a vital role in the growth and repair of muscle tissue, for athletes that undertake intense resistance training (i.e. Bodybuilding, shot put) (1 mark) the percentage of protein in the diet may increase from 15% up to 30%. (1 mark)

iii. Total kilojoule intake (2 marks)

While sedentary people may have a kilojoule intake need of approximately 6000-8000 kJ, athletes such as competition road cyclists (1 mark) expend high levels of energy and therefore may have nutritional intake requirements of 25,000 kJ or beyond. (1 mark)

Nutritional Considerations by Phase of Activity

The specific foods and drinks consumed before, during and after competition may influence athletic performance.



Pre-competition Nutrition

Carbohydrate loading

Carbohydrate loading (or glycogen loading) is a routinely used method to improve endurance performance by enhancing the amount of carbohydrate stored in the muscle.

Involves consuming high amounts of dietary carbohydrate (10–12 g per kg of body mass) in the days leading up to competition, in combination with reduced training load.

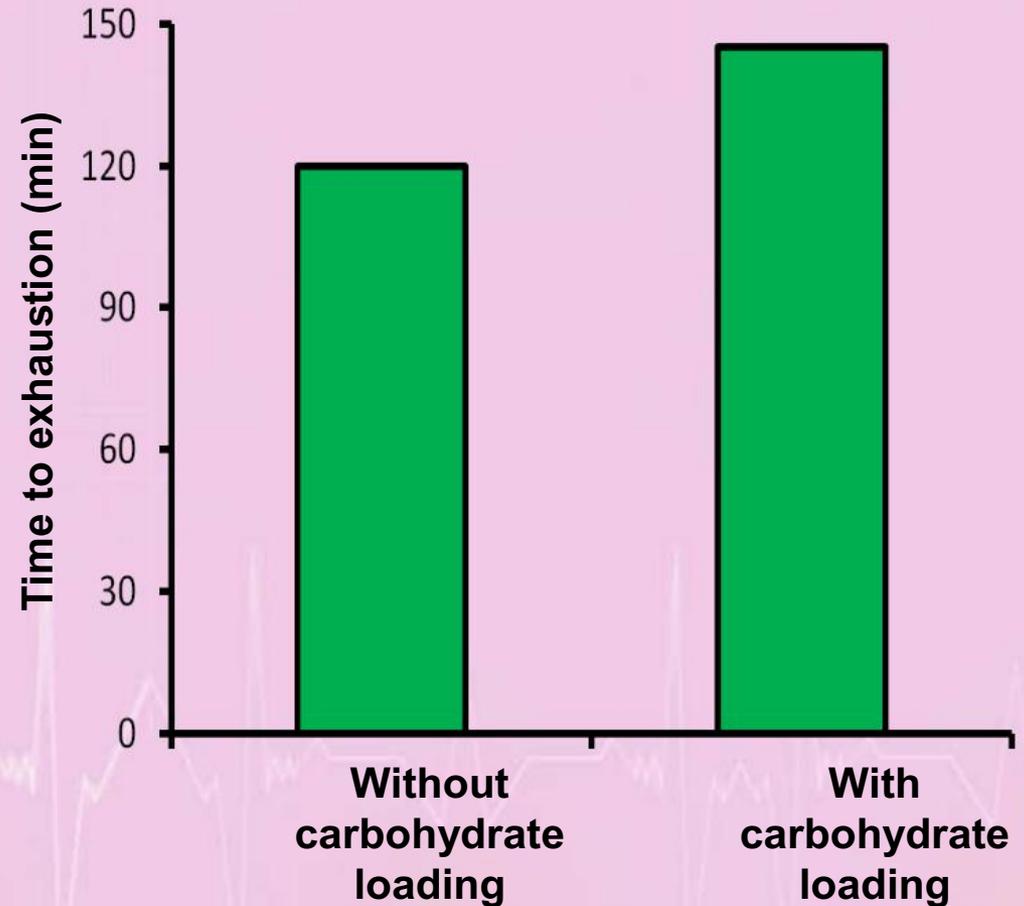
Results in higher than normal (almost double) levels of glycogen stored in the muscle ready for use on the day of competition.



Pre-competition Nutrition

Carbohydrate loading

By carbohydrate loading, an athlete will be able to work for longer at a higher intensity before the limited carbohydrate stores become depleted.



Pre-competition Nutrition



Carbohydrate loading

Carbohydrate loading will benefit events > 1 hour in duration such as a marathon or Olympic distance triathlon.

For team sports, carbohydrate loading may be useful in situations where games extend beyond 1 hour. However, it is often difficult for these athletes to carbohydrate load effectively since they cannot properly 'taper' within the context of a weekly training schedule.

In sprint or power events, carbohydrate loading may be detrimental to performance since weight gain of about 2 kg is not uncommon following a period of carbohydrate loading.

Sample carbohydrate loading diet for a 70 kg person

Meal	Food	Carbohydrate (g)
Breakfast	8 weetbix with low-fat milk and honey	118 g
	2 slices of toast with strawberry jam	40 g
	1 banana	27 g
	2 cups of orange juice	60 g
Lunch	2 rounds of sandwiches with choice of filling	80 g
	1 muffin with honey	60 g
	1 apple	25 g
	1 Sports drink	35 g
Dinner	Large serving of spaghetti bolognese (3 cups of pasta)	150 g
	3 slices of garlic bread	35 g
	1 can of lemonade	38 g
	1 serve of vanilla ice cream	30 g
Snacks	1 x museli bar	23 g
	1 x tub yoghurt	30 g
	1 x glass of cordial	20 g
	TOTAL	770 g (11 g/kg)

Pre-competition Nutrition

Carbohydrate loading

Is a potential advantage because it:

- leads to higher than normal (almost double) levels of glycogen stored in the muscle
- allows endurance athletes to work for longer at a higher intensity.

Is a potential disadvantage because it:

- increases pre-competition weight.



Pre-competition Nutrition

Exam style question

Athletes have a limited capacity to store carbohydrate. Explain the benefits of carbohydrate loading in the lead-up to a competition.

(3 marks)

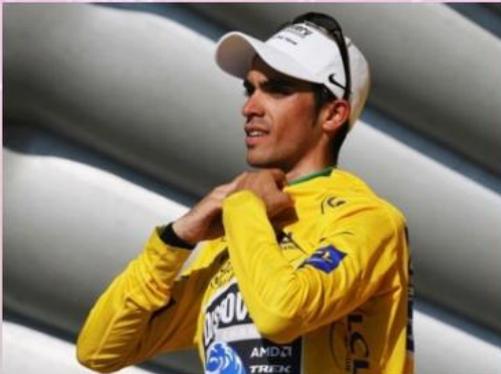


Pre-competition Nutrition

Answer

Athletes have a limited capacity to store carbohydrate. Explain the benefits of carbohydrate loading in the lead-up to a competition. (3 marks)

*An increased carbohydrate intake and reduced training load results in almost double the levels of glycogen stored in the muscle. (1 mark)
Therefore, an athlete will be able to work for longer at a higher intensity before carbohydrate stores become depleted. (1 mark) There is also an increased store of water in the body with increased levels of stored the glycogen. (1 mark)*



Pre-competition Nutrition

Pre-competition meal

Should focus on providing adequate carbohydrate and fluid for the commencement of exercise.

Pre-competition carbohydrate consumption is particularly important for endurance events lasting > 1 hour in duration.

The pre-competition meal should be:

- high in carbohydrate (low in fat and protein)
- consumed 3–4 hours prior to the event
- consider gastrointestinal upset (liquid versus solid meal?).

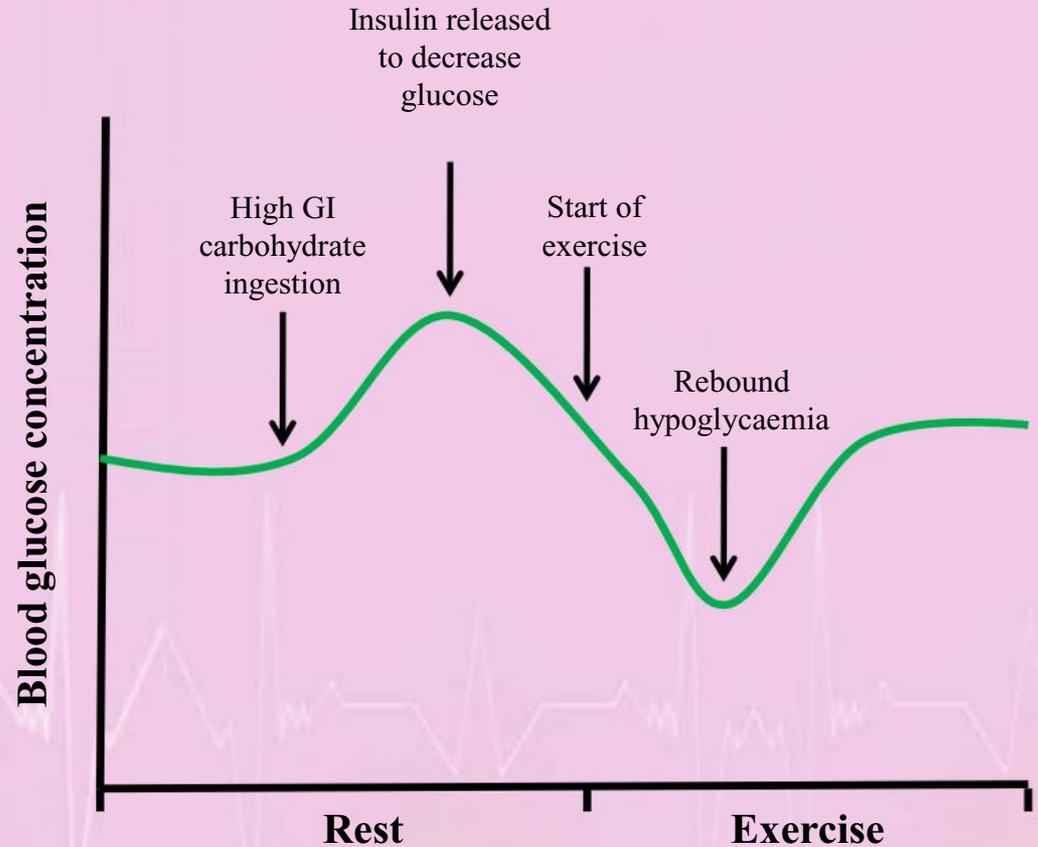
Pre-competition Nutrition

Pre-competition snack

Low-medium GI carbohydrate ingested 30–60 min prior to exercise will ‘top up’ carbohydrate stores.

Low-medium GI carbohydrate may be better (possibility of rebound hypoglycaemia?).

Liquid snack may be better tolerated.



Pre-competition Nutrition

Pre-competition fluid intake

Pre-competition fluid intake is important to ensure adequate hydration prior to the commencement of exercise.

As a general guide, athletes may consume 350–500 mL ~4 hours prior to competition.

If urine is still dark and concentrated in colour, or no urine is produced at all, the athlete should drink another 200–350 mL two hours prior to the event.



Nutrition During Exercise

The goal of nutritional strategies during exercise should be to minimise the depletion of carbohydrate stores and to replace fluid lost via sweat.



Nutrition During Exercise

Carbohydrate consumption

For endurance events, the athlete should aim to consume 30–60 g of carbohydrate for each hour of activity.

It is generally best to consume carbohydrate in a liquid form during exercise, since solid food is typically not well tolerated.

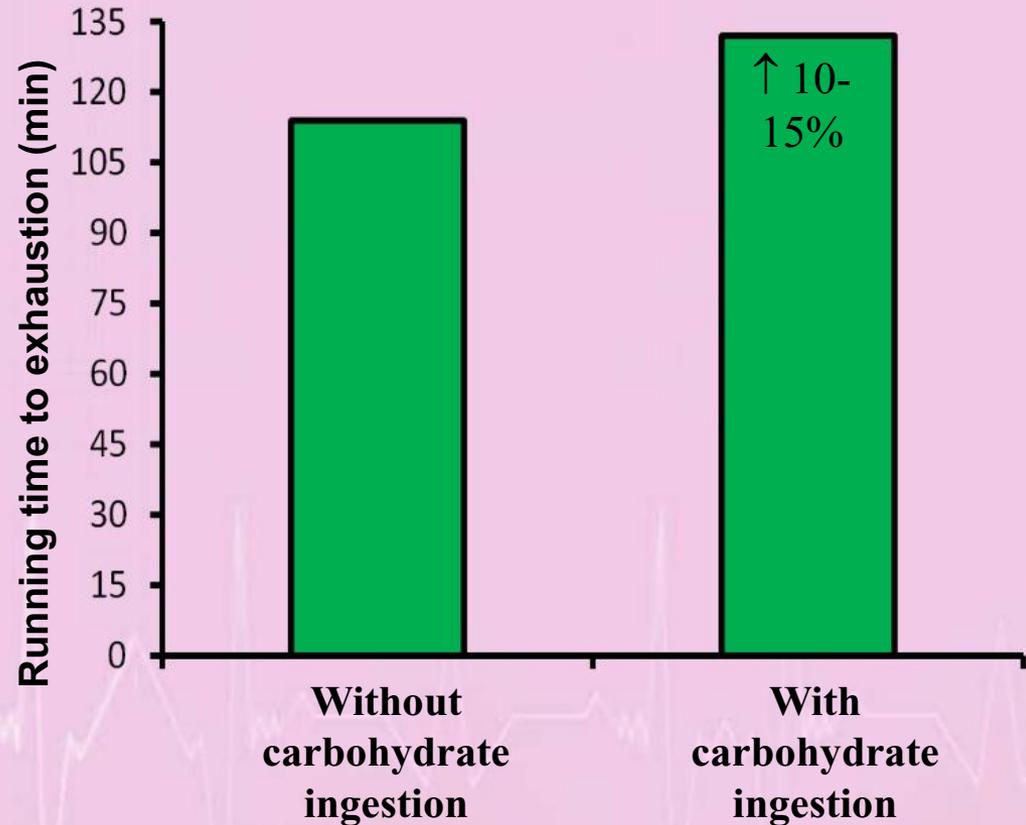
Moderate to high GI carbohydrates are preferable to low GI carbohydrates to ensure the rapid release of glucose into the bloodstream for use.



Carbohydrate gels

Nutrition During Exercise

Carbohydrate feeding during exercise will assist in prolonging endurance performance.



Nutrition During Exercise

Fluid consumption

Drinking during exercise (400–800 mL per hour) will decrease the risk of dehydration during prolonged events.

For short duration events, aim to drink 100–200 mL per 15 minutes.

Drinking plain water is adequate for exercise < 1 hour in duration.

For exercise > 1 hour, combining carbohydrate with fluid is beneficial.



Nutrition During Exercise

Fluid consumption

A carbohydrate concentration of 6–8% in solution is optimal for absorption in the gastrointestinal tract.

Cold and flavoured fluids encourage increased consumption.

Electrolytes increase the desire to drink and fluid absorption in the gastrointestinal tract.

Consuming the recommended amount of fluid during exercise may still not equate to the amount of fluid lost from sweat during exercise in hot conditions.



Recovery and Post-exercise Nutrition

Carbohydrate intake during recovery

Post-exercise nutrition should focus on replacing fuel stores (predominately carbohydrate) and body fluid losses.

Consumption of high GI carbohydrates immediately post-exercise will accelerate glycogen replenishment.



Recovery and Post-exercise Nutrition

Fluid intake during recovery

When fluid replacement is based on voluntary thirst, athletes typically drink only 50% of what is needed to replace sweat loss through exercise.

During recovery, athletes should aim to consume 1.5 times the nett fluid lost during exercise.

Post-exercise consumption of drinks containing electrolytes may speed rehydration by reducing urine production and stimulating thirst.

Sample Nutrition Plan for Half Ironman Triathlon

(Prepared by Dr Peter Peeling, Western Australian Institute of Sport)

TIME	FOOD	CHO (g)
Pre-race meal (3 hours prior)	6 Weetbix with hot water and honey 600 mL Powerade 300 mL water	80 g 35 g -
Pre-race snack (60 min prior)	1 x vanilla powerbar 300 mL Powerade 100 mL water	40 g 17 g -
Swim (28-30 min)	-	-
Swim-cycle transition	-	-
Cycle (2.5 hours)	2 x 600 mL Powerade 600 mL water 3 x Carboshotz 1 x vanilla powerbar	70 g - 90 g 40 g
Cycle-run transition	1 x Carboshotz	30 g
Run (1.5 hours)	500 mL water 1 x Carboshotz 300 mL Powerade	- 30 g 17 g
Post race (within 1 hour)	600 mL Powerade 500 mL water 2 x banana sandwich	35 g - 120 g

Sample Nutrition Plan for a Footballer

TIME	FOOD	CHO (g)
Pre-game meal (3–4 hrs before)	Spaghetti with napolitana sauce	70 g
	600 mL Sports drink	35 g
Pre-game snack (1–2 hrs before)	Banana and honey sandwich	60 g
During game	1.5 x Sports drinks	50 g
Half-time	1 x Sports drink	35 g
	Muesli bar or banana	27 g
Post-game (within 30 min)	Sports drink / Sustagen sport	50 g
	Lollies	35 g

Exam style question

A high-performance kayaker is competing in the 'Avon Decent' (2 days, paddling for 6 hours per day). Identify the sports nutrition principles for the following.

i. Pre-competition snack

ii. In-competition fluid replacement

iii. Post-day 1 competition – food and fluid replacement

(9 marks)

Answer

A high-performance kayaker is competing in the 'Avon Decent' (2 days, paddling for 6 hours per day). Identify the sports nutrition principles for the following. (9 marks)

i. Pre-competition snack (3 marks)

A low to medium GI snack (e.g. Fruit like strawberries, apples, oranges) (1 mark) consumed 30-60 minutes prior to the race to top-up carbohydrate stores and fluid. (1 mark)

ii. In-competition fluid replacement (3 marks)

Drink 400-800 mL per hour during the event – or the equivalent of the volume of fluids lost. (1 mark) The fluid should be cold and contain a carbohydrate concentration of 6-8% solution (1 mark) and some electrolytes (like Powerade). (1 mark)

iii. Post-day 1 competition – food and fluid replacement (3 marks)

Consume high GI carbohydrate immediately post-exercise. (1 mark) Evening meal should be low to medium GI – complex carbohydrate to replace the total kJ expended. (1 mark) Consume 1.5 times the nett fluid lost during exercise. (1 mark)

Environmental Influences on Performance

In order to understand the implications of preparing for and performing exercise in the heat or cold, you must first understand how the body regulates its temperature.

The body's core temperature is maintained close to 37°C .

If core temperature deviates too far from 37°C ($\pm 3^{\circ}\text{C}$), performance is severely impaired and the results can be life-threatening.



Environmental Influences on Performance

The body uses four mechanisms to regulate core temperature:

Radiation – transfer of heat by electromagnetic waves

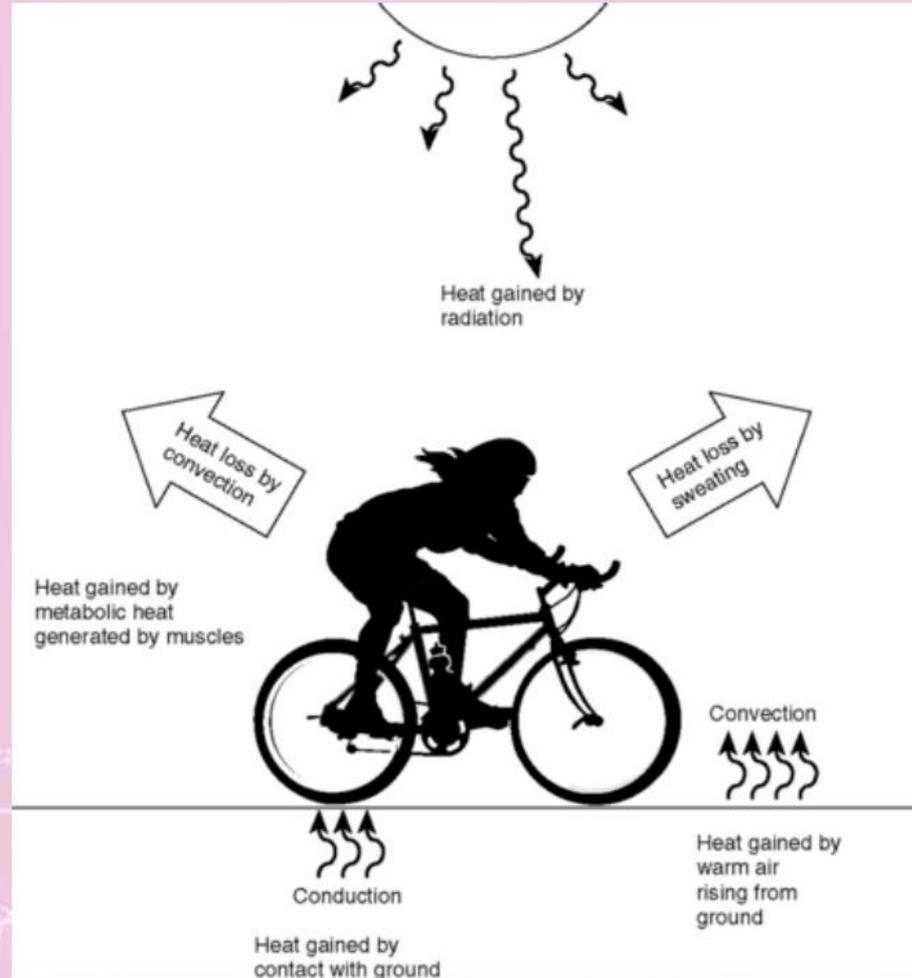
Conduction – transfer of heat through direct contact

Convection – transfer of heat by the motion of moving substances (typically air or water)

Evaporation – transfer of heat resulting from the evaporation of water (sweat) on the skin surface.

*Note: the transfer of heat is always from warmer objects to cooler objects. Also, the amount of heat transferred is relative to the temperature gradient (the temperature difference) between the two objects.

Environmental Influences on Performance

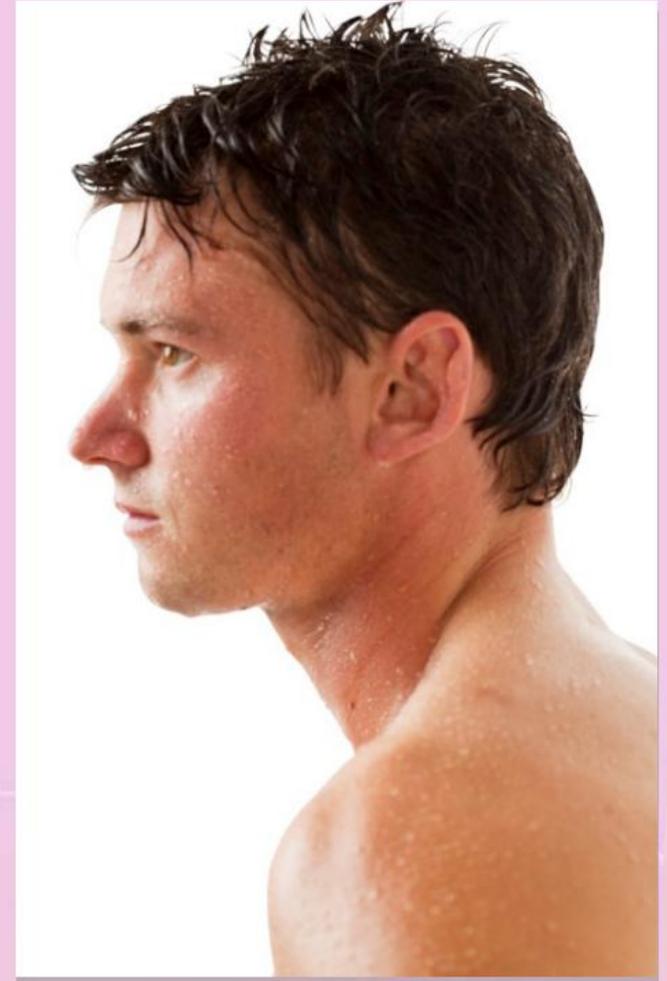


Exercise in the Heat

During exercise, the rapid increase in chemical reactions required to produce muscular work causes a major increase in heat production by the body.

This heat must be dissipated from the body in order to prevent a rise in core body temperature to a dangerous level.

During exercise in the heat, evaporation is the primary mechanism by which heat can be dissipated from the body.



Exercise in the Heat

When exercising in the heat, a significant amount of body fluid (water) is lost via sweat.

A team sport player may lose ~2 L of fluid per hour during intense exercise in the heat.

An elite marathon runner may lose up to 6 L of sweat in a race, even if taking on fluids at drinks stops along the way.

Ultimately, this amount of fluid loss causes dehydration which will impair both performance and continued heat dissipation.

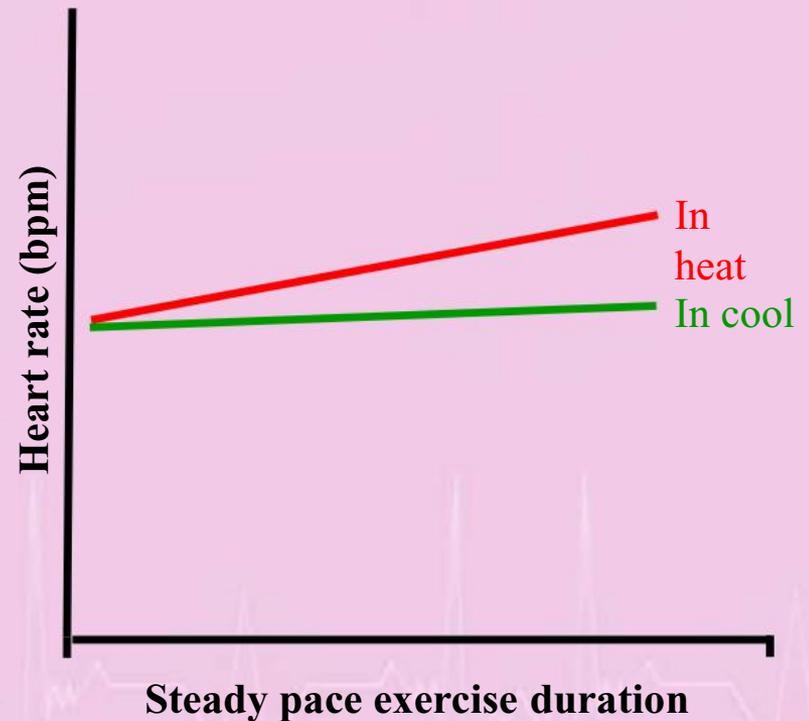
A loss of fluid equal to 1–2% of body mass during exercise will significantly impair both athletic performance and mental function.

Exercise in the Heat

Fluid loss during exercise in the heat results in reduced blood plasma volume and therefore:

- a **double heat load**
(↓ blood flow to both the working muscles *and* the skin)
- a **cardiac drift**
(↓ stroke volume leading to an ↑ heart rate to compensate).

Cardiac drift



Exercise in the Heat

Physiological responses to a 40 min treadmill run in the heat
(37° C and 36% humidity)

Time	Body mass	Heart rate	Core temperature	Skin temperature	Oxygen consumption	Blood lactate
Pre-exercise	75.7 kg	52 bpm	37.23°C	31.17°C	-	1.3 mM
20 min of exercise	-	177 bpm	39.11°C	37.26°C	4.12 L/min	4.0 mM
37 min of exercise	-	182 bpm	39.53°C	37.45°C	4.17 L/min	4.3 mM
Post-exercise	73.65 kg	-	-	-	-	-
Body mass loss 2.35 kg						

Exercise in the Heat

Pre-event hydration strategies

Adequate hydration is crucial prior to exercise in the heat.

The amount of water intake required to achieve adequate hydration will vary considerably between individuals.

As a general guide, athletes may consume 350–500 mL ~4 hours prior to competition.

If urine is still dark and concentrated in colour, or no urine is produced at all, the athlete should drink another 200–350 mL two hours prior to the event.

Hyperhydration is the consumption of excess fluid in preparation for loss of fluid in upcoming exercise.

Exercise in the Heat

Hydration strategies during exercise

Drinking during exercise (400–800 mL per hour) will decrease the risk of dehydration.

For short duration events, aim to drink 100–200 mL per 15 minutes.

Drinking plain water is adequate for exercise < 1 hour in duration.

For exercise > 1 hour, combining carbohydrate with fluid is beneficial.



Exercise in the Heat

Hydration strategies during exercise

A carbohydrate concentration of 6–8% in solution is optimal for absorption in the gastrointestinal tract.

Cold and flavoured fluids encourage increased consumption.

Electrolytes increase the desire to drink and fluid absorption in the gastrointestinal tract.

Consuming the recommended amount of fluid during exercise may still not equate to the amount of fluid lost from sweat during exercise in hot conditions.

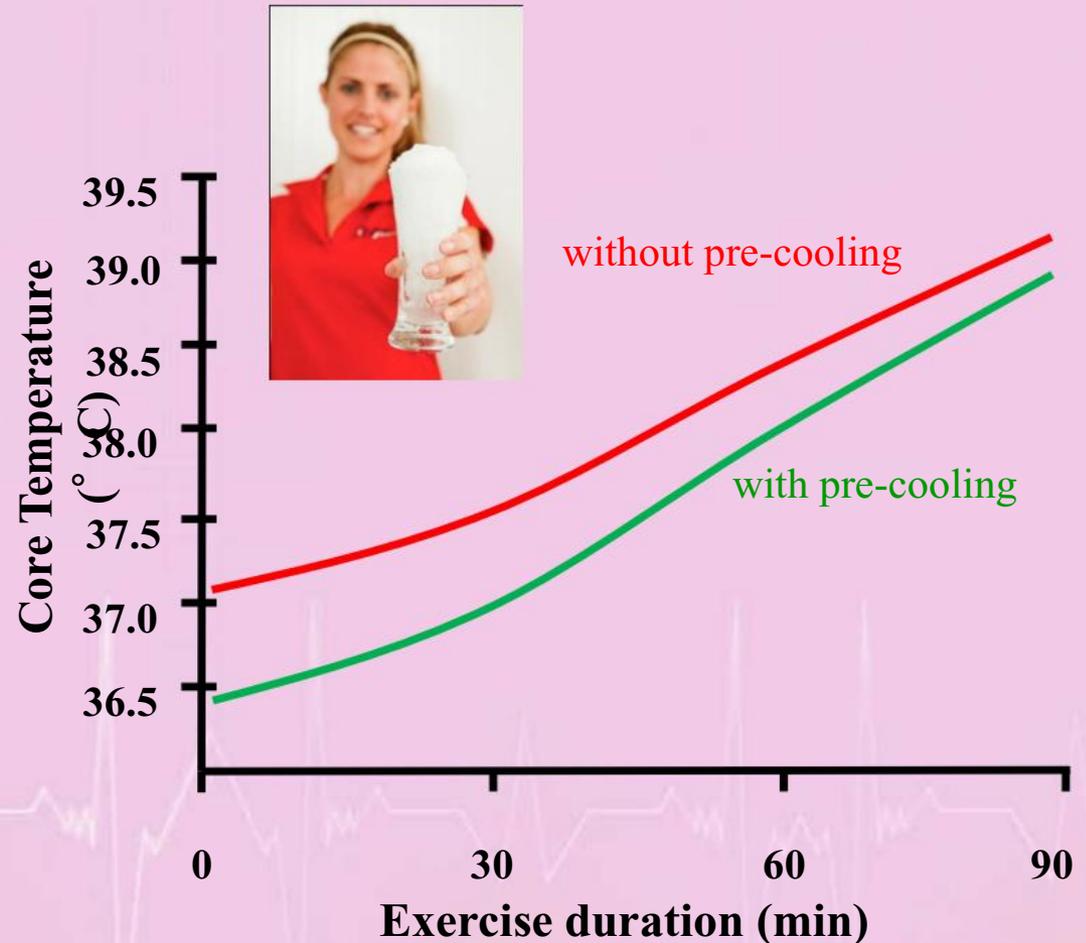
Exercise in the Heat

Other strategies for coping with exercise in the heat

Pre-cooling lowers core temperature prior to exercise allowing for a greater increase before the critical threshold is reached.

Methods of pre-cooling include:

- using cooling jackets
- cold water immersion
- crushed ice ingestion.



Exercise in the Heat

Other strategies for coping with exercise in the heat

Wear thin, light coloured cotton clothing
– the less clothing the better to allow increased skin exposure for evaporative cooling)

Individuals with a large skin surface area to body mass ratio may tolerate heat better (like endurance runners) than individuals with a low skin surface area to body mass ratio (like wrestlers, or rugby players).



Exercise in the Heat

Heat Acclimatisation

The ability to tolerate heat can be enhanced through ***heat acclimatisation***.

Heat acclimatisation involves a period of exercise training (typically 5–10 days) in a similar environment to that which is expected for competition.

This results in:

- earlier onset of sweating
- greater rate of sweating
- increased plasma volume.

Training in a climate chamber



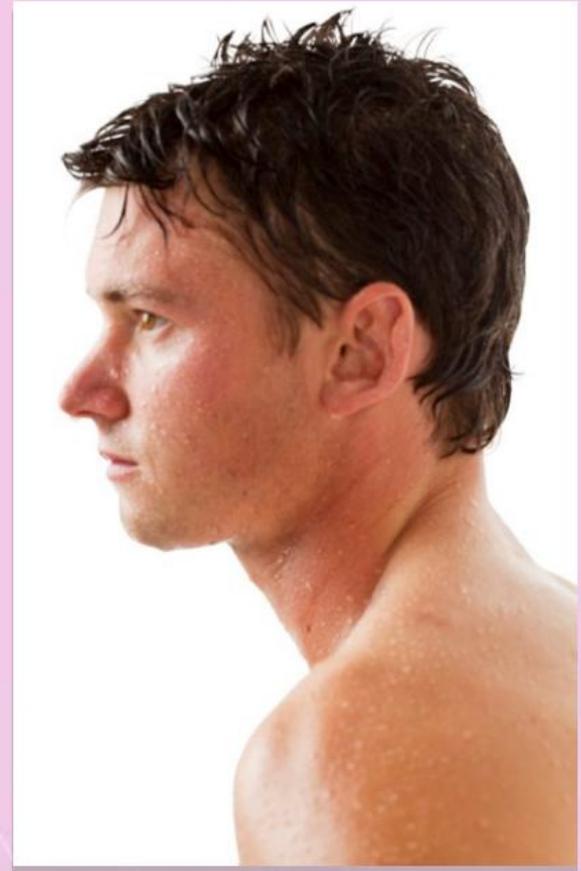
Exercise in the Humidity

Humidity represents the proportion of water in ambient air.

This has relevance for the effectiveness of evaporation as a mechanism of heat loss from the body.

If the relative humidity is high (i.e. the ambient air is already carrying a high proportion of water), there is nowhere for the sweat on the skin to evaporate to.

Under these conditions sweat will drip from the body, which is of no use for cooling and simply represents a waste of precious body water.



Environment



Exam style question

- i. A triathlete competing in a race has been running for 1 hour in hot conditions. Despite running at a consistent intensity they have noticed that their heart rate is beginning to creep higher and they feel hotter. Explain what they are experiencing.

(4 marks)
- ii. Explain how crushed ice ingestion and heat acclimatisation training will potentially improve an endurance athletes performance in hot conditions.

(4 marks)

Environment



Answer

- i. A triathlete competing in a race has been running for 1 hour in hot conditions. Despite running at a consistent intensity they have noticed that their heart rate is beginning to creep higher and they feel hotter. Explain what they are experiencing. (4 marks)

Dehydration – fluid loss is greater than fluid intake. (1 mark) A cardiac drift, steady increase in heart rate, occurs when the athlete's blood volume is decreasing. They have a decreased venous return and stroke volume. (1 mark) A double heat load is also being experienced which refers to the reduced blood plasma volume from sweating. (1 mark) This impairs the body's ability to deliver blood to both the working muscles and the periphery for cooling via sweat evaporation. (1 mark)

- ii. Explain how crushed ice ingestion and heat acclimatisation training will potentially improve an endurance athletes performance in hot conditions. (4 marks)

Crushed ice ingestion prior to performance will lower the core body temperature (1 mark) – providing scope for more time before a critical temperature threshold is reached. (1 mark) Heat acclimatisation training will assist to hasten the onset of sweating, increase sweat rate and increase plasma volume. (1 mark) All changes serve to decrease the rate at which the core temperature increases during exercise in the hot conditions. (1 mark)

Exercise in the Humidity

Physiological responses to a 10 km run in hot and humid conditions

	Perth	Darwin
Ambient temperature	22°C	32°C
Relative humidity	43%	73%
Performance time	41 min 09 sec	43 min 53 sec
Pre-run core temperature	37.0°C	37.1°C
Post-run core temperature	39.0°C	40.3°C
Pre-run skin temperature	32.3°C	33.9°C
Post-run skin temperature	27.9°C	35.7°C
Exercise heart rate	190 bpm	198 bpm
Pre-run body mass	73.2 kg	73.2 kg
Post-run body mass	72.7 kg	71.5 kg
Estimated fluid loss (L)	0.5 L	1.7 L
Estimated fluid loss (% body mass)	0.6%	2.3%

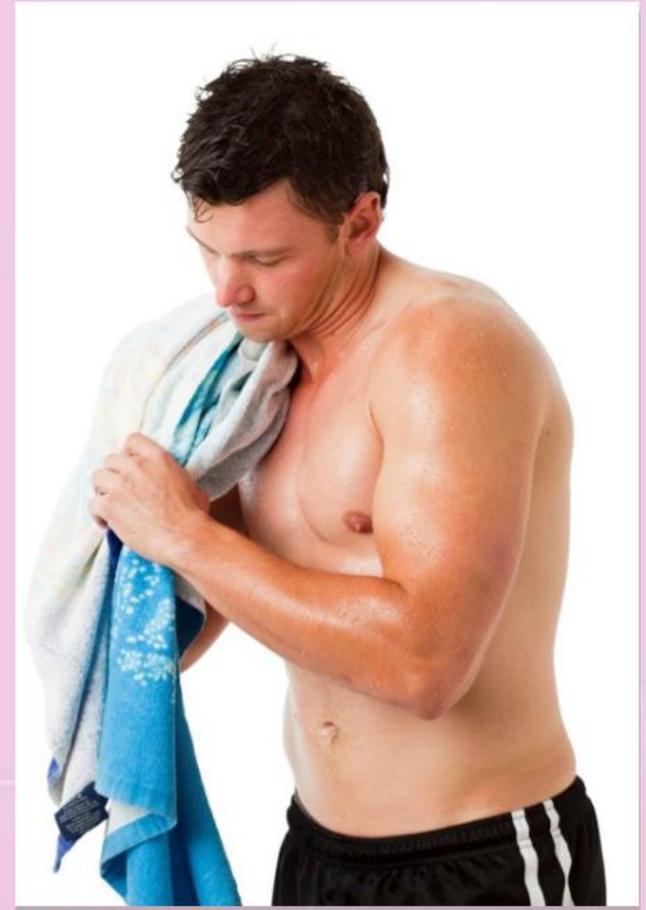
Exercise in the Humidity

Strategies for coping with humidity

The strategies for coping with humidity are similar to preparing for competition in the heat:

- pre-event hydration
- hydration during exercise
- pre-cooling techniques
- acclimatisation.

Acclimatisation can only assist to a certain extent given that there is limited evaporation of sweat in high humidity.



Exercise in the Cold

When exposed to a cold environment, the body is forced to conserve heat in order to maintain a stable core body temperature.

This is achieved by a number of mechanisms including:

Peripheral vasoconstriction – constriction of the blood vessels just below the skin surface to shunt blood away from the periphery towards the core instead.

Shivering – uncontrolled muscular contractions to elevate heat production.

Piloerection – when the hairs on the body stand on end to trap a warm layer of air close to the skin to keep the skin surface warm.

Exercise in the Cold

Strategies to cope with exercise in the cold

Acclimatisation may be of some use prior to competition in the cold.

Wear multiple layers of clothing which can be removed as the athlete's body 'warms up' from the heat produced by muscular work.

Insulation from body fat, animal fats rubbed on the skin and wetsuits help minimise heat loss from the body in cold, wet conditions.

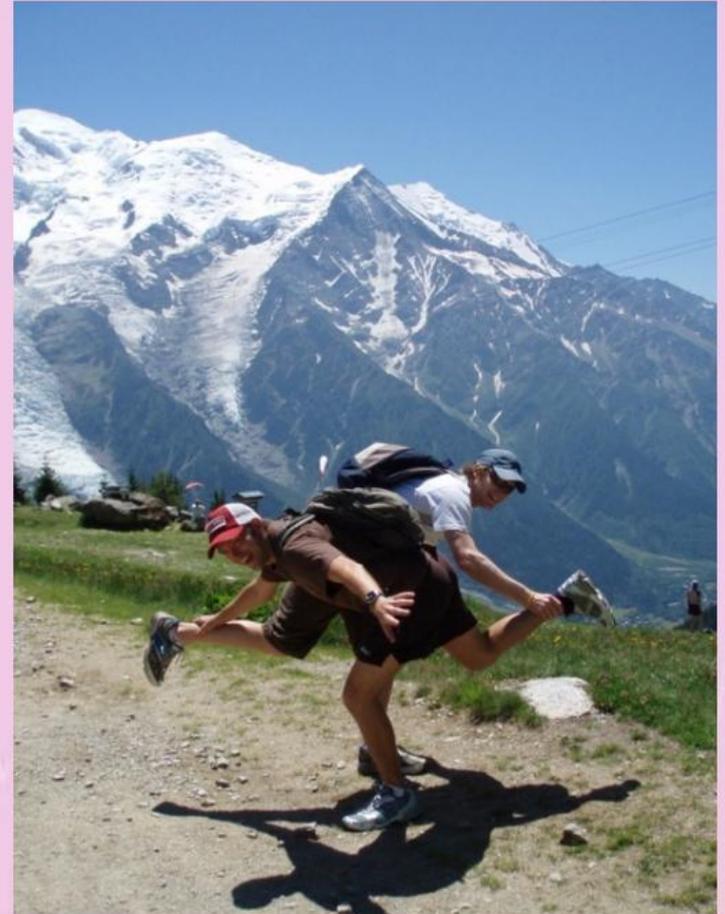


Exercise at Altitude

The air is thinner at altitude due to lower barometric pressure.

With 'thinner' air, there is less absolute oxygen available resulting in hypoxia (lack of adequate oxygen).

The lower oxygen availability at altitude translates to lower oxygen availability in inspired air, and therefore the amount of oxygen transported in the blood to the working muscles.



Exercise at Altitude

The lack of oxygen at altitude impairs the maximal rate of oxygen consumption (and therefore aerobic exercise performance).

Performance in repeated sprint exercise is also impaired due to the lower oxygen availability to replenish creatine phosphate stores and remove lactic acid.

Performance in one-off sprint or power events may be enhanced at altitude due to lower air resistance and drag.



Exercise at Altitude

Gold medal performances at the 1968 Olympic Games in Mexico City
(altitude 2300 m)

Event	Gold Medal performance in 1968	World Record in 1968
100 m Men	9.95 sec	New world record
100 m Women	11.0 sec	New world record
1500 m Men	3 min 34.9 sec	3 min 33.1 sec
10,000 m Men	29 min 27.4 sec	27 min 39.4 sec
Marathon Men	2 hr 20 min 27 sec	2 hr 12 min 0 sec
Long jump Men	8.90 m	New world record set
Long Jump Women	6.82 m	New world record set
Javelin Men	90.10 m	91.98 m
Javelin Women	60.36 m	62.40 m

Exercise at Altitude

Adaptations to altitude

Acute adaptations upon arrival at altitude include:

- increased pulmonary ventilation
- decreased plasma volume
- increased heart rate and cardiac output at rest and during submaximal exercise.

Long-term adaptations to a prolonged stay at altitude include:

- increased red blood cells and haemoglobin concentration
- increased capillarisation
- increased mitochondria
- increased aerobic enzymes.

Exercise at Altitude

Strategies to cope with altitude

Acclimatisation improves the ability to cope with hypoxia.

The duration of acclimatisation required varies with the specific elevation (i.e. the higher the elevation, the longer period of acclimatisation required).

Acclimatisation to one altitude only ensures partial acclimatisation to further increases in altitude.

Negative effects of a prolonged stay at altitude include a loss of body mass and reduced training capacity (eventually leading to detraining).



Exercise at Altitude

Altitude training

Sea level performance may be enhanced by living at altitude, but returning to sea level for training to ensure high intensity quality training sessions (live high, train low).

Hypobaric chambers or altitude tents allow athletes to sleep in conditions similar to altitude, but still train at sea level during the day.



‘Living’ in an altitude tent

Environment

Exam style question

An endurance athlete is preparing for an up-coming 2-hour event at altitude. They are debating if they should 'train high live low' or 'train low and live high'. Provide and justify an answer to their question.

(6 marks)



Environment

Answer

An endurance athlete is preparing for an up-coming 2-hour event at altitude. They are debating if they should 'train high live low' or 'train low and live high'. Provide and justify an answer to their question. (6 marks)

*Train high live low is the recommended approach. (1 mark)
It allows for the benefits of living at altitude: (three of the following required for 3 marks)*

- *Increased red blood cell and haemoglobin concentration*
- *Increased capillarisation*
- *Increased mitochondria*
- *Increased aerobic enzymes.*

Training at sea level (low) also allows high intensity training sessions (1 mark); whereas 'train low and live high', while living at altitude the athlete cannot train as hard, leading to a detraining effect and a loss of muscle mass. (1 mark)



Performance Enhancers

Elite athletes are always looking for an edge to help them run that split second faster or jump 1 cm further.

For this reason, a range of ***performance enhancers***, or ***ergogenic aids***, are applied in sport to gain any advantage.

Some methods of enhancing performance are widely accepted, while others are prohibited or controversial.

In general, those ergogenic aids that are prohibited in sport are those that result in potential harmful consequences or have detrimental side effects.

Performance Enhancers

Some substances are prohibited both in and out of competition, including:

- anabolic steroids

Other substances are prohibited during competition only, for example:

- stimulants such as cocaine and amphetamines (which may enhance alertness and decrease fatigue).

Legal Performance Enhancers

Protein supplementation

Many athletes, particularly weightlifters and bodybuilders, consume extra protein or amino acids in the form of powders.

The rationale for this is that increased protein intake will translate to increased muscle bulk and repair of muscle damage.

However, there appears to be little benefit in consuming these products for individuals that already have adequate protein intake from a balanced diet.

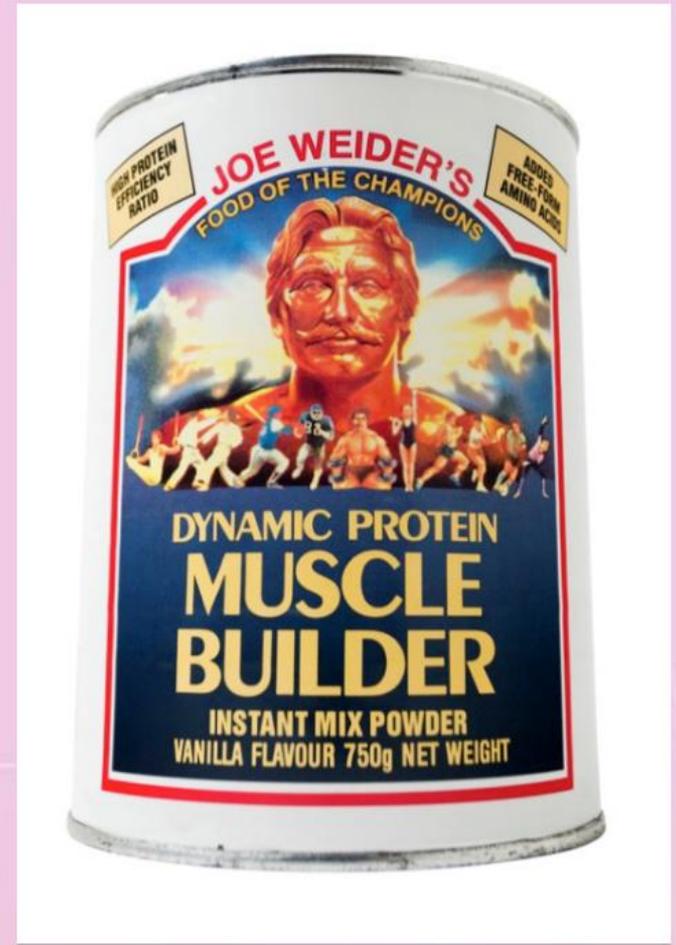
Excess protein intake alone will not stimulate muscle growth and development – resistance training is needed!

Legal Performance Enhancers

Protein supplementation

The adaptations to resistance training may be enhanced by consuming a protein and high GI carbohydrate snack immediately following weight lifting sessions

- due to enhanced production of naturally occurring anabolic hormones and protein building.



Protein supplementation

Is a potential advantage because it:

- may enhance the adaptations to resistance training (increased muscle hypertrophy), particularly if protein intake from the normal diet is inadequate.

Is a potential disadvantage because:

- high protein levels in the diet may increase the risk of osteoporosis and colonic cancers, and impair kidney function in the long-term.

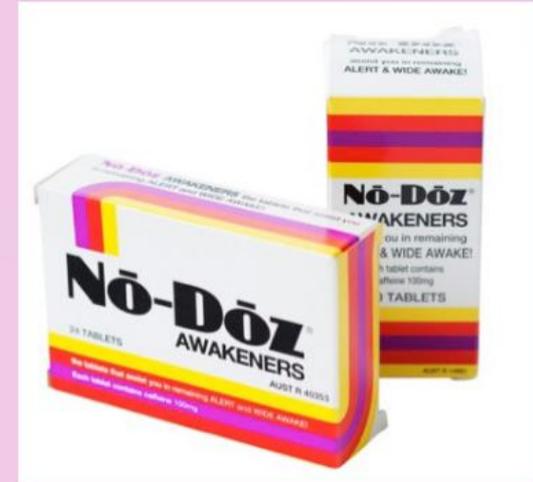
Legal Performance Enhancers

Caffeine supplementation

Caffeine is a stimulant

Effects on the body:

- increased arousal
- improved reaction time
- improved concentration and decision making ability
- reduced perception of fatigue / effort
- increased availability of free fatty acids for ATP production (may spare some muscle glycogen).

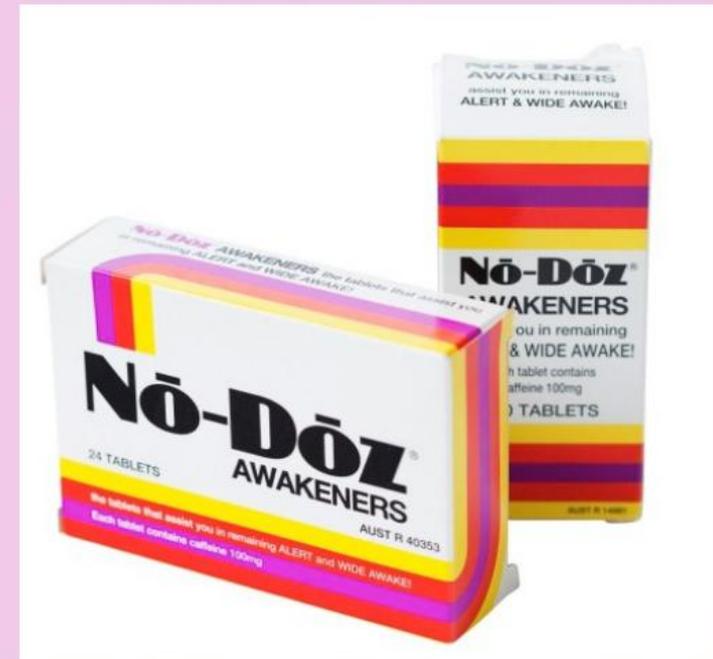


Legal Performance Enhancers

Caffeine supplementation

Typically consumed in tablet form (3–6 mg per kg of body mass) approximately one hour prior to exercise
–equivalent to consuming 6–10 cans of Coca Cola or 1.5 kg of chocolate for a 70 kg man.

The effect may be greater in individuals that do not regularly consume caffeine.



Legal Performance Enhancers

Caffeine supplementation

Is a potential advantage because it:

- increases arousal which may improve reaction time, concentration and decision making ability
- may reduce an athlete's perception of fatigue or effort
- increases the availability of free fatty acids for ATP production, which may spare muscle glycogen, thereby enhancing prolonged endurance performance.

Is a potential disadvantage because it:

- may lead to restlessness, feeling overanxious, muscle twitching, irritability, increased heart rate and blood pressure
- is a diuretic and may increase the risk of dehydration.



Illegal Performance Enhancers

Anabolic steroids

Can be taken in oral form or injected directly into the muscle.

These drugs simulate the anabolic actions of the male sex hormone testosterone which is responsible for many of the secondary sex characteristics of the male body such as facial hair and a deep voice.

Testosterone also plays a crucial role in muscular development.



Illegal Performance Enhancers

Anabolic steroids

Enhance performance in events involving muscular strength and power.

May benefit endurance performance by improving the rate of tissue repair (so athletes can train harder and longer with less recovery needed).

Banned in sport due to side-effects.

It is believed that many athletes have died prematurely as a result of prolonged use of anabolic steroids.



Illegal Performance Enhancers

Anabolic steroid use

Is a potential advantage because it:

- facilitates muscle development, assisting performance in strength and power events
- improves the rate of tissue repair, meaning athletes can train harder and longer with less recovery needed.

Is a potential disadvantage because it:

- leads to increased levels of aggression and hostility, infertility, acne, decreased testicular volume, liver dysfunction, heart disease and possibly even death
- causes a deepened voice, facial hair and menstrual irregularities in women.

Illegal Performance Enhancers

Track and field athlete Marion Jones won five medals at the 2000 Sydney Olympic Games. She was later stripped of her medals when it was found that she had been taking steroids. She still believes she would have won even without taking the drugs; however, nobody will ever know for sure.



Performance Enhancers

Exam style question

A 50 kg female marathon runner decides to significantly reduce her coffee consumption in the week leading up to a race. On the morning of the event she consumes 150 mg of caffeine. Provide a rationale for this approach and explain how it may assist her performance. Also, identify how caffeine may inhibit performance.

(5 marks)



Performance Enhancers



Answer

A 50 kg female marathon runner decides to significantly reduce her coffee consumption in the week leading up to a race. On the morning of the event she consumes 150 mg of caffeine. Provide a rationale for this approach and explain how it may assist her performance. Also, identify how caffeine may inhibit performance. (5 marks)

The body generally cannot store enough carbohydrate to meet the energy demands of running a marathon (2.5+ hours). Caffeine increases the availability of free fatty acids for ATP production, which in turn stimulates increased fat oxidation. (1 mark) This may assist in sparing some muscle glycogen and consequently enhance performance, particularly late in the race. (1 mark) Coffee contains caffeine, and for a regular coffee user, a reduction in coffee consumption in the lead up to the race, will assist to washout caffeine and increase the physiological effects of her race day caffeine consumption. (1 mark) The amount of 150 gm is equivalent to 3 mg per kg of body mass, within the suggested dose for the desired affect. (1 mark) However, caffeine is also a diuretic, which may lead to dehydration and limit endurance performance. (1 mark)

Training Programs

A successful training program involves thorough planning and is structured in a specific way to ensure that an athlete's best performances will be achieved at the right time of the season.

This is achieved through a process called ***periodisation*** whereby the training program is organised into different periods or blocks of time.

The training program for an entire season or year is typically divided into three main phases:

- ***Preparatory Phase*** (pre-season)
- ***Competition Phase*** (in-season)
- ***Transition Phase*** (off-season).

Training Programs

Preparatory Phase (Pre-Season)

To prepare for competition.

- *General preparation phase*
 - to establish a base-level of fitness and skills
 - emphasises a high volume of moderate intensity exercise.
- *Specific preparation phase*
 - training becomes more sport and competition specific
 - intensity of training is increased
 - increased focus on skill development and technique.

Competition Phase (In-Season)

- *Pre-competition phase*
 - the period leading up to competition
 - goal is to approach peak condition
 - highly specialised training, with an emphasis on quality (intensity) rather than quantity (total volume)
 - early season races or ‘scratch matches’ for experience.
- *Competition phase*
 - when the athlete is ready to perform at their peak
 - full development of all of the physical capacities and technical components required for optimal performance
 - training for maintenance of fitness levels (reduced volume, maintained intensity)
 - focus on psychological and tactical aspects of performance.

Training Programs



Transition Phase (Off-Season)

The period of time following the major competitive season.

Aim to maintain cardiorespiratory fitness, while recovering from demands of the competitive season.

‘Active rest’ is encouraged to prevent complete detraining.

The phases of training for a soccer player

Training phase	Type of activity	Purpose
General preparatory phase	<ul style="list-style-type: none"> • Moderate intensity & increased volume (e.g. long runs) • Cross training 	<ul style="list-style-type: none"> • Develop fitness (especially cardiorespiratory endurance)
Specific preparatory phase	<ul style="list-style-type: none"> • Increased intensity (e.g. intervals, time trials) • Skills • Repeated sprint ability 	<ul style="list-style-type: none"> • Further develop fitness • Enhance and develop skills & technique
Pre-competition phase	<ul style="list-style-type: none"> • Skills & tactics • Small sided games • Scratch matches 	<ul style="list-style-type: none"> • Gain competitive experience • Fine tune technical aspects of game • Hit top form
Competition phase	<ul style="list-style-type: none"> • Training (reduced volume) • Weekly Games 	<ul style="list-style-type: none"> • Maintain peak form • Adequately recover
Transition phase	<ul style="list-style-type: none"> • Swimming & cycling • Social indoor soccer 	<ul style="list-style-type: none"> • Maintain base fitness while recovering from soccer season

Training

Exam style question

A netball team has been performing poorly and the coach decides to 'make them pay' by doubling their training volume, including some additional high intensity intervals. Explain, using the principles associated with the competition-phase of training, why this may be inadvisable?

(3 marks)



Training

Answer

A netball team has been performing poorly and the coach decides to 'make them pay' by doubling their training volume, including some additional high intensity intervals. Explain, using the principles associated with the competition-phase of training, why this may be inadvisable? (3 marks)



The competition-phase should be focused on maintaining peak form. (1 mark) A one-off significant increase in training volume will potentially impact on recovery from the game (1 mark) and therefore, could lead to fatigue and increase the likelihood of poor performance and/or injury. (1 mark)

Training Programs

Macrocycles

–periods of time within the training plan (typically 4–6 weeks) in which there is a specific focus/goal for training.

Microcycles

–smaller periods of time within the training plan (typically a week) which combine to contribute towards the goal of the macrocycle.



Specific energy system requirements

The activities performed within each training session are dependent upon the components of fitness and energy systems related to the sport.

The health-related components of fitness include:

- cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition.

The performance/skill-related components of fitness include:

- agility, balance, coordination, reaction time, speed, and power.

The three energy systems include:

- ATP-CP, lactic acid and aerobic energy system.

Typical weekly in-season training program for a 100 m sprinter

Time/Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	<p>GYM</p> <p>8 exercises 3 sets x 8 reps</p> <p>Focus: Maintain Strength Power Development</p>	OFF	OFF	OFF	REST DAY	<p>COMPETITION</p> <p>Maximal intensity performance</p>	<p>RECOVERY SESSION</p> <p>Beach</p> <p>15 min Light Sand Jog 10 min Group Stretch Flags/short beach sprints 10 min in Ocean (Wade/Swim)</p>
PM	<p>TRACK SESSION</p> <p>1 km jog w/up 10 min stretching 10 min drills</p> <p>4 x 5 reps through (60 m, 80 m, 100 m, 120 m, 140 m) walk back recovery</p> <p>1 km c/down</p>	<p>GRASS SESSION</p> <p>1 km jog w/up 10 min stretching 10 min drills</p> <p>Plyometrics 2 x 3 x 20 m bounding 2 x 3 x 20 m hopping</p> <p>2 x 6 reps 80 m</p> <p>1 km c/down</p>	<p>GYM</p> <p>8 exercises 3 sets x 8 reps</p> <p>Focus: Maintain Strength Power Development</p>	<p>TRACK SESSION</p> <p>1 km jog w/up 10 min stretching 10 min drills</p> <p>2 x 6 reps block starts</p> <p>3 x 6 reps speed play (maximal 30 m sprint, coast 30 m, sprint 30 m)</p>	REST DAY	<p>OFF</p> 	OFF

**Energy system =
ATP-CP system**

**Components of fitness = Speed,
muscular strength, power, reaction time**

Typical weekly in-season training program for an open water swimmer

Time/Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	1500 m w/up Easy swim + drills 5 x 800 m Depart on 12' Target = 11' / rep 2 x 400 m c/dwn (swim/kick/pull/swim) TOTAL - 6.3 km	Gym 10 Exercises 4 Sets of 15 Reps Focus = Endurance	800 m w/up Easy swim + drills 1000 m + 800 m + 400 m Depart on 15', 12', 6' Target = 13'30, 11', 5'15 TWICE THRU 5 x 200 dps c/dwn TOTAL - 6.2 km	Gym 10 Exercises 4 Sets of 15 Reps Focus = Endurance	1200 w/up Easy swim + drills 4 x 500 descending 1-4 Rep 4 @ MAX EFFORT Departing on 7' 8 x 200 IM tempo Departing on 3' 400 (kick/swim) c/dwn TOTAL - 5.2 km	Race 5 km Open Water Ocean Swim MAX RACE EFFORT TOTAL - 5 km	REST DAY
PM	800 m w/up Easy swim + drills 400m+300m+200m+100m Depart on 5'45, 4'15, 3', 2' FOUR TIMES THRU 4 x 200 (100 kick/100 pull) TOTAL - 5.6 km	1500 m w/up Easy swim + drills 8 x 400 m Depart on 6' Target = 5'10/rep 1000 m Tempo c/dwn TOTAL - 5.7 km	1000 m w/up Easy swim + drills 30 x 100 m Depart on 1'30 Target = 1'15/rep 3 x 200 m c/dwn TOTAL - 4.6 km	1500 m w/up Easy swim + drills 3 x 1000 m Pull/Paddles Depart on 14' 10 x 100 Fartlek c/dwn Depart on 1'45 TOTAL - 5.5 km	OFF	OFF	REST DAY



Energy system =
Aerobic energy system

Components of fitness =
Cardiorespiratory & muscular endurance

Typical weekly in-season training program for a hockey player

Time/Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	OFF	OFF	GYM 15 min Aerobic Cycle (on ergo) 6 Exercises (2 Push, 2 Pull, 2 Legs) Focus: Maintain Strength Power Development	OFF	REST DAY	GAME Maximal Game Intensity	RECOVERY SESSION Beach 10 min Light Sand Jog 10 min Group Stretch 10 min in Ocean (Wade/Swim)
PM	PITCH SESSION 30 min Match Analysis 30 min W/up + Light Skills 15 min Penalty Corners 15 min Top-up Conditioning: 8 x Pitch Lap (Stride Length/Jog Width) Departing every 2 min	PITCH SESSION 20 min w/up + skills 5 x 3:30 4 v 3 (SSG) ½ Pitch (width) 2 min Recovery / Rep 5 min Recovery 4 x 2:00 ½ Pitch Press Attack vs Defense 1 min Recovery / Rep 10 min c/dwn + Stretch	X-TRAIN Optional 30 min Swim Session or LSD Jog	PITCH SESSION 20 min w/up + skills 8 x 1:30 3 v 3 (SSG) ½ Pitch (width) 1 min Recovery / Rep 20 min Penalty Corners 10 min c/dwn + Stretch	REST DAY	OFF 	OFF

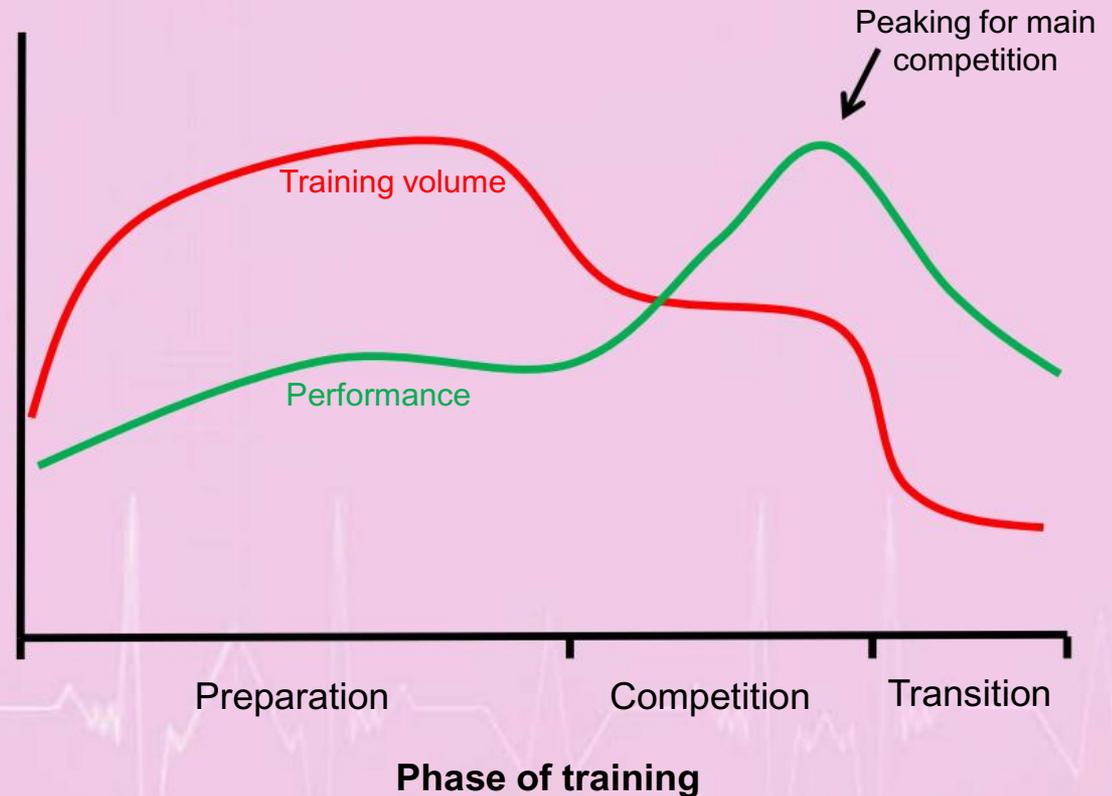
Energy system =
ATP-CP, lactic acid & aerobic systems

Components of fitness = Cardiorespiratory
endurance, agility, reaction time, speed,
muscular strength, power & endurance

Training Programs

Peaking

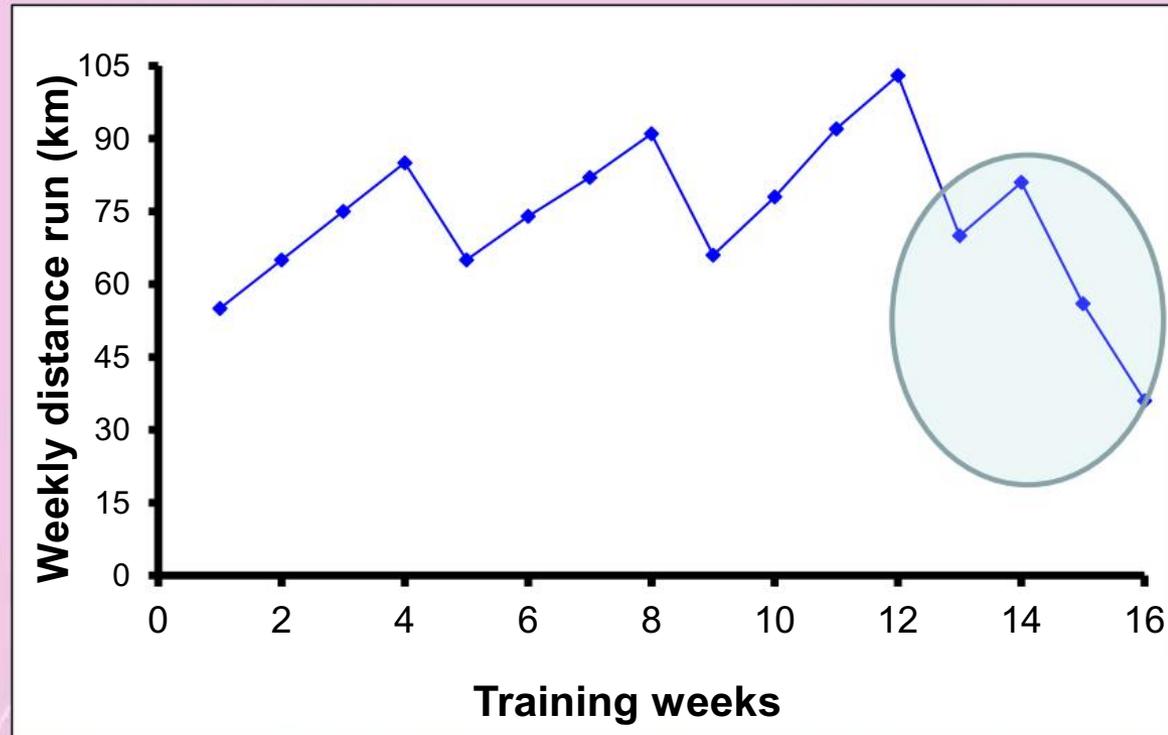
The achievement of optimal performance at the appropriate time in the training plan.



Training Programs

Tapering

The reduction of training volume in the days/weeks leading up to a competition to allow the body to recover and perform optimally.



Training Programs

Maintenance

Fitness levels need to be maintained throughout the season with an appropriate training load that permits maximum performance.

During this period, the amount of work completed in training is simply enough for the maintenance of fitness levels (reduced volume and maintained intensity), rather than continued overload to try to stimulate further improvement.

Training

Exam style question

The coach of a 400 m swimmer is training to peak her athlete for a major competition. Outline the rationale of peaking and periodisation and how they would be incorporated into a training program to ensure maximum performance.

(4 marks)



Training



Answer

The coach of a 400 m swimmer is training to peak her athlete for a major competition. Outline the rationale of peaking and periodisation and how they would be incorporated into a training program to ensure maximum performance. (4 marks)

Periodisation: Will ensure the best performances occur at the appropriate time. (1 mark)

Peaking: Achieved by appropriate periodisation and the inclusion of a taper. (1 mark)

Taper: A decrease in the volume of training with an increase or maintenance of intensity, with increased time for recovery. (1 mark)

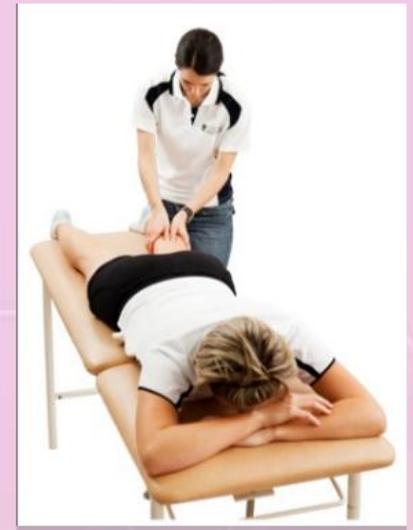
The implementation of these training principles will serve to decrease fatigue and improve performance. (1 mark)

Training Programs

Recovery

Adequate recovery between training sessions is needed to allow a physiological training effect (overcompensation).

Recovery strategies commonly employed by athletes include: massage, compression garments, cold water immersion, warm water immersion, contrast water therapy, and stretching.



Training Programs

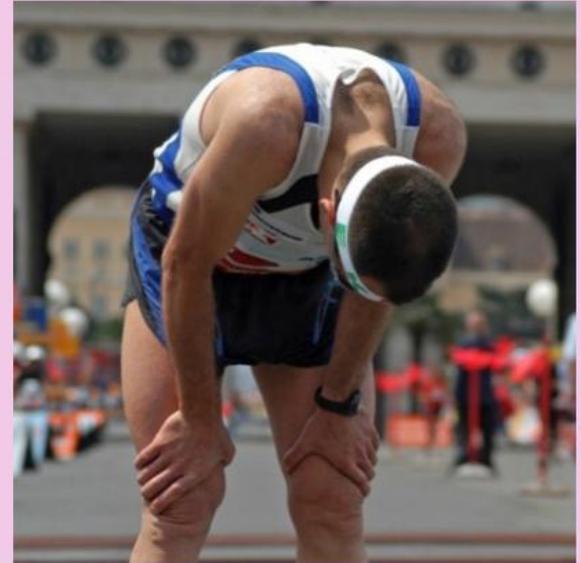
Overtraining

An inadequate balance between training load and the time allowed for recovery may result in a state of ***overtraining***.

Symptoms of overtraining include:

- a lack of energy, muscle aches, impaired performance, lack of enthusiasm, increased risk of injury and illness (especially colds).

Risk may be reduced by allowing 24–48 hours of recovery between ‘heavy sessions’ and ensuring adequate rest, sleep and nutrition.



Training Programs

The injured athlete

The primary goal for the injured athlete is to limit the amount of detraining that results during the period in which they are unable to compete in their sport.

The injured athlete should be included as much as possible in team activities.



One-legged cycling

Training

Exam style question

The school netball team undertakes a ten-week training program prior to a major competition. At the end of each training session the players were fatigued. The coach conducted a warm-down activity.

List three specific actions, other than a warm-down, the players could undertake to ensure they recover as rapidly as possible after each session.

(3 marks)



Training

Answer

The school netball team undertakes a ten-week training program prior to a major competition. At the end of each training session the players were fatigued. The coach conducted a warm-down activity.

List three specific actions, other than a warm-down, the players could undertake to ensure they recover as rapidly as possible after each session. (3 marks)

(List three of the following for 1 mark each)

Recovery strategies:

- *Cold water immersion, warm water immersion, contrast water therapy*
- *Massage*
- *Compression garments.*

Nutrition:

- *Carbohydrate feeding*
- *Fluid replacement.*





THE UNIVERSITY OF
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AUSTRALIA**

SPORT PSYCHOLOGY

Dr James Dimmock

Dr Peter Whipp

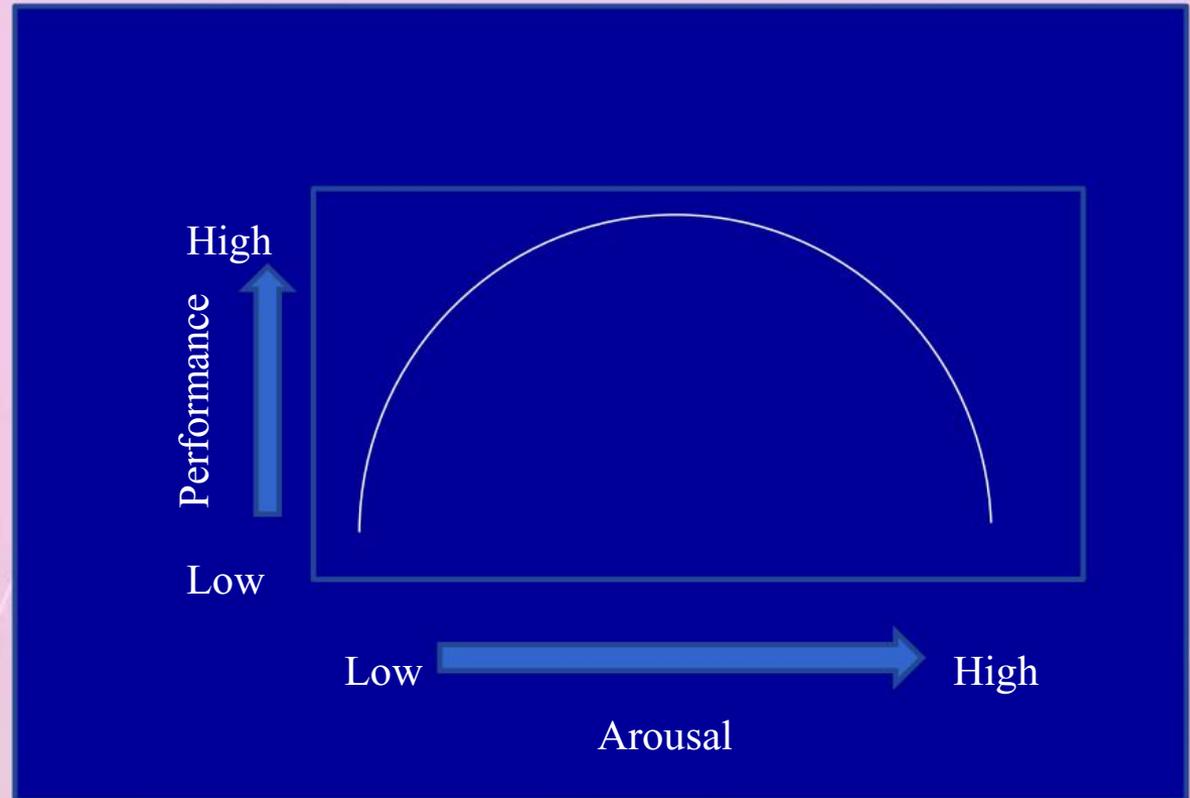
Ms Monica Leslie



PHYSICAL EDUCATION STUDIES ATAR UNITS 3 AND 4
A TEXTBOOK FOR TEACHERS AND STUDENTS

The Inverted-U Hypothesis

Performance is best when athletes experience a moderate level of arousal.

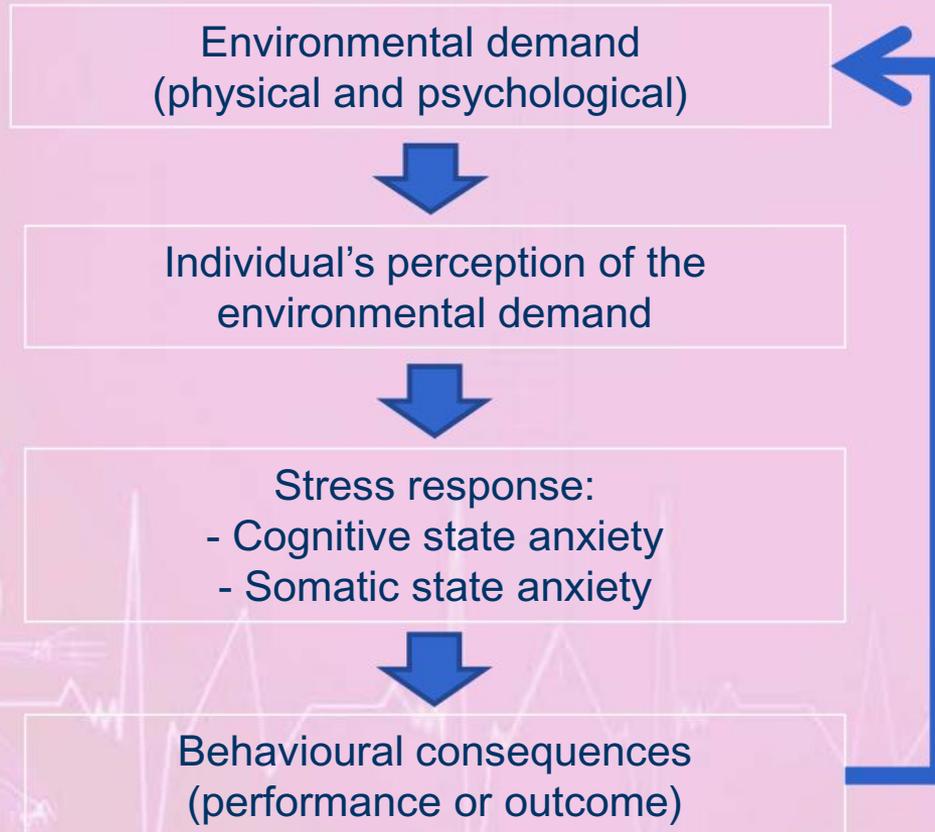


Routines and Arousal

Routines to influence arousal are most useful when undertaken before and during performance.



The Stress Process according to McGrath (1970)



Routines and Stress

Performance routines can influence stages 2 and 3 of the stress process. An effective routine can ward away a perception that a demand is threatening and can moderate the reaction to stress.

Routines to reduce stress are most useful when undertaken before and during performance.



Routines and Motivation

Routines can activate motivation that has come to be associated with events via a conditioning process.

Routines can stimulate motivational intensity before or during a performance.



Routines and Concentration



Routines can help athletes to concentrate on relevant cues.

Concentration on task-relevant cues is important to performance success.

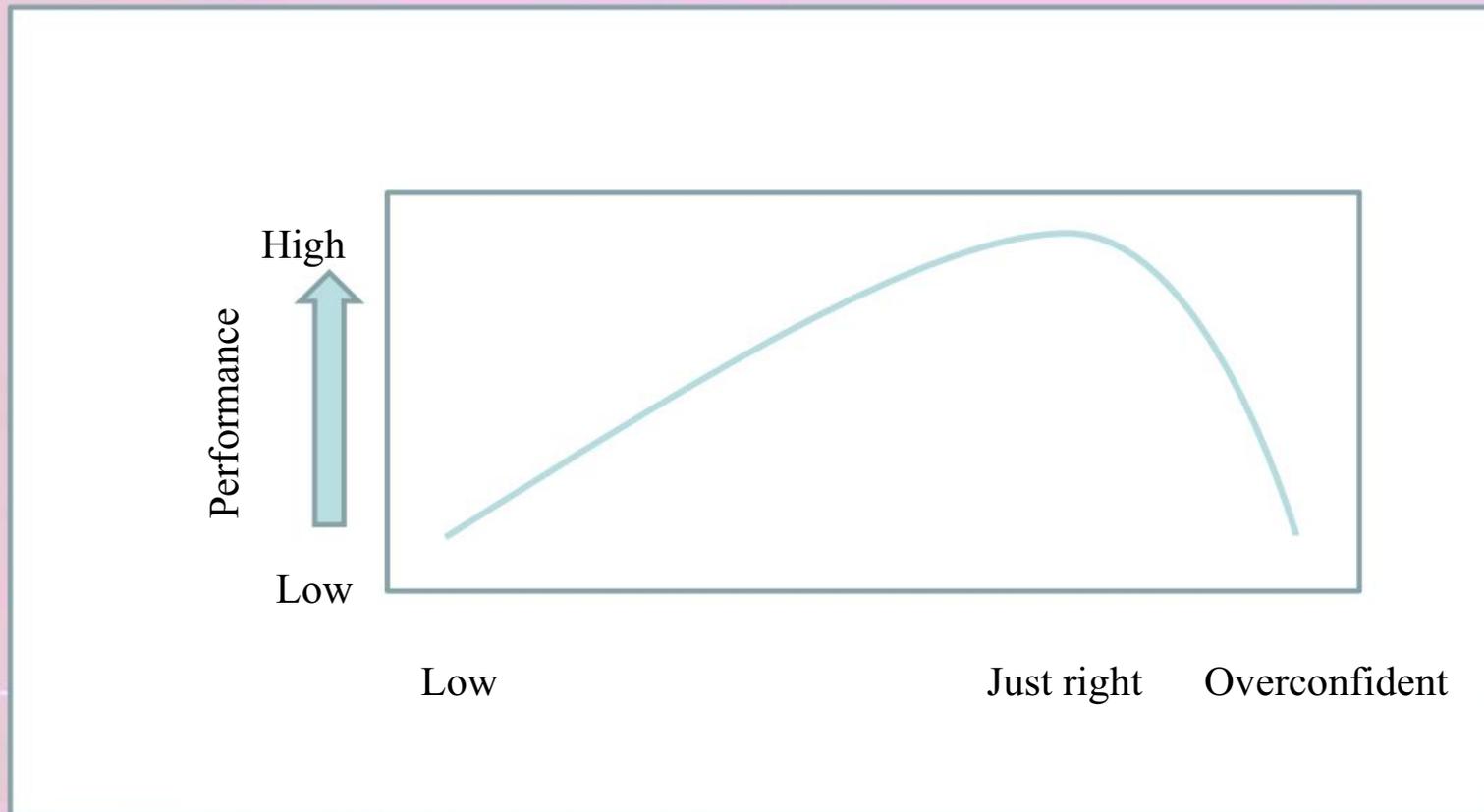
Routines to improve concentration are most useful when undertaken during performance.

Routines and Confidence

Routines before and during a performance can influence the confidence of athletes as well as the confidence of their opponents.



Relationship Between Confidence and Performance



Performance Routines: Examples

Arousal	A basketball player bounces the ball three times and exhales deeply before each free throw in order to release physical tension.
Stress	Figure skaters might focus on the key words, “Height then tight,” as part of their routine before every jump. Focusing on technique helps to put worries about the importance of a competition out of mind.
Motivation	Many tennis players use routines such as spinning their racquets and bouncing the ball the same way before every serve. This can help to trigger feelings of motivation that have come to be associated with the routine.
Concentration	By using a routine that involves lining up his shot, getting into a comfortable position and eyeing the hole one last time, a golfer can make sure he focuses on the right cues before every shot.
Self-confidence	A high jumper might think the phrase, “I can do this,” before every jump in order to boost self-confidence.

Routines

Exam style question



A volleyball player has expressed that when in high pressure situations, and it is their turn to serve, they often feel rushed and distracted. Upon asking: what does your pre-performance routine involve?; they reply – ‘I don’t have a routine’.

Define and describe a possible pre-performance routine they could employ and justify the use of pre-performance routines by identifying a likely benefit.

(4 marks)

Routines

Answer



A volleyball player has expressed that when in high pressure situations, and it is their turn to serve, they often feel rushed and distracted. Upon asking: what does your pre-performance routine involve?; they reply – ‘I don’t have a routine’.

Define and describe a possible pre-performance routine they could employ and justify the use of pre-performance routines by identifying two likely benefits. (4 marks)

A pre-performance routine is a sequence of task-relevant thoughts or actions used systematically prior to performance. (1 mark)

A possible pre-performance routine could involve:

•hold the ball with one hand and use their serving hand to slap to ball with firm contact, then taking two deep breaths and exhaling slowly. (1 mark)

1. Routines can assist you not to neglect task-relevant thoughts or behaviours prior to execution. (1 mark)

2. Routines can assist you to avoid distractions. (1 mark)

Imagery and Arousal

Using imagery to influence arousal is most useful when undertaken prior to performance.



Imagery and Stress

Using imagery to influence stress is most useful when undertaken prior to performance.

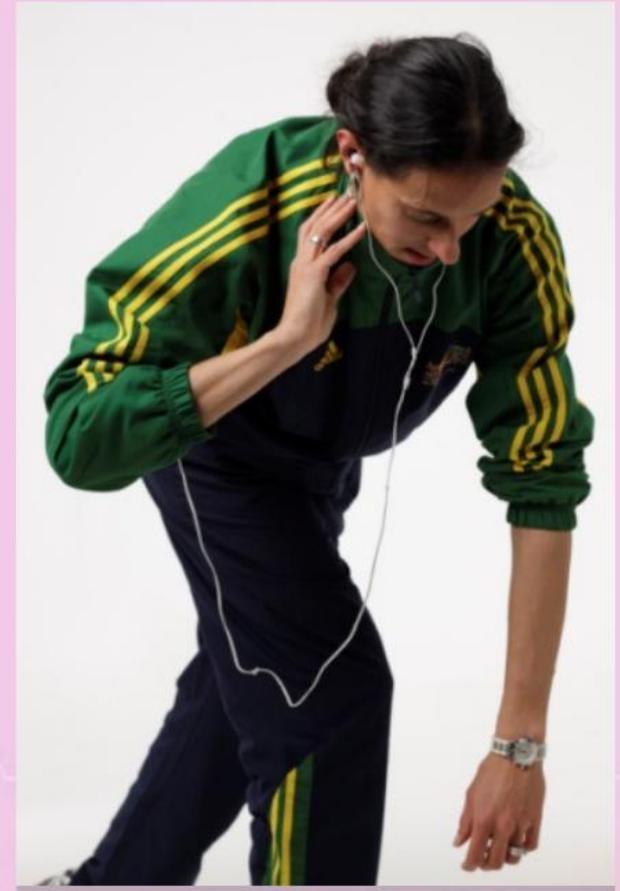
Imagery is likely to influence stages 2 (perception of demand) and 3 (stress response) in the stress process.



Imagery and Motivation

Imagery of successful performance can help an athlete approach activities (motivational direction) and persist at those activities (motivational intensity).

Using imagery to influence motivation is most useful when undertaken prior to performance.



Imagery and Concentration

Imagery can be used by athletes prior to an event so that they focus on task-relevant cues during the event.



Imagery and Self-confidence

Imagery can be used to build confidence before a game or during a game.



Imagery: Examples

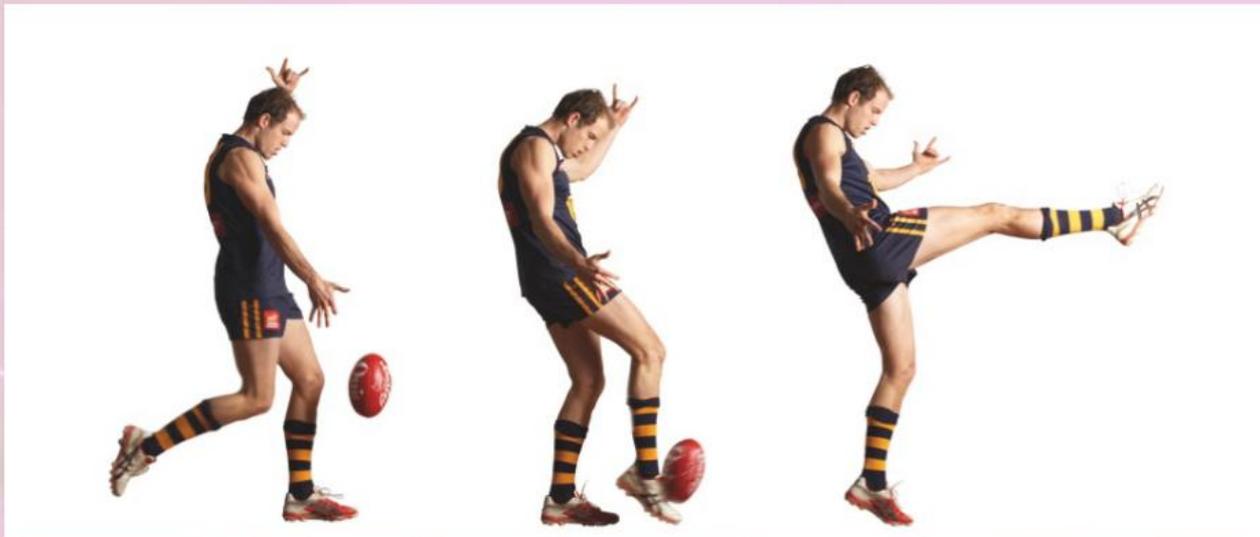
Arousal	If a slalom skier was feeling highly tense and anxious before his event, he could take a moment to engage in imagery. Imagining himself relaxing on the beach would help to decrease his level of arousal.
Stress	A shot-putter who was experiencing intense worries before a major event could use imagery to bring her last successful performance to mind. This would help to strengthen her belief that she was capable of meeting environmental demands.
Motivation	If a wrestler was feeling relaxed and complacent before a match, he could use imagery of himself celebrating after a win to trigger stronger feelings of motivation.
Concentration	Soccer players can imagine possible set-piece plays (e.g., corner kick) prior to important matches in order to identify which cues would be important to focus on in each situation.
Self-confidence	A gymnast might use imagery to visualise, feel and hear herself performing a flawless routine. Imaginal experiences encourage athletes to perceive that effective performance is within their grasp.

Imagery

Exam style question

An AFL player tells you that he has been using imagery to improve goal kicking. But, he says it has made him worse at set shots. Having asked what does he imagine, he says: 'when I am running in to kick at goal, I mentally rehearse and see how I don't want things to go, then I imagine a good kick while I am kicking it'. Describe two changes to assist the AFL player.

(2 marks)



Imagery



Answer

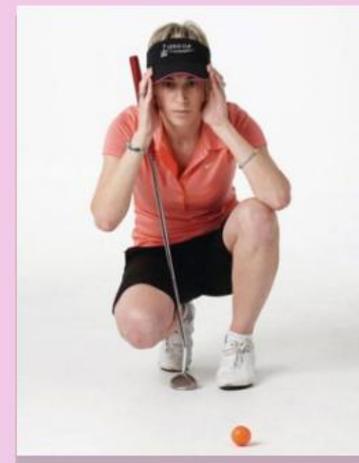
An AFL player tells you that he has been using imagery to improve goal kicking. But, he says it has made him worse at set shots. Having asked what does he imagine, he says: 'when I am running in to kick at goal, I mentally rehearse and see how I don't want things to go, then I imagine a good kick while I am kicking it'. Describe two changes to assist the AFL player. (2 marks)

Firstly, the mental imagery should be performed in the time between having marked the ball and prior to running in and kicking the ball. That is, imagery should not be undertaken during the performance. (1 mark)

Secondly, imagery training involves focusing strongly on the desired way of performing and avoid imaginings of past mistakes or poor performances. (1 mark)

Personal Relaxation

Arousal regulation techniques can include progressive relaxation, breathing control, imagery, thought stopping, performance routines, listening to music, and self-talk.



Personal Relaxation and Arousal



The matching hypothesis recommends that athletes use physical anxiety reduction techniques to reduce physical symptoms of anxiety, and mental techniques to reduce cognitive symptoms of anxiety.

Relaxation methods can be used prior to an event, during an event, or after an event to decrease arousal.

Personal Relaxation and Stress



Relaxation methods can be used to reduce stress before competition, during competition, or after competition.

Using relaxation to reduce stress is most useful when undertaken prior to and after competition.

Personal Relaxation and Motivation

Relaxation methods can be used to influence motivation before and during performance.

Using relaxation to influence the impact of high levels of motivation is most useful when undertaken prior to and sometimes during competition.

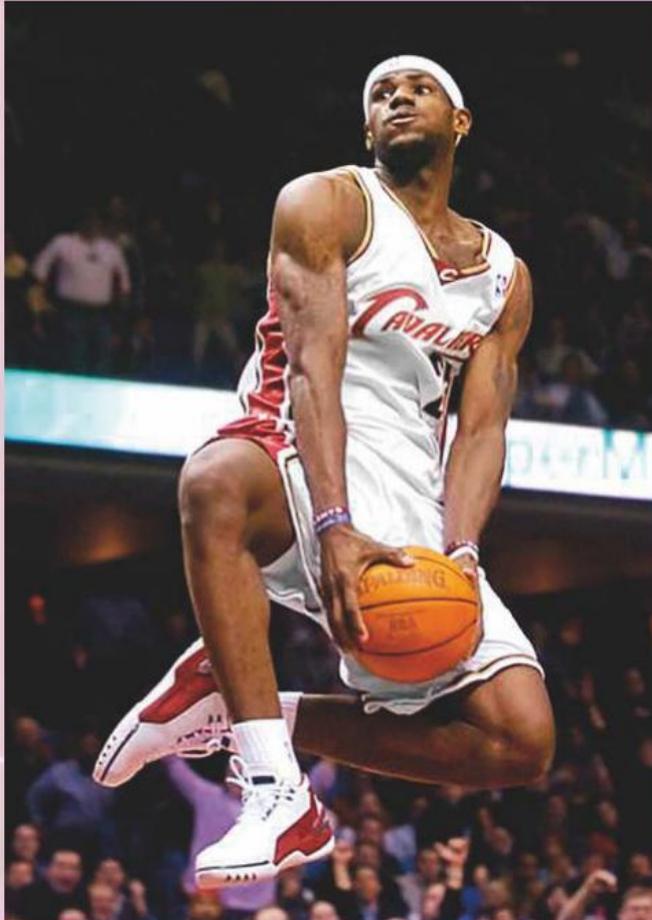


Personal Relaxation and Concentration

Using relaxation to improve concentration is most useful when undertaken during performance.



Personal Relaxation and Self-confidence



Relaxation methods that are incorporated into a tapering process can be used to influence confidence.

Relaxation techniques such as breathing control may influence confidence during or after performance.

Personal Relaxation: Examples

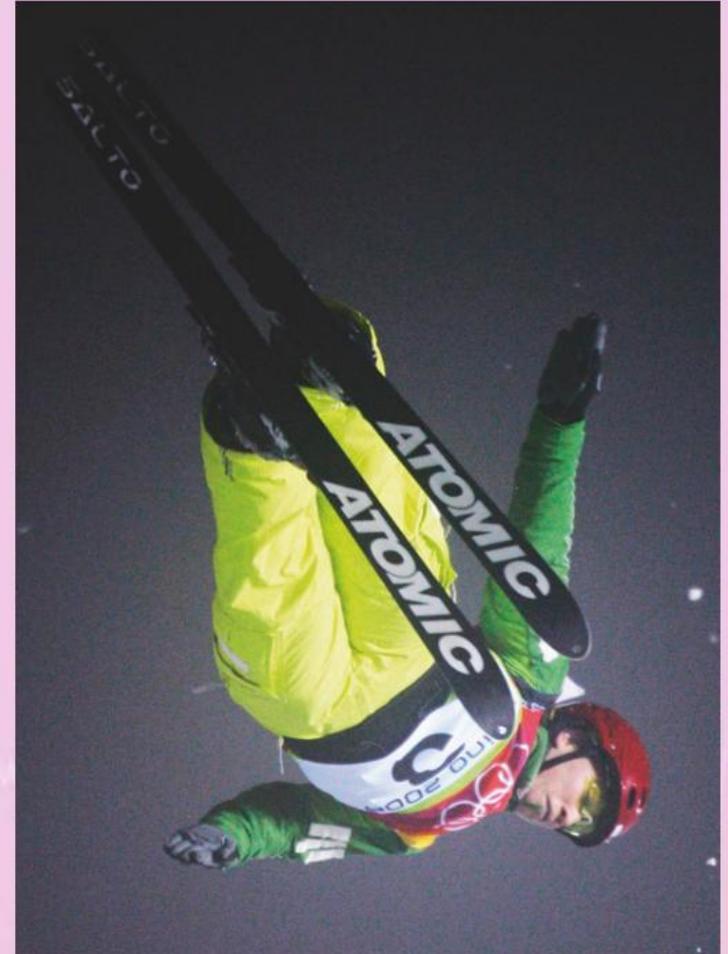
Arousal	By regularly practising progressive muscle relaxation, a long-distance runner could learn to detect and release physical tension in her upper body in order to conserve energy.
Stress	A rower who was experiencing doubts during a race against a tough opponent could use thought stopping to re-evaluate his perception of threat.
Motivation	Prior to the final serve of a game, a volleyball player who was feeling overly-motivated might use positive self-talk to calm her mind and avoid 'choking' under the pressure.
Concentration	Quarterbacks in American football can use breath control to decrease their level of arousal. Doing so would help to broaden their scope of attention so that they could assess the whole playing field.
Self-confidence	A swimmer who was feeling anxious just prior to a race could listen to some relaxing music. Returning her body and mind to her ideal performance state would help to boost her self-confidence.

Personal Relaxation

Exam style question

An athlete tells you that they have been experiencing physical symptoms of arousal or anxiety – in the form of sweaty palms and an elevated heart rate. They confirm that they are using ‘self-talk’ to address the situation. Using the ‘matching hypothesis’, explain why you might adopt a different mental skills strategy.

(3 marks)

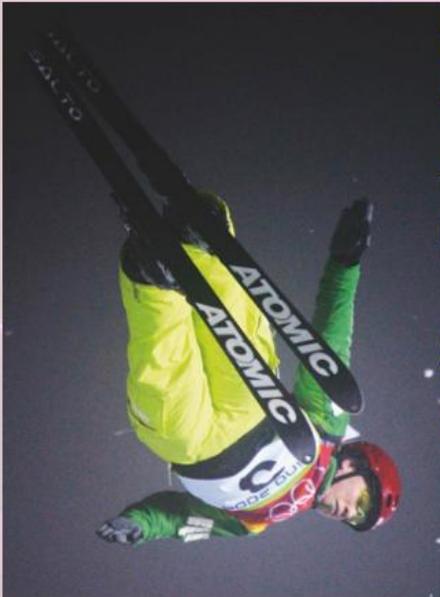


Personal Relaxation

Answer

An athlete tells you that they have been experiencing physical symptoms of arousal or anxiety – in the form of sweaty palms and an elevated heart rate. They confirm that they are using ‘self-talk’ to address the situation. Using the ‘matching hypothesis’, explain why you might adopt a different mental skills strategy. (3 marks)

matching hypothesis involves matching the personal relaxation technique to the context of the situation and the outcome sought. (1 mark) In this situation, the athlete is experiencing physical symptoms and therefore is advised to use a physical technique (1 mark) such as breath control, rather than self-talk which is a mental skills technique. (1 mark)



Self-talk and Arousal



Using self-talk to influence arousal is most useful when undertaken prior to and during performance.

Self-talk can possibly be used after performance to influence arousal.

Self-talk and Stress



Self-talk can influence stages 1 (environmental demand), 2 (perception of demand), or 3 (stress response) of the stress process.

Using self-talk to influence arousal is most useful when undertaken prior to performance.

Self-talk can possibly be used during and after performance to influence stress.

Self-talk and Motivation

Self-talk can influence the direction and intensity of an athlete's motivation, and it can be used pre-, during, and post-performance.



Self-talk and Concentration



Using self-talk to influence concentration is most useful when done during performance.

Self-talk can possibly be used prior to performance to influence concentration.

Self-talk and Self-confidence

Self-talk can possibly be used prior to, during, or after performance to influence self-confidence.



Self-talk: Examples

Arousal	A weight lifter who was feeling lethargic before a morning competition could use self-talk to remind himself of the importance of performing well. This technique helps to increase arousal.
Stress	In AFL, a footy player might use the phrase, 'I've done this before so I can do it again,' before taking a critical shot at goal. This would help to increase his belief in his capability to meet environmental demands.
Motivation	At the end of a long match, a cricket player who was feeling tired and demotivated could use self-talk cues such as 'Come on!' to elicit greater levels of motivation.
Concentration	A hockey player who was under pressure could use the phrase 'Scan' to remind herself to broaden her scope of attention. That way, she would increase her chances of noticing free team members to pass to.
Self-confidence	Just before her team's performance at Nationals, a synchronised swimmer might use the phrase, 'I've got this,' to persuade herself of her ability to deliver a successful performance.

Self-talk



Exam style question

A PE student feels stressed by the teacher's request to perform a gymnastics routine in front of the class. How might the use of positive self-talk influence the perception of the demand and their stress response?

(4 marks)

Self-talk

Answer

A PE student feels stressed by the teacher's request to perform a gymnastics routine in front of the class. How might the use of positive self-talk influence the perception of the demand and their stress response? (4 marks)



Self-talk can be used to re-appraise an environmental demand (stage 2 of the stress response), or one's ability to meet it, or it can work to decrease the perceptions of the demand. (1 mark)

Statements used before the class, such as 'what doesn't kill me will make me stronger' can be used to reduce the perceived significance of the task. (1 mark)

Self-talk can be used to moderate the worry and physical symptoms that characterise stage 3 of the stress process. (1 mark)

By using phrases just before the performance, such as 'breathe deep', an athlete can reduce the physical symptoms of stress. (1 mark)

Goal Setting and Arousal



Goal setting can be used prior to, during, or after an event to influence arousal.

Goal Setting and Stress



Goal setting can influence all stages of the stress process and can influence stress before, during, or after a performance.

Goal Setting and Motivation

Goal setting can influence motivation before, during, or after competition.



Goal Setting and Concentration



Goal setting can be used to focus on relevant cues in training before a competition, during competition, or after a competition.

Goal Setting and Self-confidence



Self-confidence after a performance can be boosted or diminished as a result of goals.

Goal Setting

Exam style question

A player's concentration is seen to be waning during a game of badminton. Justify the use of goal setting after the performance to bring about potential improvements in the next tournament.

(3 marks)



Goal-setting: Examples

Arousal	A track runner who has set himself a goal to beat his best time in the hurdles event is likely to experience greater levels of arousal just before he runs.
Stress	As stated by the 'SMARTS' principles of goal-setting, cyclists should set realistic goals for time trials that they feel capable of achieving. This helps to regulate the level of stress experienced.
Motivation	Setting a goal to compete at Nationals will influence a gymnast's decision to participate and exert large amounts of effort in qualifying competitions throughout the year.
Concentration	In netball, a GS might set herself a specific goal to follow through with her wrist action on every shot at goal. This goal is likely to direct her attention towards this specific component of performance during the game.
Self-confidence	A triathlete who successfully achieves his goal of winning the swimming component of his race is likely to feel more confident in his ability to meet future goals that he sets for himself.

Goal Setting



Answer

A player's concentration is seen to be waning during a game of badminton. Justify the use of goal setting after the performance to bring about potential improvements in the next tournament. (3 marks)

Setting goals will assist the badminton player to focus on particular aspects of their performance (1 mark) – thereby facilitating the player to maintain concentration. (1 mark) The goals will provide a reference point to evaluate the quality of the performance and these can be re-set to accommodate successes. (1 mark)

Group Cohesion

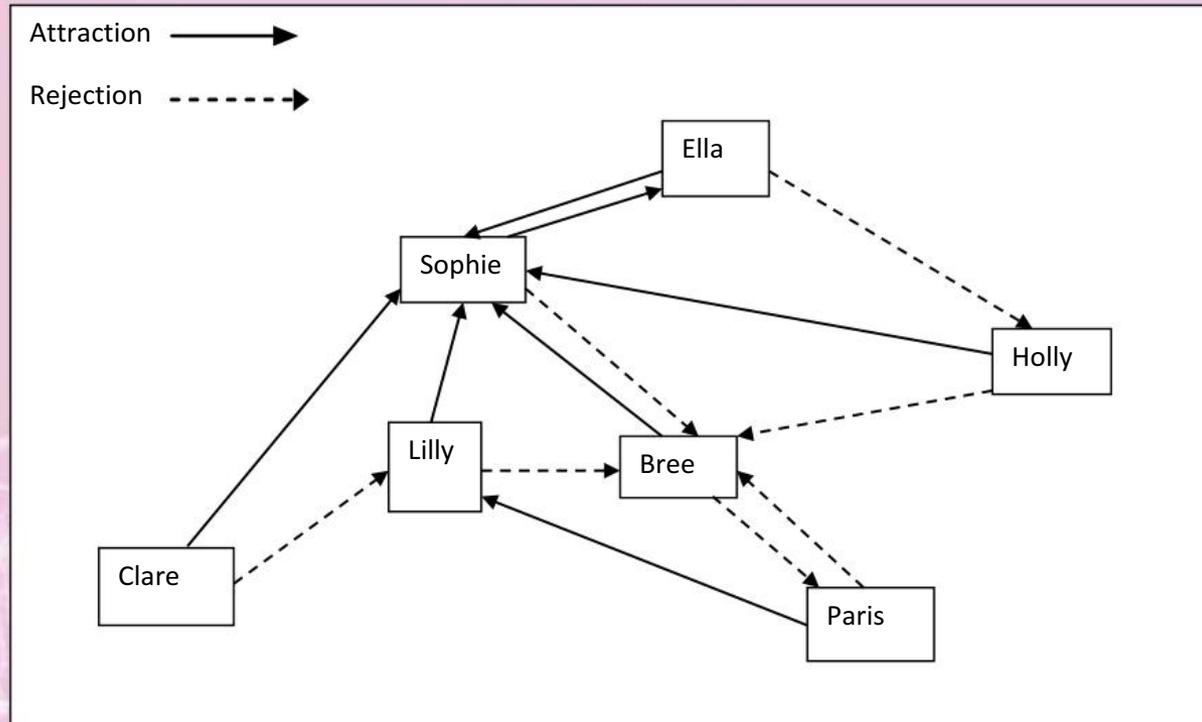
“The most deadly of basketball viruses, a disturbing lack of chemistry and complaints about playing time, threaten to sink this stink bomb as one of the all-time American disgraces in Olympic competition.”

Mariotti (2004, cited in Carron et al., 2005)



Reigning gold medalists from the Sydney 2000 Summer Olympics, the 2004 United States of America Olympic Basketball Team failed to retain its men's title, which went to Argentina. While some players chose not to represent their country, the team included plenty of stars; Carmelo Anthony, Carlos Boozer, Tim Duncan, Allen Iverson, LeBron James, Lamar Odom and Dwyane Wade.

Sociograms



Issues associated with social cohesion can be measured with a sociogram.

Group Cohesion



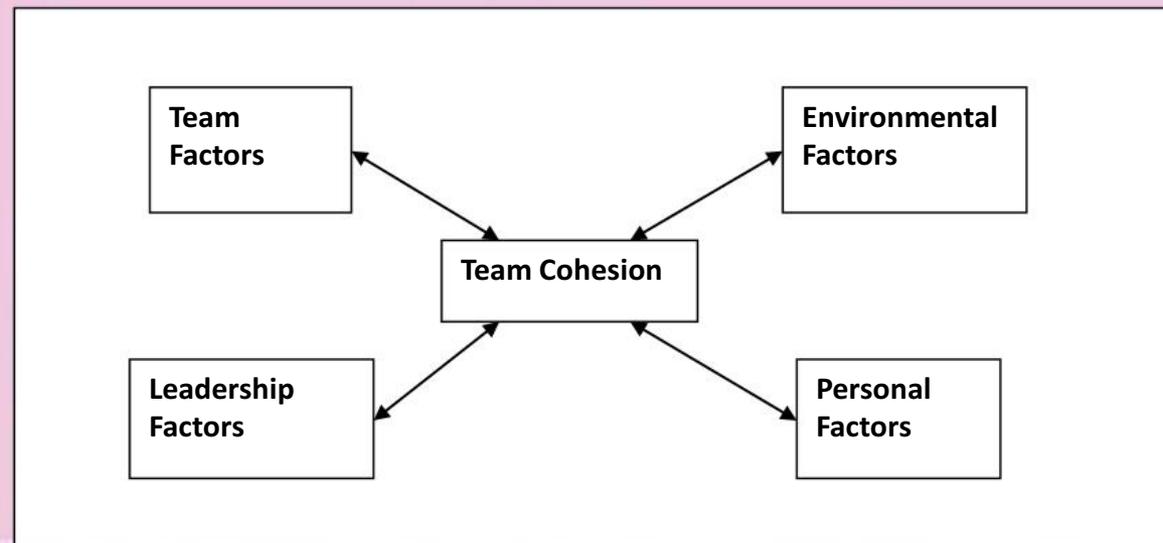
Group cohesion is a dynamic process which is reflected in the tendency for a group to stick together and remain united in the pursuit of its instrumental objectives and/or for the satisfaction of member bonds or friendship.

Carron's model states that:

- environmental
- personal
- leadership, and
- team factors

can influence cohesion, and cohesion can also influence these factors.

Carron's Model: Showing relationships involving team cohesion



The Ringelmann Effect and Social Loafing

The tendency for team members' performance to decrease as the team size increases is known as the Ringelmann effect.

The Ringelmann effect can partially be explained by social loafing, which refers to performance decrements as a result of losses in motivation.



Group Cohesion



Coaches and leaders can help to build cohesion by explaining individual roles in team success, setting challenging group goals, encouraging group identity, avoiding excessive turnover, and knowing the team climate.



Group members can help to build cohesion by avoiding the formation of social cliques, learning about other group members, helping teammates, giving encouragement and other positive reinforcement, and resolving conflicts quickly.

Group Cohesion

Exam style question

Leadership factors are said to be one of the categories of Carron's model of team cohesion.

- (i) Describe the leadership factors that influence cohesion. (3 marks)
- (ii) Provide two strategies a coach could employ to build team cohesion. (2 marks)



Group Cohesion



Answer

Leadership factors are said to be one of the categories of Carron's model of team cohesion.

- (i) Describe the leadership factors. (3 marks)
- (ii) Provide two strategies a coach could employ to build team cohesion. (2 marks)

(i) Leadership factors include the coach's leadership style (1 mark) and the behaviours that professional's exhibit. (1 mark) The dynamics of the coach-athlete interpersonal relationships and the coach-team relationships are also included in leadership factors. (1 mark)

(ii) Two strategies include:

- a. setting challenging group goals (1 mark)*
- b. encouraging group identity (1 mark)*



THE UNIVERSITY OF
**WESTERN
AUSTRALIA**

MOTOR LEARNING AND COACHING

Dr Brendan Lay and
Dr Peter Whipp



PHYSICAL EDUCATION STUDIES ATAR UNITS 3 AND 4
A TEXTBOOK FOR TEACHERS AND STUDENTS

Transfer of Learning

What is it and Why is it Important?

Transfer of learning is the gain (or loss) in proficiency in one skill as a result of practice on some other skill.

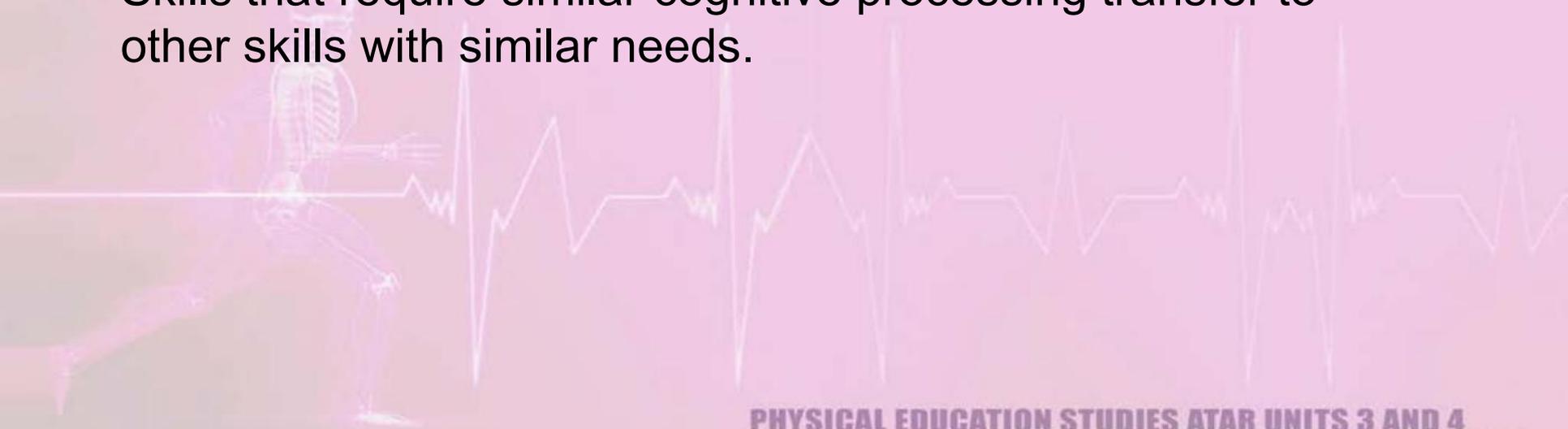
Understanding transfer of learning will assist with decisions about what to practice and how that will best improve performance.

Transfer of Learning

Why Does Transfer of Learning Occur?

Previously learned skills that are very similar to new skills can be used to physically execute the new skill.

Skills that require similar cognitive processing transfer to other skills with similar needs.



Transfer of Learning

Positive Transfer of Learning

Positive transfer of learning occurs when previous experience facilitates performance of a skill in a new context or the learning of a new skill.



Transfer of Learning

Negative Transfer of Learning

Negative transfer of learning occurs when previous experience inhibits or negatively affects performance of a skill in a new context or the learning of a new skill.



Transfer of Learning

Zero Transfer of Learning

Zero transfer of learning occurs when previous experience has no influence on the performance of a skill in a new context or the learning of a new skill.



Categories of Transfer of Learning

Skill-to-Skill

Skill-to-skill transfer of learning occurs when previous experience or practice of a skill impacts on the execution of the skill in a new context or performance of another skill.



Categories of Transfer of Learning

Proactive Skill-to-Skill Transfer

Proactive transfer of learning occurs when skills practiced in the past have an effect on motor skills that you will learn in the future.



Categories of Transfer of Learning

Retroactive Skill-to-Skill Transfer

When a skill that you have learned previously is altered by a new skill that you learn, that is retroactive transfer of learning.



Categories of Transfer of Learning



Theory-to-Practice

Theory-to-practice transfer of learning refers to transferring knowledge of sport or skill into the actual performance.

Categories of Transfer of Learning

Training-to-Competition

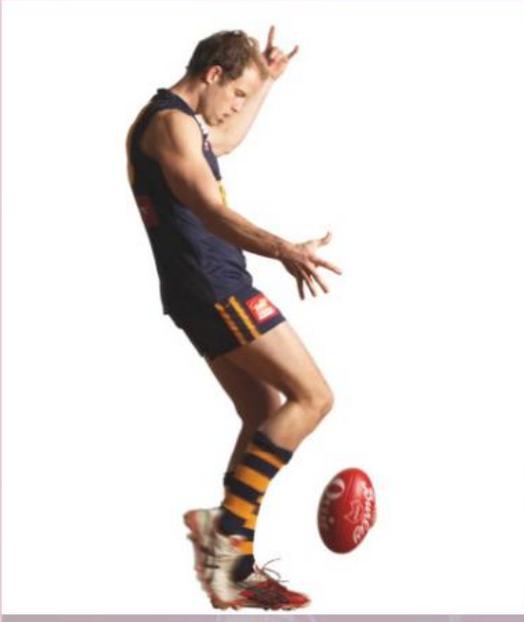
To increase the positive transfer between practice and competition, the practice should imitate the competitive situation, by incorporating into the training session:



- the aspects of the skill
- the context of the skill
- the perceptual stimuli (visual, proprioceptive and auditory cues)
- the time critical nature of making decisions and responding to those stimuli.

Transfer of Learning

Exam style question

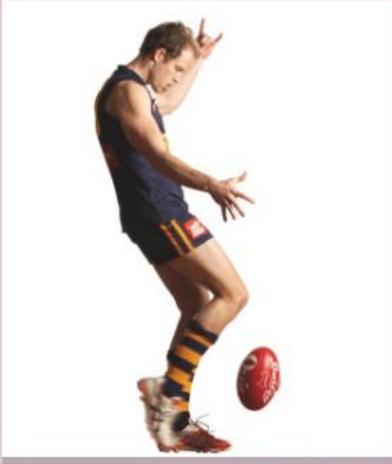


An AFL coach is deciding on the sequence of training activities. They are not sure if they should include time for the forwards to rehearse kicking for goal as part of the warm-up or after the aerobic and anaerobic fitness component of training. Using your understanding of training principles to enhance positive transfer of learning from practice to competition provide a rationale for choosing the time period after the fitness activities are completed.

(2 marks)

Transfer of Learning

Answer



An AFL coach is deciding on the sequence of training activities. They are not sure if they should include time for the forwards to rehearse kicking for goal as part of the warm-up or after the aerobic and anaerobic fitness component of training. Using your understanding of training principles to enhance positive transfer of learning from practice to competition provide a rationale for choosing the time period after the fitness activities are completed. (2 marks)

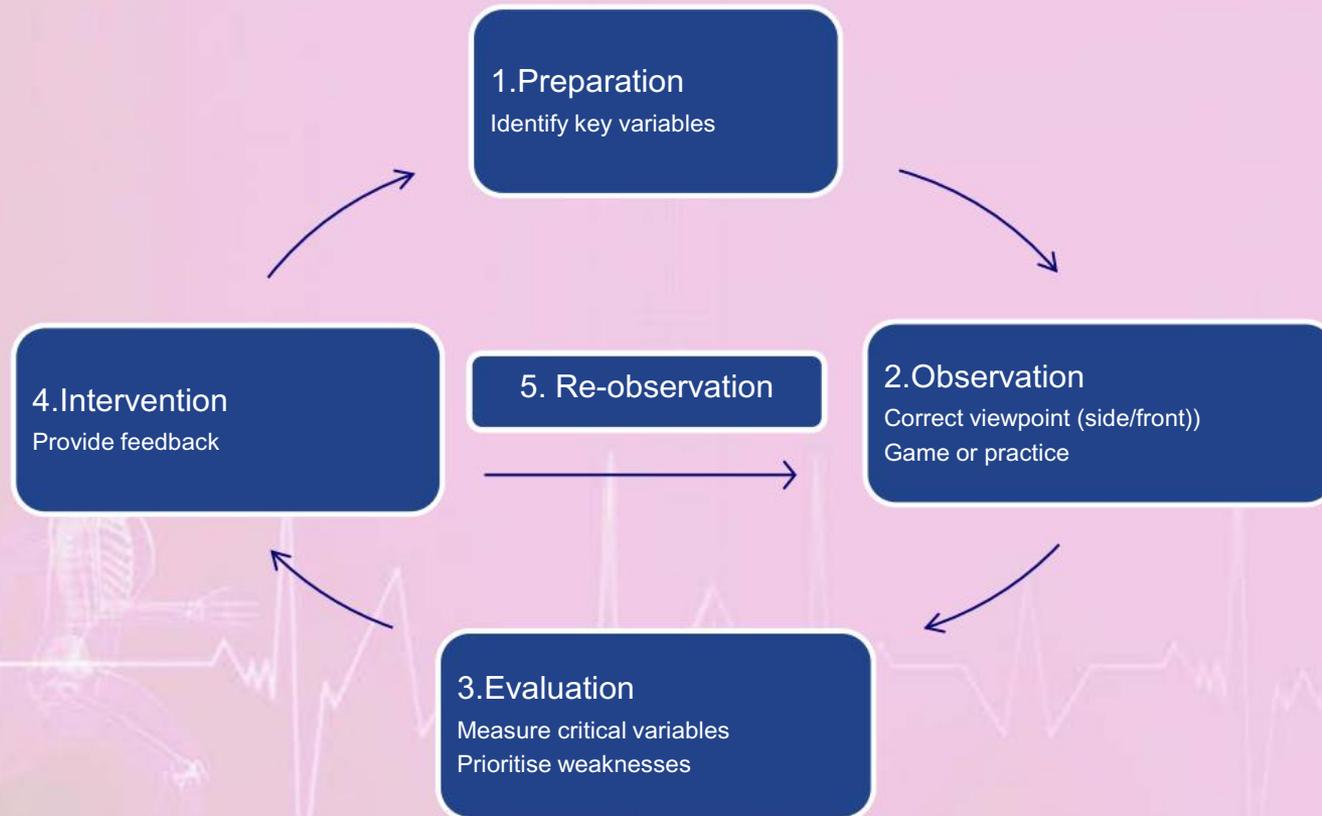
To enhance the positive transfer of learning it is important for training to replicate the context with which the skill is performed in competition. (1 mark) In the case of AFL, rehearsing a kick for goal whilst experiencing some level of fatigue accumulated during the fitness activities, serves to more accurately replicate the game context. (1 mark)

Considering the Type of Movement Analysis

- The aim or purpose of the analysis.
- The need to assess the product (what the outcome is) or the process (how the action is performed) of the motor skill.
- Skill level of performers/athletes.
- Environment that the analysis will be performed in.

Analyse Movement Skills of Self and Others

The Motion Analysis Model



Movement Analysis to Identify Errors

The primary aim of analysis is to identify errors that may be limiting performance or injury prevention and is undertaken during the 'evaluation (or diagnosis) phase of motion analysis'.



Movement Analysis to Provide Feedback

Feedback has three main purposes:

- provide information about performance
- reinforce aspects of the movement just performed
- motivate the athlete to continue to strive towards their goals.

Analyse Movement Skills of Self and Others

Movement Analysis to Provide Feedback

Augmented feedback is extra information given about the performance of a skill that is not inherent to the performing task through the performer's senses.

Augmented feedback can be provided as:

visual



verbal



written



kinaesthetic.



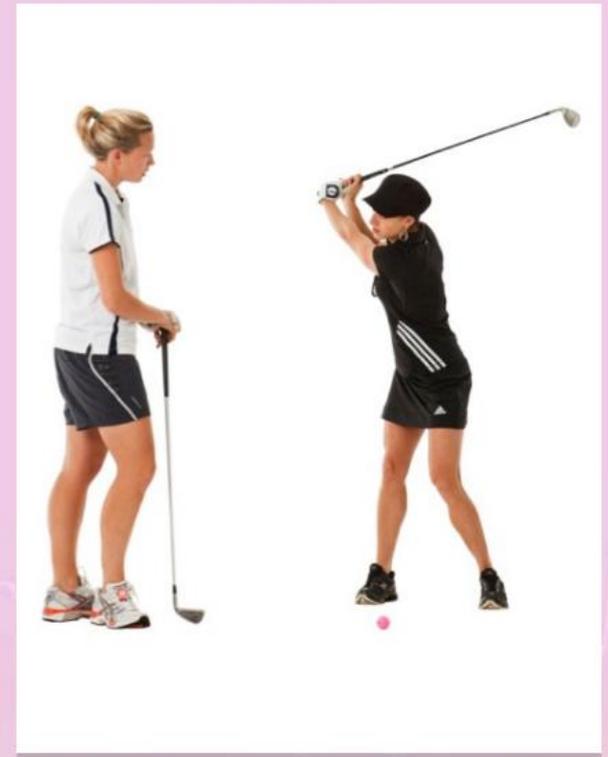
Movement Analysis to Provide Feedback

When learners are able, augmented feedback should not be presented continuously nor immediately after performance. Learners should be encouraged to self-evaluate using inherent feedback.

Descriptive augmented feedback identifies the errors, while *prescriptive* augmented feedback identifies the errors and a means to correct them.

Movement Analysis to Suggest Corrections to Improve Performance

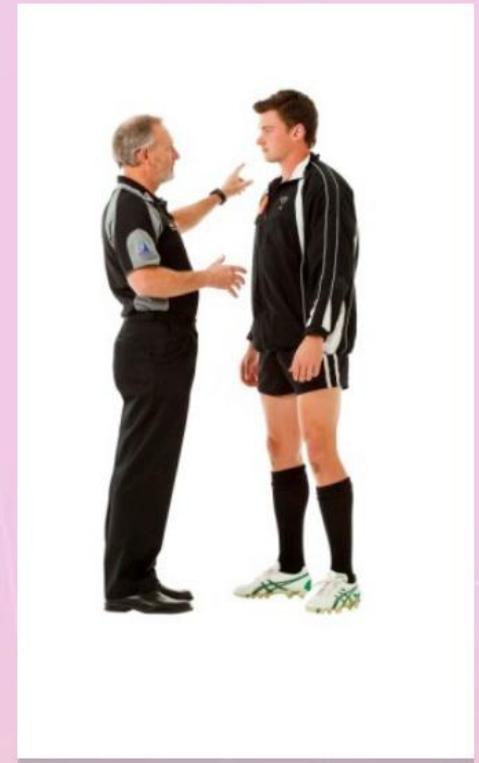
Visual cues used to improve performance include demonstrations, visual aids, and enhancement of the visual environment.



Analyse Movement Skills of Self and Others

Movement Analysis to Suggest Corrections to Improve Performance

A verbal cue is a concise phrase that directs attention to the most important feature(s) in the environment, or prompts performers to attend to key components of the skill.



Movement Analysis to Suggest Corrections to Improve Performance

Proprioceptive feedback refers to internal sensory information that informs us about our own joints, muscles and the orientation of our bodies in space (kinaesthesia).



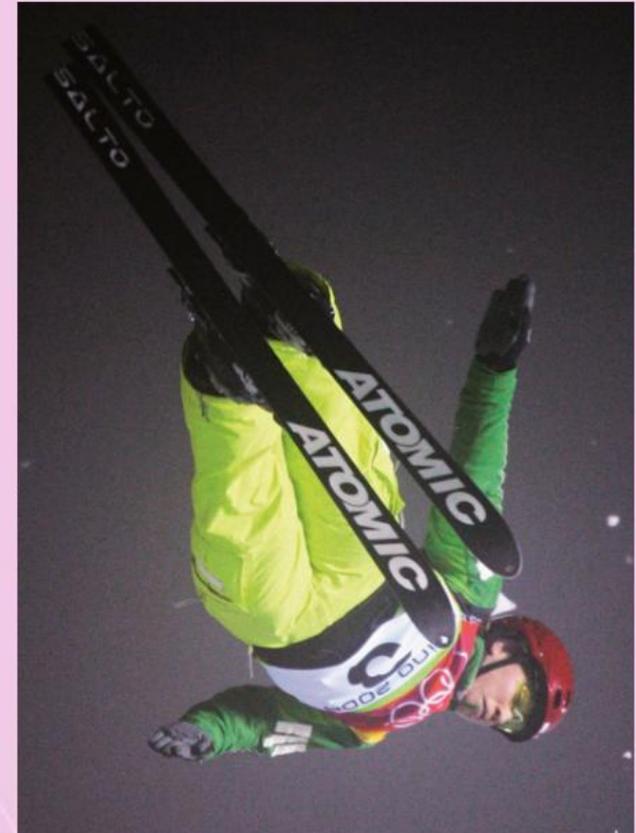
It often involves the coach physically moving the athlete through the required action to enhance their understanding of what a successful performance feels like.

Improving Performance in Selected Skills

Complex and Simple Skills

Complex skills have a large number of components and demand a lot of attentional resources.

A *simple skill* has few components and low demand on attention.



Simplifying Complex Motor Skills

Method of Simplification	Skill Acquisition Example
Reduce object difficulty	Using silk scarves for juggling Using a foam bat and ball for baseball or cricket
Reduce attention demands	Decrease the number of opponents in a drill Reduce the number of options or cognitive processing
Reduce speed	Slow down speed of tennis serve, emphasise accuracy
Add auditory cues	Using a metronome to learn a piece of music
Sequencing skill progressions	Chaining and shaping skills (see further in this section)
Simulators or virtual reality	For driver and pilot training

Improving Performance

Exam style question

Using your understanding of the strategies that can simplify a complex skill, explain how someone learning to hit a softball may benefit from practising in the sequence represented by the following images.

(5 marks)



2



3

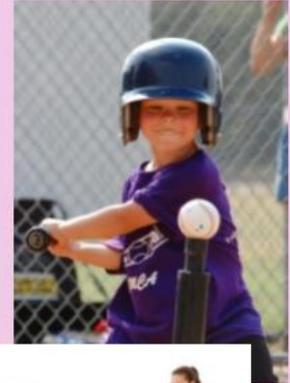


Improving Performance

Answer

Using your understanding of the strategies that can simplify a complex skill, explain how someone learning to hit a softball may benefit from practising in the sequence represented by the following images. (5 marks)

Sitting the ball on the T in the first task (eliminating the ball motion) (1 mark) and using a bigger ball and lighter bat in the second learning task (1 mark) (reducing the difficulty of the objects used, and reducing the speed of the task) (1 mark) – all serve to reduce the attention demands when compared to hitting a pitched ball. (1 mark) By simplifying the task, the teacher enhances the opportunity to focus on the important cues for learning. (1 mark)



Shaping a Skill

Shaping is when simplified or incomplete versions of a skill are rehearsed initially and then missing components are gradually added.



Chaining a Skill

Chaining is when the skill is broken down into components that are rehearsed separately, as if they were isolated skills. Over time, the components of the skill are then put together to perform the whole skill.

- *Forward chaining* – skill components are rehearsed in the order that the whole skill is performed.
- *Backward chaining* – last component is practised first and the whole skill is built by working backwards.

The Decision to Break Down a Motor Skill

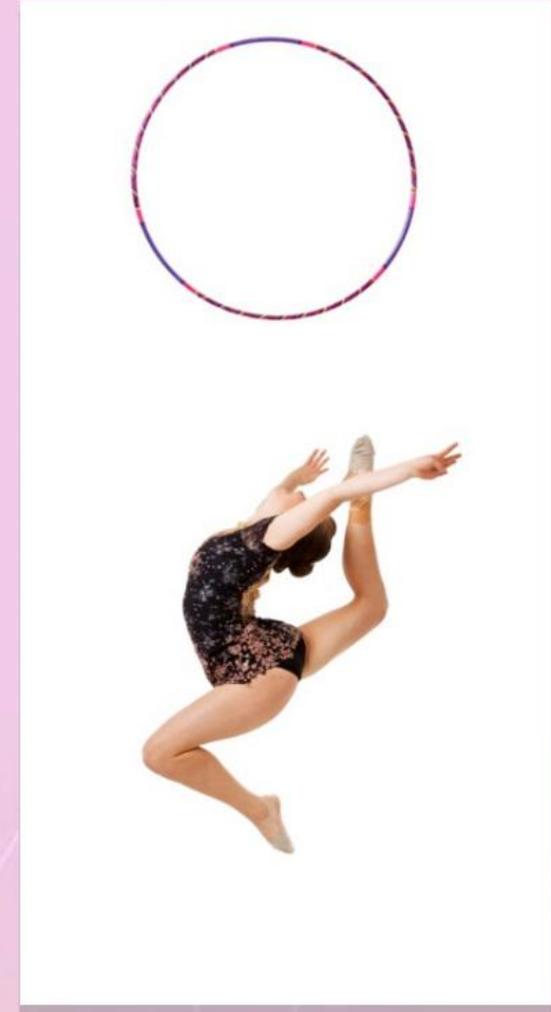
Whole practice involves practicing the entire motor skill. Used for skills that are low in complexity and high in organisation.

Part practice involves breaking the skill down into parts that can be rehearsed separately. Used for skills that are high in complexity and low in organisation.

Static and Dynamic Drills

Static drill – the athlete will stay on the same spot and perform the skill. They reduce the attention demands.

Dynamic drill – performed while the athlete is in some form of locomotion.



Improving Performance in Selected Skills

Exam style question

Using the example of learning a spike in volleyball, explain and justify your choice to teach this skill with the whole or part method with chaining.

(4 marks)



Improving Performance in Selected Skills

Exam style question

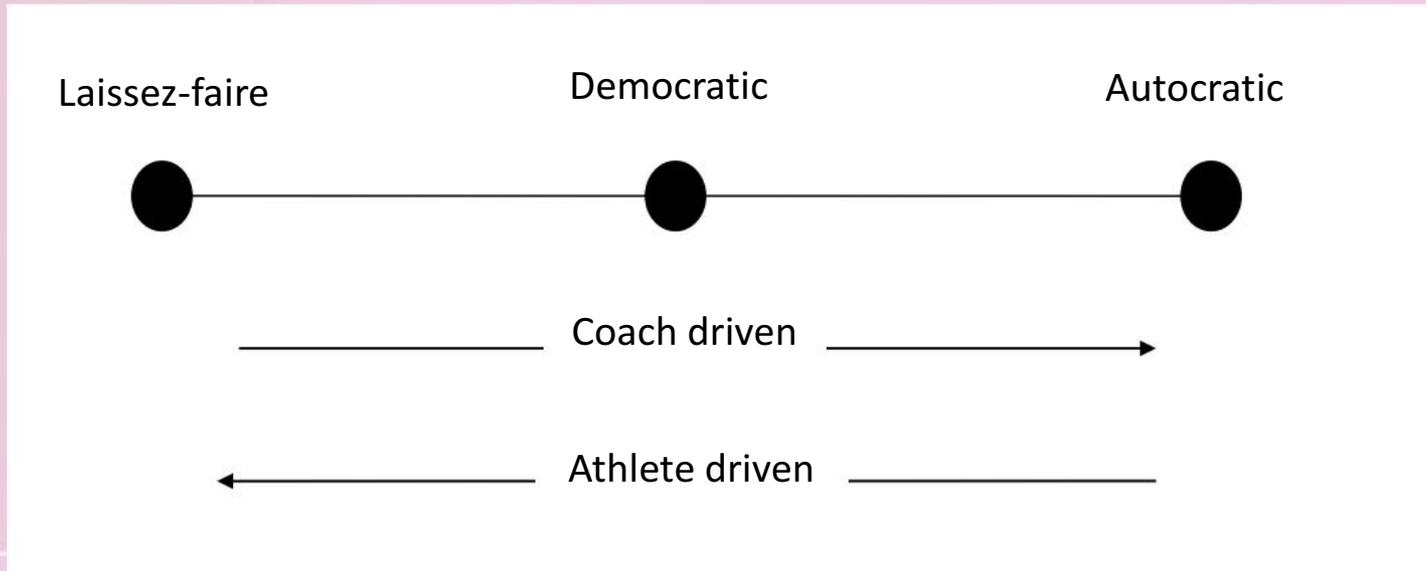
Using the example of learning a spike in volleyball, explain and justify your choice to teach this skill with the whole or part method with chaining. (4 marks)



The volleyball spike is a skill that is high in complexity and low in organisation. (1 mark) The spike can also be easily broken into and taught as separate components, such as the approach and take-off, the preparation to hit, the hit, the hit and landing. (1 mark) Therefore, it should be taught using the part method and with chaining. (1 mark) Chaining is when the skill is broken down into components that are rehearsed separately. (1 mark)

Leadership Styles

Using Different Leadership Styles to Suit Audience Needs



Using Different Leadership Styles to Suit Audience Needs

An autocratic leader makes the decisions

Suits athletes who:

- need support and answers
- value extrinsic motivation
- value extrinsic setting of benchmarks and are goal driven.

Using Different Leadership Styles to Suit Audience Needs

A democratic leader consults, asking the group to be a part of any decision-making process.

Suits athletes who:

- have their own answers
- are intrinsically motivated
- want to contribute.



Using Different Leadership Styles to Suit Audience Needs

Laissez-faire describes a leadership style where the teacher or coach will 'let people do as they choose'.

Suits athletes who:

- want to focus on participation, socialisation and enjoyment
- are intrinsically motivated
- determine self-defined standards of performance
- are experienced or Masters level.

Leadership Styles

Exam style question

Justify a leadership style that a coach might employ to best suit the needs of one of the world's most successful tennis players - Roger Federer.

(4 marks)



Leadership Styles

Answer



Justify a leadership style that a coach might employ to best suit the needs of one of the world's most successful tennis players - Roger Federer. (4 marks)

A democratic style of leadership, (1 mark) which is characterised by a process of consultation between the coach and Federer. (1 mark) This approach would serve to empower the athlete and potentially provides them with a sense of control over their current and future career. (1 mark) This style respects and would allow benefits from Federer's extensive experience, expert knowledge and motivation. (1 mark)

Using Checklists and Videos to Evaluate Movement Technique

Checklists and video provide a mechanism for feedback as part of the important ongoing process of performance evaluation and error correction.

Checklists are a record of performance in relation to a set of predetermined criteria.



Using Checklists and Videos to Evaluate Movement Technique

Coaches use checklists and videos to:

- supplement visual, verbal and written feedback
- improve the quality of performance analyses
- provide a more objective review
- de-personalise feedback.



Using Checklists and Videos to Evaluate Movement Technique

Athletes use checklists and videos to:

- improve understanding
- be more involved in correcting their own performance
- determine the impact of mental or physical performance
- engage in reflective learning.



Using Checklists and Video to Analyse Mental versus Physical Performance

The performance impact of mental functioning can be assessed by:

- comparisons with performance successes and errors
- quality and consistency recorded in checklists
- by video from training and past performances.



Using Checklists and Video to Analyse Mental versus Physical Performance

Also, athletes can undertake self-reflection using checklists and video.

Use the checklists and video to evaluate performance through discussion with the coach.



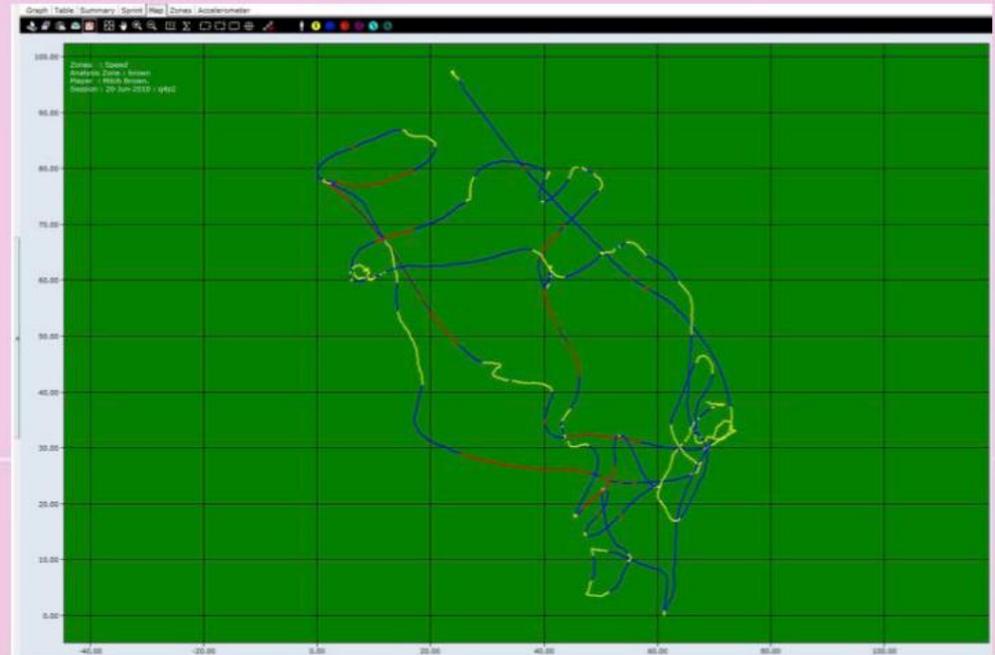
Using Checklists and Video for Error Correction

Obtaining feedback about errors in motor skill is the best way to improve performance.



Performance and Notational Analysis

Observations made by coaches during the game are limited to what they see and remember. They can be biased by their own motives and beliefs.



Performance and Notational Analysis

A notational analysis of performance using checklists, live observation and video is an analysis of data for players:

- analysis of success or failure of skills performed
- tactical evaluation and patterns of play
- player movements on the field.



Analyse Learning and Skill Development

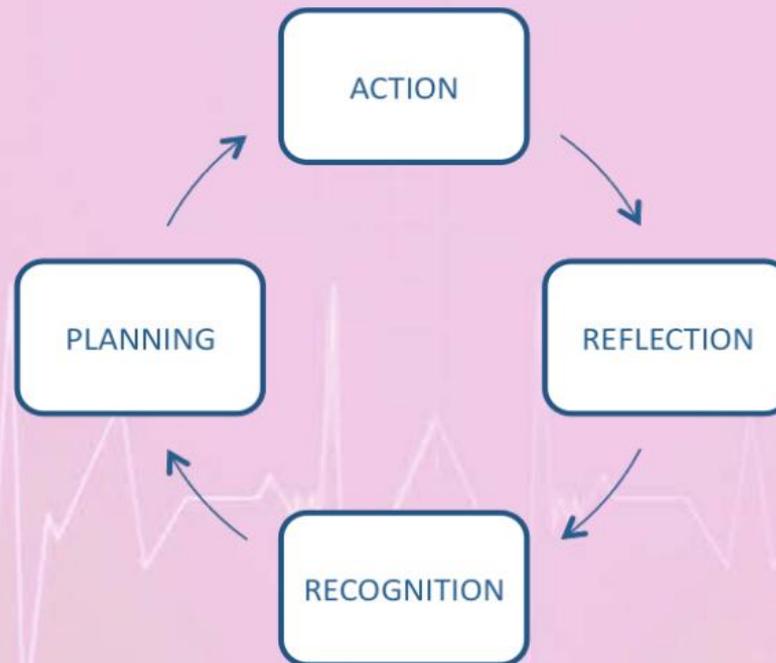
Learning is the change in the capability to perform a skill that is derived from a relatively permanent improvement in performance as a result of practice or experience.

Performance is an observable behaviour at a specific time and location.

To analyse learning and skill development, focus on assessing a number of performances over a period of time.

Reflective Learning

Reflective learning sees the athlete actively involved in gaining and examining feedback to improve performance.



Reflective Learning

Athletes make comparisons between the goals that have been set previously and what is actually occurring, planning for improvement and also monitoring improvement, by considering:

- what and how they are learning
- strengths and challenges
- how to improve
- working towards goals.



Methods of Reflection

Video analysis

Reflective journals

Peer/mentor/coach feedback

Questionnaires



Exam style question

An athlete is seeking answers from the coach to assist future learning, but the coach said they would be a better athlete in the long term if they firstly try reflective learning strategies to sort it out for themselves. Justify the position taken by the coach and identify one self-reflective methods an athlete could use.

(3 marks)



Analysis of Learning for Improved Performance

Exam style question

An athlete is seeking answers from the coach to assist future learning, but the coach said they would be a better athlete in the long term if they firstly try reflective learning strategies to sort it out for themselves. Justify the position taken by the coach and identify two self-reflective methods an athlete could use. (3 marks)

Sometimes learners become dependent on the augmented feedback from the coach and will not utilise task-intrinsic feedback or reflective learning to improve. (1 mark) For augmented feedback to be most effective, it is important to allow learners to problem solve for themselves and to utilise task-intrinsic error detection and self-reflective methods. (1 mark)



Provide one self-reflective methods (1 mark) that could include :

- (a) peer/mentor feedback , or*
- (b) video analysis.*