STUDENT UNIT GUIDE

NEW EDITION

AQA Physical Education

A2 UNIT 3

Optimising Performance and Evaluating Contemporary Issues within Sport

Symond Burrows • Michaela Byrne • Sue Young

- clear **revision guidance**
- **examiner** advice
- sample **questions** and **answers**

PHILIP ALLAN

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Getting the most from this book

Examiner tips

Advice from the examiner on key points in the text to help you learn and recall unit content, avoid pitfalls, and polish your exam technique in order to boost your grade.

Knowledge check

Rapid-fire questions throughout the Content Guidance section to check your understanding.

Knowledge check answers

1 Turn to the back of the book for the Knowledge check answers.

Summary

Summaries

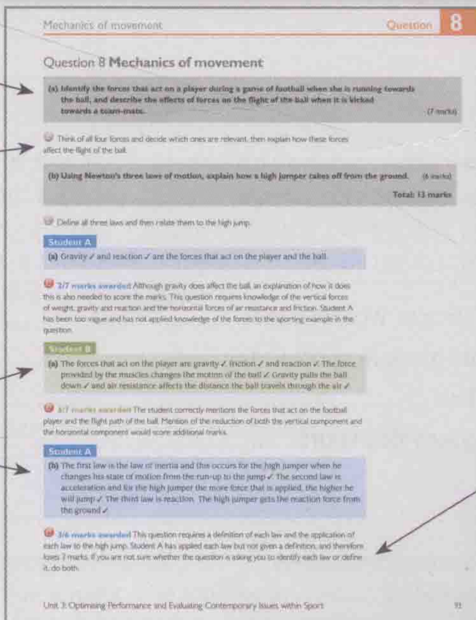
- Each core topic is rounded off by a bullet-list summary for quick-check reference of what you need to know.

Questions & Answers

Exam-style questions

Examiner comments on the questions
Tips on what you need to do to gain full marks, indicated by the icon ⓔ.

Sample student answers
Practise the questions, then look at the student answers that follow each set of questions.



Mechanics of movement — Question 8

Question 8 **Mechanics of movement**

(a) Identify the forces that act on a player during a game of football when she is running towards the ball, and describe the effects of forces on the flight of the ball when it is kicked towards a team-mate. (7 marks)

ⓔ Think of all four forces and decide which ones are relevant, then explain how these forces affect the flight of the ball.

(b) Using Newton's three laws of motion, explain how a high jumper takes off from the ground. (6 marks)

Total: 13 marks

ⓔ Define all three laws and then relate them to the high jump.

Student A

(a) Gravity ✓ and reaction ✓ are the forces that act on the player and the ball.

ⓔ **2/7 marks awarded** Although gravity does affect the ball, an explanation of how it does this is also needed to score the marks. This question requires knowledge of the vertical forces of weight, gravity and reaction and the horizontal forces of air resistance and friction. Student A has been too vague and has not applied knowledge of the forces to the sporting example in the question.

Student B

(a) The forces that act on the player are gravity ✓, friction ✓ and reaction ✓. The force provided by the muscles changes the motion of the ball ✓. Gravity pulls the ball down ✓ and air resistance affects the distance the ball travels through the air ✓

ⓔ **3/7 marks awarded** The student correctly mentions the forces that act on the football player and the flight path of the ball. Mention of the reduction of both the vertical component and the horizontal component would score additional marks.

Student A

(b) The first law is the law of inertia and this occurs for the high jumper when he changes his state of motion from the run-up to the jump ✓. The second law is acceleration and for the high jumper the more force that is applied, the higher he will jump ✓. The third law is reaction. The high jumper gets the reaction force from the ground ✓

ⓔ **3/6 marks awarded** This question requires a definition of each law and the application of each law to the high jump. Student A has applied each law but not given a definition, and therefore loses 3 marks. If you are not sure whether the question is asking you to identify each law or define it, do both.

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Examiner commentary on sample student answers
Find out how many marks each answer would be awarded in the exam and then read the examiner comments (preceded by the icon ⓔ) following each student answer.

About this book

This unit guide is written to help you prepare for the AQA PE Unit 3 exam. The exam covers the A2 theoretical content of three separate aspects of PE:

- applied physiology to optimise performance
- psychological aspects that optimise performance
- evaluating contemporary issues and their influence on the performer

Each aspect of the specification required for the Unit 3 test is covered in the **Content Guidance**. The **Questions and Answers** section provides examples of questions from various topic areas, together with student answers and examiner comments on how these could have been improved.

In the examination, each topic area has four questions: one compulsory extended-answer question and three further questions from which you must answer two. The Content Guidance section summarises the key information that you need to understand and apply in the Unit 3 exam. Remember that the Content Guidance is designed to support your revision and should be used in conjunction with your textbook, your own revision notes and other resources.

Content Guidance

Applied physiology to optimise performance

Energy sources and systems

Adenosine triphosphate

Adenosine triphosphate (ATP) is the only usable form of energy in the body. The energy we derive from the foods that we eat, such as carbohydrates, has to be converted into ATP before the potential energy in them can be used. ATP consists of one molecule of adenosine and three phosphate groups (see Figure 1):

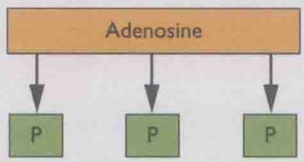

Figure 1

Examiner tip

Try to remember the following equation. It will help you to remember how ATP is broken down:

$\text{ATP} \xrightarrow{\text{ATPase}} \text{ADP} + \text{P} + \text{energy}$

Energy is released by breaking down the bonds that hold ATP together. ATPase is the enzyme that breaks down ATP into ADP + P.

Sources of energy to replenish ATP

Phosphocreatine is used to re-synthesise ATP in the first 10 seconds of intense exercise. It is easy to break down and is stored in the muscle cells but stores of it are limited.

Food is also used for ATP re-synthesis. The main energy foods are:

- **Carbohydrates** — stored as **glycogen** in the muscles and the liver and converted into glucose during exercise. During high-intensity anaerobic exercise, glycogen can be broken down in the absence of oxygen, but it is broken down much more effectively during aerobic work when oxygen is present.
- **Fats** — stored as **triglycerides** and converted to free fatty acids when required. At rest, two-thirds of our energy requirements are met through the breakdown of fatty acids. This is because fat can produce more energy per gram than glycogen.
- **Protein** — approximately 5–10% of energy used during exercise comes from proteins in the form of amino acids. It tends to be used when stores of glycogen are low.

Carbohydrates and fats are the main energy providers and the intensity and duration of exercise play a major role in determining which of these are used. The breakdown of fats to free fatty acids requires more oxygen than the breakdown of glycogen, so during high-intensity exercise, when oxygen is in limited supply, glycogen will be the preferred source of energy. Fats, therefore, are the favoured fuel at rest and during long endurance-based activities.

Stores of glycogen are much smaller than stores of fat and it is important during prolonged periods of exercise not to deplete glycogen stores. Some glycogen needs to be conserved for later when the intensity could increase — for example, during the last kilometre of a marathon.

Examiner tip

Make sure you know *when* each energy source is used.

Knowledge check 1

What are the main energy sources used during the 200 m?

Energy systems

There are three energy systems that re-synthesise/replenish/produce ATP:

- the ATP-PC system
- the lactic acid system
- the aerobic system

When a question asks how energy is produced, always look at the intensity and duration of the activity to help you decide which energy system is required.

Examiner tip

High-intensity activities lasting less than 10 seconds = the *ATP-PC system*

High-intensity activities with a duration of approximately 1 minute = the *lactic acid system*

Low-intensity activities with a duration longer than 1 to 2 minutes = the *aerobic system*

ATP-PC system

High-intensity activities lasting less than 10 seconds use predominantly the ATP-PC system. This system is anaerobic (no oxygen). Phosphocreatine is stored in the muscles and broken down to creatine and phosphate by the enzyme creatine kinase. Then energy is released for ATP re-synthesis. Aerobic energy is needed for this system to recover.

Advantages

- ATP can be re-synthesised rapidly using the ATP-PC system.
- Phosphocreatine stores can be re-synthesised quickly — (30 s = 50% replenishment and 3 min = 100%).
- There are no fatiguing by-products.
- It is possible to extend the time for the ATP-PC system through use of creatine supplementation.

Disadvantages

- There is a limited supply of phosphocreatine in the muscle cell — it lasts for only 10 s.
- Only one mole of ATP can be re-synthesised through one mole of PC.
- PC re-synthesis can take place only in the presence of oxygen (i.e. the intensity of the exercise is reduced).

Knowledge check 2

How is the majority of energy produced during the 100 m?

Lactic acid system

High-intensity activities with a duration of approximately 1 minute use mainly the lactic acid system. This system is anaerobic (no oxygen). In a process called **glycolysis**, glycogen is broken down into glucose using the enzyme phosphofructokinase (PFK), which is then broken down to pyruvic acid. In the absence of oxygen, the pyruvic acid is converted to lactic acid and two molecules of ATP are produced.

Knowledge check 3

At the 2008 Beijing Olympics, swimmer Eamon Sullivan from Australia won gold in the 100 m freestyle in a time of 47.05 s. How was the majority of energy produced during the race?

Advantages

- ATP can be re-synthesised quite quickly because there are few chemical reactions.
- In the presence of oxygen, lactic acid can be converted back into liver glycogen or used as a fuel through oxidation into carbon dioxide and water.
- It can be used for a sprint finish (i.e. to produce an extra burst of energy).

Disadvantages

- Lactic acid is the by-product. The accumulation of acid in the body denatures enzymes and prevents them increasing the rate at which chemical reactions take place.

Aerobic system

Low-intensity activities with a duration of longer than 1–2 minutes use the aerobic system predominantly. This system uses oxygen. ATP is regenerated from glucose and fats in three stages:

- **Glycolysis** — glycogen is broken down into glucose, which is then broken down into pyruvic acid.
- **Krebs cycle** — the pyruvic acid diffuses into the matrix of the mitochondria and a complex cycle of reactions occurs. The reactions result in the production of two molecules of ATP plus carbon dioxide and hydrogen. The carbon dioxide is breathed out and the hydrogen is taken to the electron transport chain.
- **Electron transport chain** — the hydrogen given off in the Krebs cycle is carried to the electron transport chain by hydrogen carriers. This occurs in the cristae of the mitochondria and the hydrogen splits into hydrogen ions and electrons. They are charged with potential energy. The hydrogen ions are oxidised to form water while the hydrogen electrons provide the energy to re-synthesise ATP. Throughout this process 34 molecules of ATP are formed.

Beta oxidation

Fats can also be used as an energy source in the aerobic system. They are broken down first into glycerol and then free fatty acids. These fatty acids undergo a process called beta oxidation, whereby they are broken down in the mitochondria to generate acetyl-CoA, which is the entry molecule for the Krebs cycle. From this point on, fat metabolism follows the same path as carbohydrate (glycogen) metabolism. More ATP can be made from one mole of fatty acids than from one mole of glycogen, which is why in long-duration exercise fatty acids will be the predominant energy source.

Knowledge check 4

How is the majority of energy produced during the marathon?

Advantages

- More ATP can be produced — 36 ATP molecules.
- There are no fatiguing by-products (only carbon dioxide and water).
- There are large stores of glycogen and triglyceride, so exercise can last a long time.

Disadvantages

- This is a complicated system. It takes a while for enough oxygen to become available to meet the demands of the activity and to ensure glycogen and fatty acids are completely broken down.
- Fatty acid transportation to muscles is low and requires 15% more oxygen to be broken down than glycogen.

The energy continuum

This refers to the continual movement from one energy system to another depending on the intensity and duration of the exercise. The ATP-PC/lactic acid threshold is the point at which the ATP-PC energy system is exhausted and the lactic acid system takes over. The lactic acid/aerobic threshold is the point at which the lactic acid system is exhausted and the aerobic system takes over. These thresholds can be highlighted in a graph (see Figure 2).

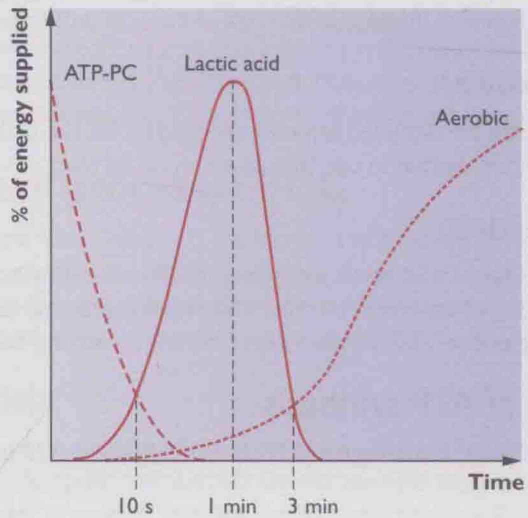

Figure 2

The **lactate threshold** is the point at which lactic acid rapidly accumulates in the blood. It occurs when lactate is produced faster than it can be removed. It is a useful guide for deciding which intensity of exercise to work at. When individual performers reach their lactate threshold, their performance starts to deteriorate and the intensity of the workload starts to decrease so that the aerobic system becomes the predominant method of producing ATP.

The **lactate threshold** is the point at which lactic acid rapidly accumulates in the blood.

Knowledge check 5

What do you understand by the term 'energy continuum'?

Summary

After studying this topic you should be able to:

- identify where energy sources are located in the body and which energy source is used, according to the intensity and duration of exercise
- explain how ATP is re-synthesised
- describe the ATP-PC system and the lactic acid system and their use in sporting situations
- describe the stages of the aerobic system, including the Krebs cycle, the electron transport chain and the role of the mitochondria
- explain the lactate threshold through the energy continuum

Causes of fatigue, and the recovery process

Examiner tip
Questions on the causes of fatigue tend to ask you to give the causes for a particular activity and explain them.

Causes of fatigue

There are many causes of fatigue and these depend on the intensity and duration of the activity. For example, a marathon runner will fatigue through glycogen depletion whereas an 800 m runner will fatigue through lactic acid build-up.

Glycogen depletion

When glycogen stores are depleted athletes are said to 'hit the wall' as the body tries to metabolise fat but is unable to use this as a fuel on its own.

Lactic acid build-up

An accumulation of lactic acid releases hydrogen ions. These hydrogen ions cause an increase in the acidity of the blood plasma. This inhibits enzyme action and therefore the breakdown of glucose, and irritates nerve endings, causing pain.

Reduced rate of ATP synthesis

When stores of ATP and PC are depleted there is insufficient ATP to sustain muscular contractions.

Dehydration

Water is lost through sweating during exercise and if it is not replaced then dehydration occurs. Dehydration can have an effect on blood flow to the working muscles and results in a loss of electrolytes, such as calcium, which help with muscular contractions. Blood viscosity increases and blood pressure decreases. There is a reduction in sweating to prevent further water loss, which in turn increases core body temperature. This results in the performer being unable to meet the demands of the activity.

Reduced levels of calcium

For muscle contraction to occur there has to be a release of calcium. An increase in hydrogen ions (due to acid build-up) decreases the amount of calcium released.

Reduced levels of acetylcholine

This is a neurotransmitter that can help a nerve impulse to jump the synaptic cleft (the gap that separates the nerve ending from the muscle fibre) and initiate muscular contraction. When levels of acetylcholine are low the muscles become fatigued.

Thermoregulation

During exercise heat is generated in the body as a result of all the chemical reactions (metabolic processes) that take place to produce energy. Long-distance runners sometimes experience difficulty with temperature regulation. The heat produced through muscle contraction raises the core body temperature, which causes the blood viscosity to increase and metabolic processes to slow down. This means the performer is unable to sweat efficiently and dehydration occurs.

The thermoregulatory centre in the medulla oblongata controls temperature. Heat is transported to the surface of the skin by the blood and the vessels vasodilate, enabling heat to be lost through radiation, convection or the evaporation of sweat.

When the body is dehydrated, total blood volume decreases. More blood is redirected to the skin (to aid cooling), so the amount of blood and therefore oxygen available to the working muscles is reduced and this affects performance. In hot conditions this situation is exacerbated so it is important to acclimatise, enabling the body to modify the control systems that regulate blood flow to the skin and sweating.

Knowledge check 6

Explain the main cause of muscle fatigue during a 200 m race.

The recovery process: EPOC

During recovery the body takes in increased amounts of oxygen. The oxygen is transported to the working muscles to maintain elevated rates of aerobic respiration. This surplus energy is used to help return the body to its pre-exercise state. This is known as excess post-exercise oxygen consumption (EPOC).

Examiner tip

Exam questions often ask about the importance of taking in extra oxygen or EPOC (excess post-exercise oxygen consumption).

The oxygen debt

When we start to exercise, insufficient oxygen is distributed to the tissues for all the energy production to be met aerobically, so the two anaerobic systems have to be used. The amount of oxygen that the subject was short of during the exercise is known as the **oxygen deficit**. This is compensated for by the surplus amount of oxygen — or oxygen debt — that results from EPOC (see Figure 3).

The fast replenishment stage (alactacid component)

This involves the restoration of ATP and phosphocreatine stores and the re-saturation of myoglobin with oxygen. Elevated rates of respiration continue to supply oxygen to provide the energy for ATP production and phosphocreatine replenishment. Complete restoration of phosphocreatine takes up to 3 minutes but 50% of stores can be replenished after only 30 seconds, during which time approximately 2–3 litres of oxygen are consumed.

fast replenishment is the restoration of ATP and phosphocreatine stores and the re-saturation of myoglobin with oxygen

Myoglobin and replenishment of oxygen stores

Myoglobin has a high affinity for oxygen. It stores oxygen in the muscles, where it is released into the mitochondria for energy provision. After exercise oxygen stores in the mitochondria are limited. The surplus of oxygen supplied through EPOC helps replenish these stores, taking up to 2 minutes and using approximately 0.5 litres of oxygen.

myoglobin is an oxygen-binding protein found in the heart and the skeletal muscles

The slow replenishment stage (lactacid component)

This is concerned with the removal of lactic acid. It is the slower of the two processes and full recovery may take up to an hour, depending on the intensity and duration of the exercise. Lactic acid can be removed in the following ways:

slow replenishment is concerned with the removal of lactic acid

Destination
Oxidation into carbon dioxide and water in the inactive muscles and organs
Used as an energy source
Conversion into glycogen — then stored in muscles/liver
Conversion into protein
Conversion into glucose
Excreted in sweat/urine

Knowledge check 7

Explain how lactate is removed from the blood by the body.

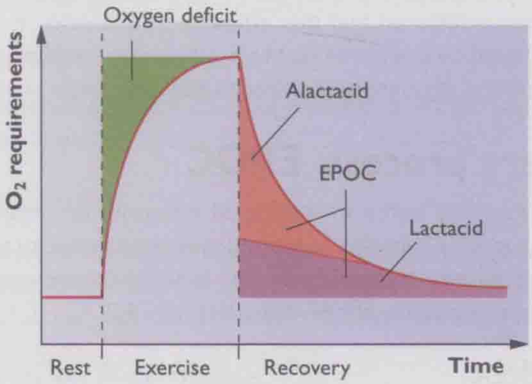

Figure 3 Recovery after maximal exercise

Glycogen replenishment

The replacement of glycogen stores depends on the type of exercise undertaken and when and how much carbohydrate is consumed following exercise. It may take several days to complete the restoration of glycogen after a marathon, but a significant amount of glycogen can be restored in less than an hour after long-duration, low-intensity exercise. Eating a high-carbohydrate meal will accelerate glycogen restoration, as will eating within an hour following exercise.

Increase in breathing and heart rates

This is important to assist in recovery where extra oxygen is required to return the body to its pre-exercise state. However, the increase in breathing and heart rates requires additional extra oxygen to provide energy for the muscles of the heart and respiratory system.

Increased activity of hormones

The continuation of submaximal exercise (such as a cool-down) will keep hormone levels elevated and this will keep respiratory and metabolic levels high so that extra oxygen can be taken in.

Increase in body temperature

When temperature remains high, respiratory rate will also remain high and this will help the performer take in more oxygen during recovery. However, extra oxygen is needed to fuel this increase in temperature until the body returns to normal.

Summary

After studying this topic you should be able to:
- identify the causes of fatigue
- define 'oxygen deficit'
- define EPOC
- describe the fast and slow components of recovery

What makes a successful endurance performance?

VO_2 max and sporting performance

VO_2 max is the maximum volume of oxygen that can be taken in and used by the muscles per minute. A person's VO_2 max will determine endurance performance in sport.

Average VO_2 max values		
Female A-level PE student	Male A-level PE student	Paula Radcliffe
35–44 $ml\,kg^{-1}\,min^{-1}$	45–55 $ml\,kg^{-1}\,min^{-1}$	80 $ml\,kg^{-1}\,min^{-1}$

Examiner tip

Questions on this topic often involve what is meant by VO_2 max and the factors that allow for a good VO_2 max.

Knowledge check 8

What do you understand by the term 'VO_2 max'?

Factors affecting VO_2 max

Gender

A male endurance athlete will have a bigger VO_2 max (70 $ml\,kg^{-1}\,min^{-1}$) than a female endurance athlete (60 $ml\,kg^{-1}\,min^{-1}$). This is because the average female is smaller than the average male and females have:
- a smaller left ventricle and therefore a lower stroke volume
- a lower maximum cardiac output
- a lower blood volume, resulting in lower haemoglobin levels
- lower tidal and ventilatory volumes

Age

As we get older our VO_2 max declines as our body systems become less efficient:
- maximum heart rate drops by around 5–7 beats per minute per decade
- an increase in peripheral resistance results in a decrease in maximal stroke volume
- blood pressure increases both at rest and during exercise
- less air is exchanged in the lungs due to a decline in vital capacity and an increase in residual air

Lifestyle

Smoking, sedentary lifestyle and poor diet can all reduce VO_2 max values.