SACE TWO

PHYSICAL EDUCATION

WORKBOOK

SIXTH EDITION

NEIL MCNAUGHTON
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Essentials education

ADELAIDE TUITION CENTRE

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Focus Area 1: In Movement

1.1 Application of energy sources affecting physical performance

- The contribution of energy systems in specific activities
- The interplay of energy systems
- Energy contributions and fatigue

The Contribution of Energy Systems in Specific Activities

ATP – The Immediate Energy Source

The human body requires a constant supply of energy to fuel all of our daily bodily functions, including physical activity. As physical activity increases, there is also an increased demand for energy due to increased muscular contractions. Ultimately, it is our capacity to transfer energy at a high rate to the contractile elements of the muscular system that determines our capacity for exercise.

An 'energy rich' molecule called adenosine triphosphate (ATP) is the universal and immediate usable form of chemical energy for all 'biological' work performed by any cell within the body. ATP is considered the energy 'currency' of the human body.

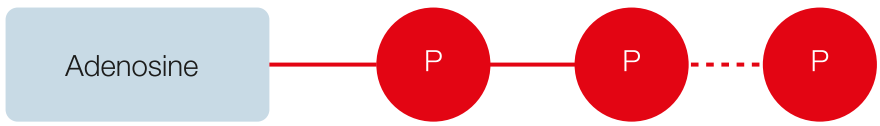


Figure 1.1.1: ATP consists of one adenosine molecule and three phosphate molecules.

The ATP molecule is very complex, but essentially its structure consists of a 'high energy' bond that glues the end two phosphate (P) molecules together. This connection contains a great deal of potential chemical energy, so when the phosphate bond is chemically broken, energy is released to allow the body's cells to perform work.

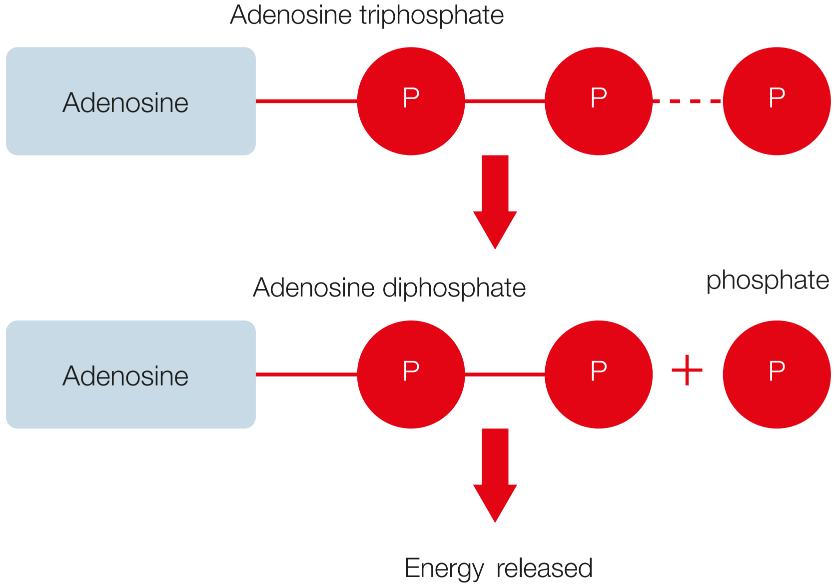


Figure 1.1.2: Energy stored inside the ATP molecule is released when the last phosphate (P) high energy-bond is broken forming the molecule ADP.

The chemical equation of this process can be represented as follows:

$$ATP \rightarrow ADP + P + ENERGY$$

Because ATP is stored directly in nearly every cell of the human body, the energy provided by the breakdown of ATP is used for all 'biological' functions including mechanical work (muscle fibres), nerve conduction (nerve cells) and secretion (endocrine cells) etc.

Although the ATP molecule is stored 'onsite' in all skeletal muscles ready to supply energy for muscular contractions, its stores are extremely limited. The muscles only have enough ATP to fuel approximately 2 seconds of maximal activity before ATP is fully exhausted.

Because the stored ATP is in such small supply and easily exhausted, the body needs to continually rebuild the ATP molecule to maintain a constant energy supply. The molecules required to rebuild ATP are found in the products of its initial breakdown – **adenosine diphosphate (ADP) + phosphate (P)**, but the rebuilding process also requires energy.

$$\text{ADP} + \text{P} + \text{ENERGY} \rightarrow \text{ATP}$$

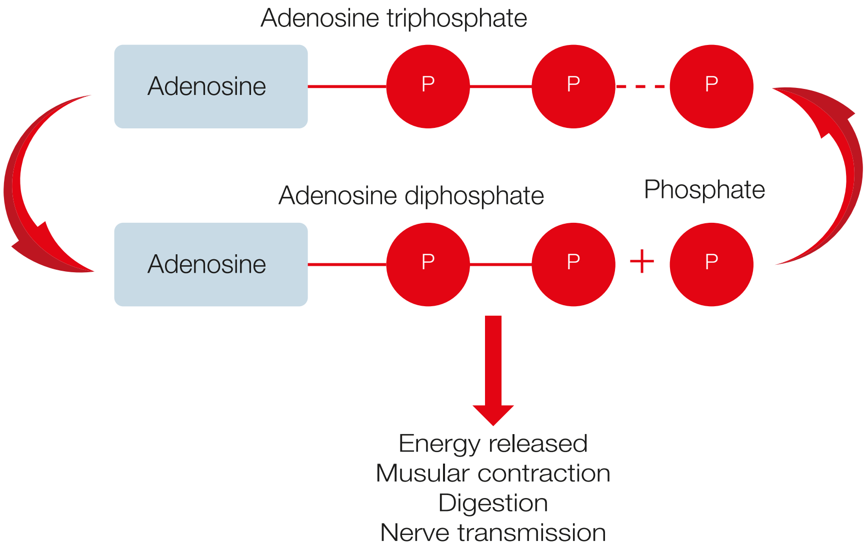


Figure 1.1.3: Energy is required to rebuild the ATP molecule using the adenosine diphosphate (ADP) and phosphate (P) molecules.

The energy required to rebuild the ATP molecule comes from three different chemical reactions within the body, referred to as our **energy systems**. Two of the energy systems rely on the food we eat to provide the energy to rebuild ATP, whilst the other uses a stored chemical compound called creatine phosphate.

The three energy systems are:

- ATP-CP system
- Lactic acid system
- Aerobic system

Each energy system has its own advantages and disadvantages when rebuilding ATP. No matter the activity we are performing, it is likely that all three energy systems will contribute to the rebuilding of ATP. The dominant energy system used to rebuild ATP will depend to a large degree upon the **intensity** and **duration** of the activity being performed.

Energy System: ATP-CP

During very high intensity activity, energy is needed by the muscles as quickly as possible to rebuild the ATP molecule, and this comes from another 'high energy' bond compound known as **Creatine Phosphate (CP)**. Like ATP, when the creatine (C) and phosphate (P) bond is chemically broken, energy is instantly released to rebuild the ATP molecule.

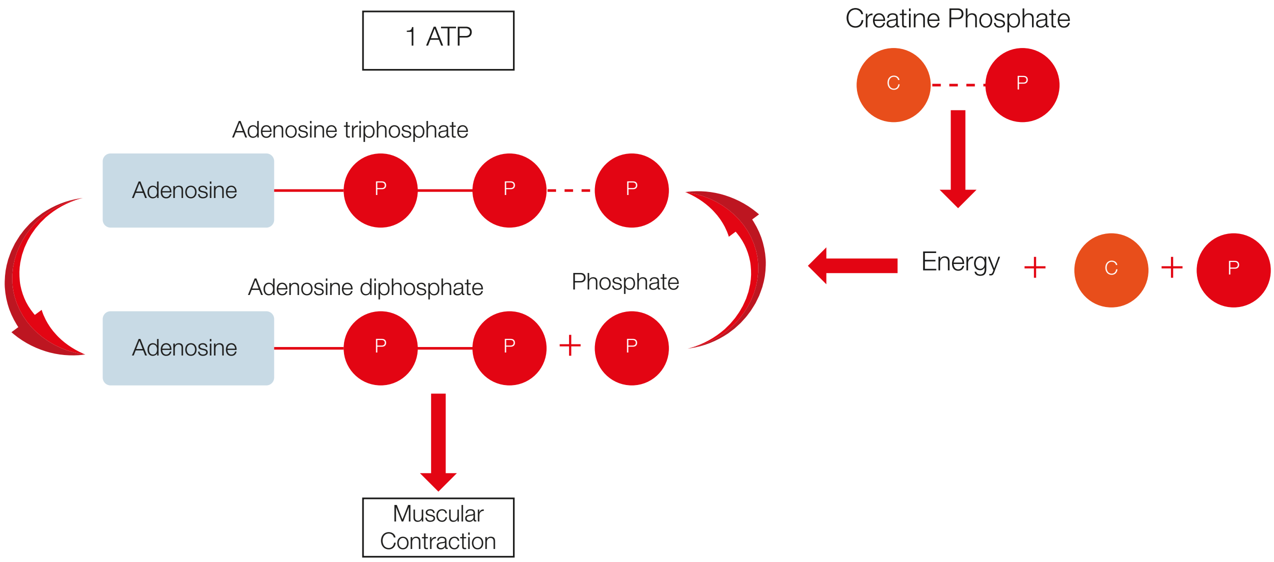


Figure 1.1.4: Energy released from the breakdown of Creatine Phosphate (CP) is used to rebuild ATP.

The ATP-CP system supplies immediate energy for any sprint or maximal intensity, short duration work <10 seconds.

Alternative names for the ATP-CP energy system:

- ATP-PC system
- Alactacid system
- Phosphate system.

Muscle stores of CP are very limited, so less than 10 seconds is the average time for which this system can be the dominant energy system to rebuild the ATP molecule.

Figure 1.1.5 and 1.1.6: Maximal (100%) effort for a short duration (<10 seconds) see the ATP-CP energy system dominant.

Once depleted, the ATP-CP energy system can quickly recovery with 50% CP restored after 30 seconds and 100% CP restored after approximately 3 minutes following a passive recovery.

Table 1.1.1: Summary of the ATP-CP Energy System

ATP–CP Energy System	
Positives	**Negatives**
CP stored in muscles 'ready to go' instantly	Very limited CP stores in muscle – fully depleted <10 seconds maximal effort
Used for maximal intensity (100% effort)	
Anaerobic (does not require O_2 to be delivered to muscles) = instant energy	
No fatiguing by-products, so termed 'alactacid' = no lactic acid produced	
Quick to rebuild CP: • 50% CP rebuilt in 30 seconds • 100% CP rebuilt in 3 minutes	

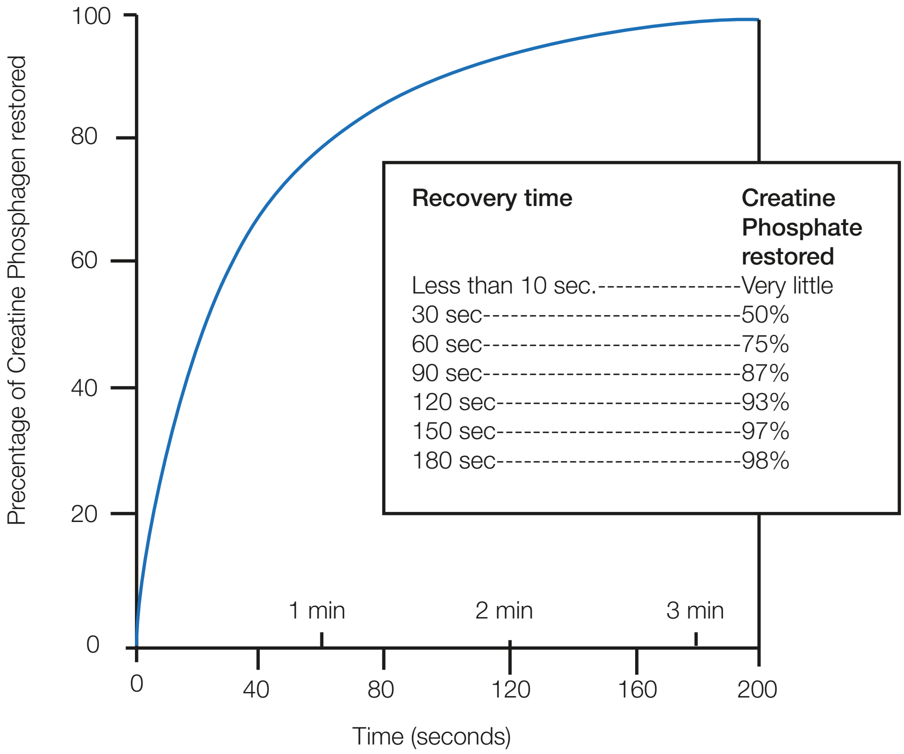


Figure 1.1.7: The rate of Creatine Phosphate (CP) restored over time, following exhaustive exercise.

Focus Questions

1. Describe the intensity and duration of exercise where the ATP-CP system would be the dominant source of energy to rebuild ATP.

2. Explain the term Alactacid:

3. Identify and explain two specific athletic events (track or field) and two (specific game related) activities within a team-sport that would rely predominantly on the ATP-CP system for energy to rebuild ATP:

   (a) Track or Field:

   (b) Team sport (specific game related):

4. With reference to the Figure 1.1.7 showing the rate of Creatine Phosphate (CP) restored over time, answer the following:

   Why is it possible for an athlete to sprint maximally (100%) for 50m in 6 seconds; rest for 3 minutes, sprint another 50m in 6 seconds and repeat this cycle several times without a drop in speed?

   Explain your answer using information from the graph:

Energy System: Lactic Acid

The lactic acid energy system is important to supply quick energy to rebuild ATP during high intensity efforts (85%+) ranging from 10 seconds to approximately 1 minute of high intensity exercise.

Alternative names for the Lactic Acid energy system:

- Anaerobic Glycolysis
- Lactacid energy system.

Definitions

Anaerobic – a process that does not require oxygen

Glycolysis – breakdown of carbohydrate (glycogen)

Lactacid – lactic acid is produced

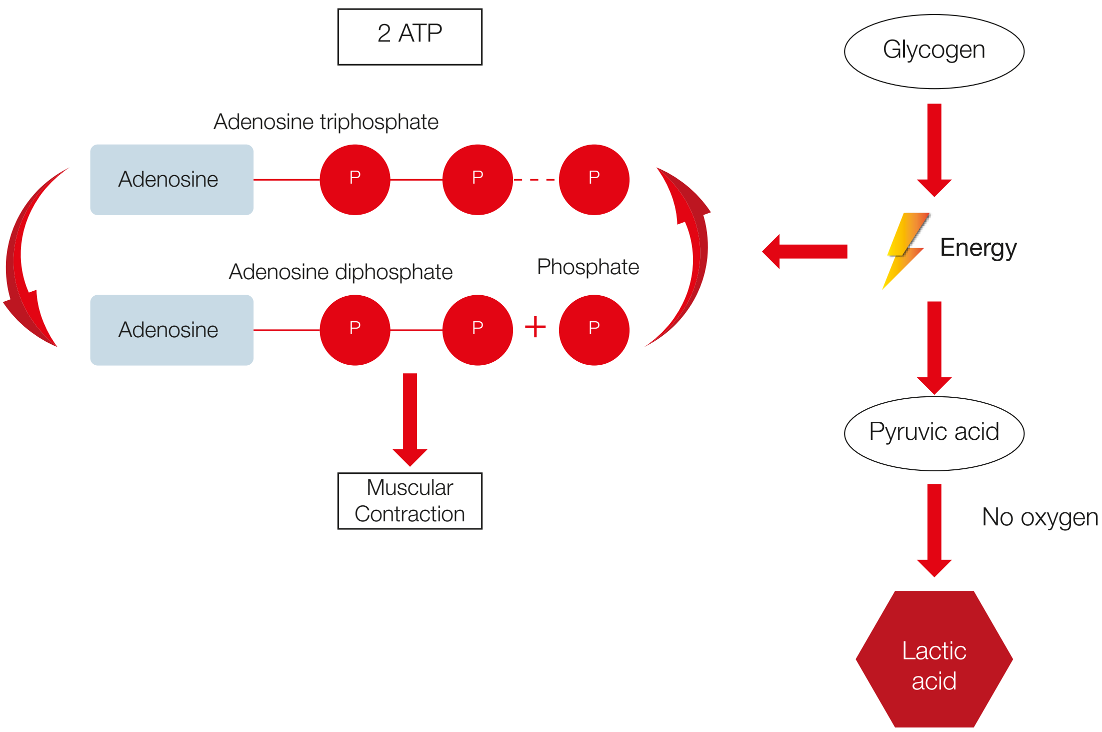


Figure 1.1.8: Anaerobic glycolysis energy pathway

The lactic acid system partially breaks down some of the energy stored within a glycogen molecule to rebuild ATP. This process occurs in the cytoplasm of the muscle cell and involves a series of chemical reactions that break down glucose into pyruvic acid, producing enough energy to rebuild 2 ATP molecules.

When exercise intensity is high, the body is unable to deliver sufficient oxygen to the exercising muscles. This means glycogen is only partially broken down to a substance called pyruvic acid, which (in the absence of oxygen) converts to a byproduct called lactic acid. The lactic acid produced in the muscles during high intensity exercise quickly moves out of the muscle into the bloodstream as lactate and hydrogen ions (H^+). The accumulation of lactate and the corresponding increase in hydrogen ions (H^+) in the blood are considered contributing factors to muscular fatigue because they lower the muscle pH levels (increasing acidity) and interfere with the skeletal muscle's ability to contract. When an athlete is rapidly accumulating lactate during exercise, they are said to be exercising at a level above their **lactate threshold** or **Onset of Blood Lactate Accumulation (OBLA)** – refer to Table 1.1.6 and Figure 1.1.17.

The lactic acid energy system is dominant when supplying energy to rebuild ATP in short term (10 seconds to 1 minute), high intensity activities >85% (HR_{max}). This is when an athlete is exercising above their **lactate threshold** or **OBLA** where the rapid accumulation of blood lactate (>4mmol/L) and hydrogen (H^+) ions will cause muscular fatigue.

Figure 1.1.9 and Figure 1.1.10: High intensity (85% HR_{max}) effort and short duration (10 seconds to 1 minute) exercise rely predominantly on the lactic acid energy system

These track athletes (Figure 1.1.9) are running at a high intensity for approximately 45 seconds in a 400m race. This is a classic example of high intensity exercise (>85% HR_{max}) for a short duration (< 1 minute) using the lactic acid energy system as the dominant energy system to rebuild ATP.

The accumulation of lactate and H^+ towards the end of the race can cause high levels of fatigue.

The soccer player is jumping maximally for a contested ball. In isolation, this may appear that the ATP-CP system will be dominant to rebuild ATP because it is a maximal (100%) effort of very short duration (<10 seconds).

However, in team sports, an elite player will often make many high intensity, repeated efforts without a full recovery to replenish muscle CP stores. Therefore, with CP muscle stores depleted, the lactic acid system will become the dominant supplier of energy during repeated high intensity efforts as a game progresses, explaining the high levels of lactate accumulation and fatigue associated with elite team sport competition.

Since lactic acid is produced from the incomplete breakdown of a carbohydrate, it can actually be removed from the blood following exercise by being rebuilt into a carbohydrate (either glucose or glycogen) where it can be stored again in the liver or muscles (18%) or used as a fuel source in the skeletal muscles (72%). Some lactate is converted to protein in the liver (8%) and some is excreted from the body as sweat or urine (2%).

Research shows that the speed of removal of blood lactate following exhaustive exercise depends on the type of recovery undertaken, with an active cool-down accelerating its removal from the blood, but not necessarily in muscle tissue. Performing aerobic activity in recovery accelerates blood lactate removal with the optimal level of recovery exercises ranging from between 30-45% VO_2max (bicycle) and 55-60% VO_2max (running).

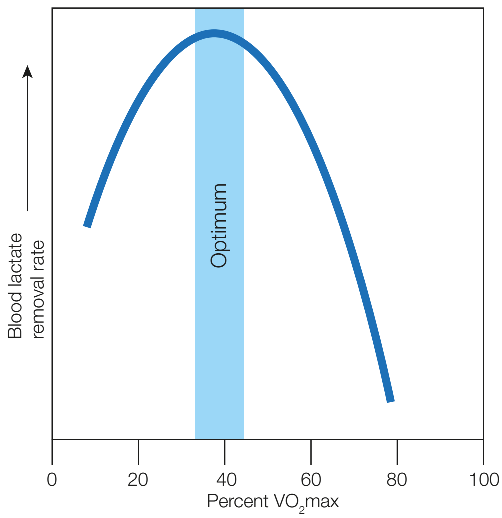


Figure 1.1.11: The relationship between exercise intensity and blood lactate removal rate following exhaustive exercise whilst cycling.

Table 1.1.2: Summary of the Lactic Acid Energy System

Lactic Acid Energy System	
Positives	**Negatives**
Anaerobic (does not require O_2 to be delivered to the muscles) = quicker release of energy	The accumulation of lactate and hydrogen ions cause fatigue: • 'lactacid' = lactic acid produced
High intensity (85% +) energy supply	Slow recovery–lactate and H^+ removal: • 50% removal in 15 minutes • 100% removal in 90 minutes *Note: Active recovery increases removal rate*
Longer duration high intensity energy supply when ATP-CP is depleted: • 10 seconds to 1 minute	Only one fuel: Glycogen

Focus Questions

5. Explain the following terms:

   (a) Pyruvic acid

   (b) Lactacid

6. Describe the intensity and duration of exercise where the lactic acid system would be dominant.

7. Identify and explain two specific athletic events (track or field) and two (specific game related) activities within a team-sport that would rely predominantly on the lactic acid system for energy to rebuild ATP:

   (a) Track or field

   (b) Team sport (specific game related)

Focus Questions

8. On a marked athletics track, complete a timed 400m maximal intensity (100%) run. Record your time and answer the following questions:

   Time:................sec.

   Describe and explain how you felt at:

   (a) The 100m mark?

   ....

   ....

   ....

   ....

   (b) The end of the run?

   ....

   ....

   ....

   ....

Energy System: Aerobic

When exercise intensity is low (submaximal), the body will have time to deliver the required amounts of O_2 to active skeletal muscles, allowing for the complete breakdown of carbohydrates to provide energy to rebuild ATP.

The aerobic energy system is dominant when providing energy to rebuild ATP during low intensity, prolonged activities. The aerobic system is typically associated with endurance athletes such as triathletes, Tour de France cyclists or AFL midfielders who can cover up to 15km per game etc.

Figure 1.1.12a, b & c: The aerobic energy system is dominant during submaximal intensity (<85% HR_{max}) and long duration (> 1 minute) exercise.

Figure 1.1.13: The aerobic energy system is used to recover from high intensity efforts in team sports.

It should also be noted that the aerobic energy system is vital for power athletes who need to recover from high intensity exercise, when the anaerobic energy systems have been dominant.

The aerobic energy system can help fatigued athlete's to recover by supplying energy to rebuild the CP molecule (100% in 3 minutes) and also remove accumulated lactate and H^+ (100% removal in 90 minutes) following high intensity sprints.

The aerobic energy system is more accurately referred to as the **aerobic glycolysis** system:

- Aerobic: a process that requires oxygen
- Glycolysis: breakdown of carbohydrate (glycogen).

The oxidation of one molecule of glycogen (aerobic glycolysis) begins in exactly the same manner as the lactic acid system, with a series of chemical reactions that break down glycogen into pyruvic acid, producing enough energy to resynthesise 2 ATP molecules. However, if the body is able to deliver sufficient oxygen to the muscles, the pyruvic acid moves into the **mitochondria** of the muscle cells. The mitochondria are specialised cells that permit the breakdown of macronutrient fuels (e.g. glycogen, fatty acids) through interaction with oxygen to produce large amounts of energy.

When pyruvic acid enters the mitochondria, it is completely broken down by a series of complex chemical reactions (known as the Kreb Cycle and the Electron Transport System) into the non-fatigue causing by-products of carbon dioxide (CO_2) and water (H_2O). This process releases enough energy to rebuild a further 36 ATP molecules (providing a total of 38 ATP for the complete process).

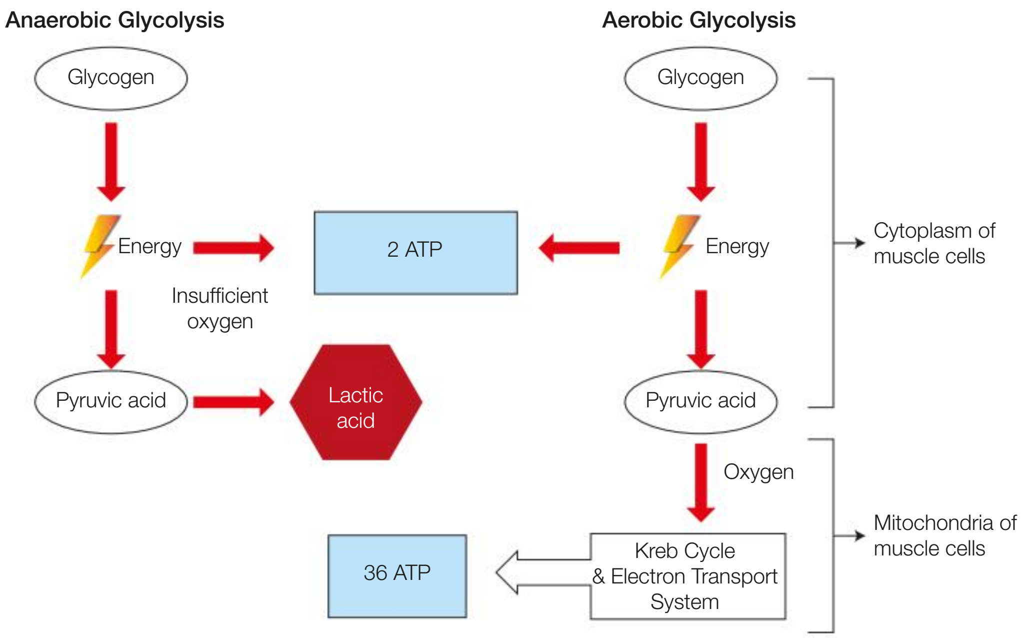


Figure 1.1.14: Oxygen energy pathway (with comparison of aerobic glycolysis and anaerobic glycolysis).

Figure 1.1.14 highlights the similarities in both anaerobic glycolysis (lactic acid system) and aerobic glycolysis (aerobic system) while in the cytoplasm of the muscle cell. However, If exercise is submaximal and sufficient oxygen is delivered to the muscles, pyruvic acid then moves into the mitochondria of the cell, where aerobic glycolysis takes place.

The aerobic energy system is also capable of breaking down fats as a fuel source to provide energy for the rebuilding of the ATP molecule, called **aerobic lipolysis** (refer to Focus Area 3.1). When the oxygen delivery systems of the body (circulatory & respiratory) are not under stress, fats can contribute up to ⅔ of energy requirements during rest and low intensity aerobic exercise such as walking (refer to Figure 3.1.10). However, during moderate to high intensity exercise, the body is simply unable to provide enough oxygen to enable the more complex chemical reactions involved to 'split' the larger fat molecules. Therefore, the contribution of fats during high intensity exercise is limited.

Alternative names for the Aerobic energy system:

- Oxidative system
- Aerobic glycolysis
- Aerobic lipolysis.

At the onset of exercise, there is always an increase in the oxygen consumption of an athlete as they try to deliver extra oxygen to the working muscles. However, it will generally take up to a minute or so for the body to deliver the necessary volume of oxygen to enable the aerobic energy system to become the dominant supplier of energy. This should not be too surprising, because the cardiovascular and respiratory systems will need a bit of time to meet the new oxygen demands. For example, there may be an increase in the ventilation rate (from 12 breaths per minute up to 25 breaths per minute) and an increase in heart rate (from 60 bpm up to 130 bpm) in order to meet the greater volume of oxygen required.

From the onset of submaximal exercise, it may take 1-2 minutes before the athlete can reach a **'steady state'** where their oxygen consumption is matching their oxygen requirements for a given workload and the aerobic energy system is dominant. A steady state is represented by a flat oxygen consumption line on an oxygen consumption graph.

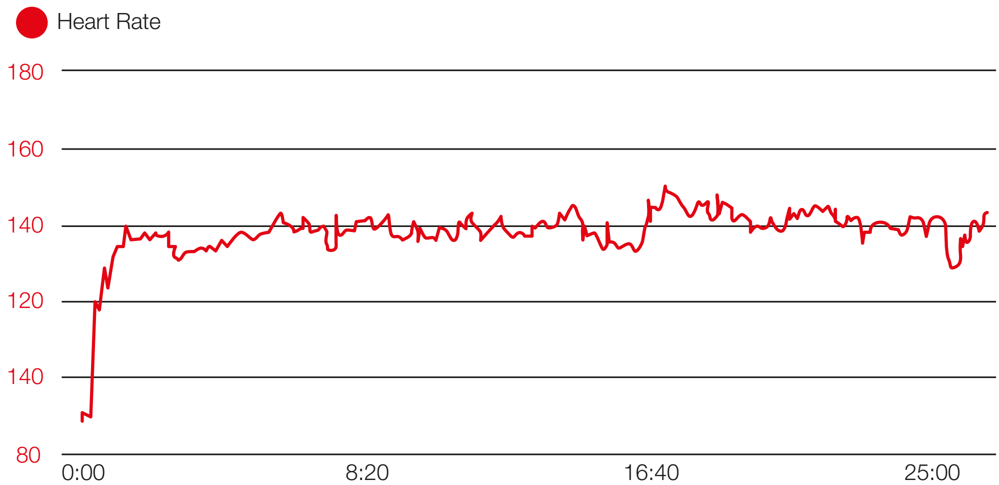


Figure 1.1.15: Heart rate (HR) recorded using a GPS / HR watch during an 'Easy Run' session

The heart rate recording above shows that it took approximately 1-2 minutes for heart rate to rise from 85 bpm to 140 bpm where a steady state (O_2 supply = O_2 demand) was reached and the aerobic energy system is dominant.

It also shows that in reality, a steady state heart rate is not flat! The recording shows heart rate fluctuations within a 135 bpm–142 bpm zone but this is still an 'easy' aerobic training zone.

Until a steady state heart rate is reached, a person's anaerobic energy systems (the lactic acid or perhaps even the ATP-CP system) will need to play a greater role in supplying the energy to rebuild ATP until the athlete's heart rate and ventilation rate increases sufficiently to meet the new oxygen requirements – this is referred to as an O_2 deficit – refer to Focus Area 1.1.18.

Although the aerobic energy system produces no fatiguing by-products when rebuilding ATP, after continuous exercise of 1-2 hours or more, there is likely to be a depletion of the primary fuel stores (muscle and liver glycogen) and an athlete may experience a sudden onset of fatigue known as **'hitting the wall'**. It may take 24-48 hours for the body to replenish muscle glycogen stores even with a high carbohydrate diet – refer to Focus Area 3.1: Nutrition and performance.

Table 1.1.3: Summary of the Aerobic Energy System.

Aerobic Energy System	
Positives	**Negatives**
Long duration energy supply	Aerobic (requires O_2 to be delivered to the muscles) = slow energy
No accumulation of fatigue causing by-products	Only dominant during low intensity (< 85%) exercise
Capable of breaking down all macronutrients: carbohydrates (glycogen & glucose) and fats (also protein in extreme circumstance i.e. starvation)	Slow to increase O_2 supply at the beginning of exercise, causes an O_2 deficit
Provides energy to recover from high intensity exercise	

Focus Questions

9. Explain the terms:

   (a) Submaximal exercise

   (b) Steady state

10. Describe the intensity and duration of exercise where the oxygen system would be the dominant source of energy to rebuild ATP:

11. Identify and explain two specific athletic events (track or field) and two (specific game related) activities within a team-sport that would rely predominantly on the Aerobic system for energy to rebuild ATP:

    (a) Track or field

    (b) Team sport (specific game related)

12. Identify and explain three differences between aerobic and anaerobic glycolysis:

Energy System – Overview

The table below shows an overview of the energy systems available to rebuild the ATP required for muscular contraction.

Table 1.1.4: Energy system overview.

	Anaerobic		Aerobic	
	ATP-CP	**Lactic Acid**	**Aerobic Glycolysis**	**Aerobic Lipolysis**
Other names	ATP-PC, Phosphate, Alactacid	Anaerobic Glycolysis, Lactacid	Aerobic / Oxygen	
Duration of dominant contribution	<10 seconds • 100m Sprint • Javelin/ Slam Dunk	10 seconds – 60 seconds • 400m • REPEAT max efforts (depleted CP)	60 seconds – 1 ½ hrs+ • 1500m Runner • 10,000m Runner • Jogging	60 seconds – 1 ½ hrs+ • Walking • Marathon (42.2km) • Ultra endurance
Intensity of effort	Maximal Intensity		Sub-maximal Intensity	
	Maximal (95-100%)	High (85-95% HR_{max}) Above OBLA / Lactate Threshold	Moderate (75-85% HR_{max})	Low (50%–75% HR_{max})
Speed of ATP resynthesis	Instant	Fast	Medium	Slow
Fuel	Creatine Phosphate	Glycogen (glucose)	Glycogen (glucose)	Triglycerides – fatty acids
By-product	N/A	Lactate, Hydrogen ions	CO_2 and H_2O	CO_2 and H_2O
Fatigue factor	Limited supply of CP	Lactate / H^+ (low pH = muscle acidity)	Depletion of Glycogen – Hitting the Wall	Fats require lots of O_2 to break down – very slow
Recovery	Time to rebuild CP • 50% = 30 seconds • 100% = 3 minutes	Time to remove Lactate / H^+ • 50% = 15 min • 100% = 90 min Recovery time quicker with an active warm down	Time to replenish muscle glycogen stores: • 1–24 hours, using nutritional strategies	N/A

Maximum Oxygen Consumption (VO_2 Max)

The volume of oxygen consumed by the body for energy production is called the VO_2 and it is measured in litres of oxygen consumed per minute (L/min). If an athlete were to slowly increase exercise intensity, there would be a corresponding increase in oxygen consumption until they reached maximum oxygen consumption (VO_2 max) – the region where oxygen uptake peaks despite further increases in exercise intensity (refer Figure 1.1.16).

Because larger people tend to consume more oxygen than smaller people (purely because of their larger size), VO_2 max is usually expressed as a relative VO_2 max in millilitres of oxygen consumed per kilogram of body weight per minute (ml/kg/min). This allows for the comparison of different-sized individuals. For example, in Figure 1.1.16, the athlete's peak VO_2 max value was 3.6 litres per minute. If the athlete undergoing this test had a mass of 68kg, then their relative oxygen consumption would be calculated as follows:

$$3.6\text{L/min} \times 1000 = 3600\text{ml}$$

$$3600/68\text{kg} = 52.9\text{ml/kg/min}$$

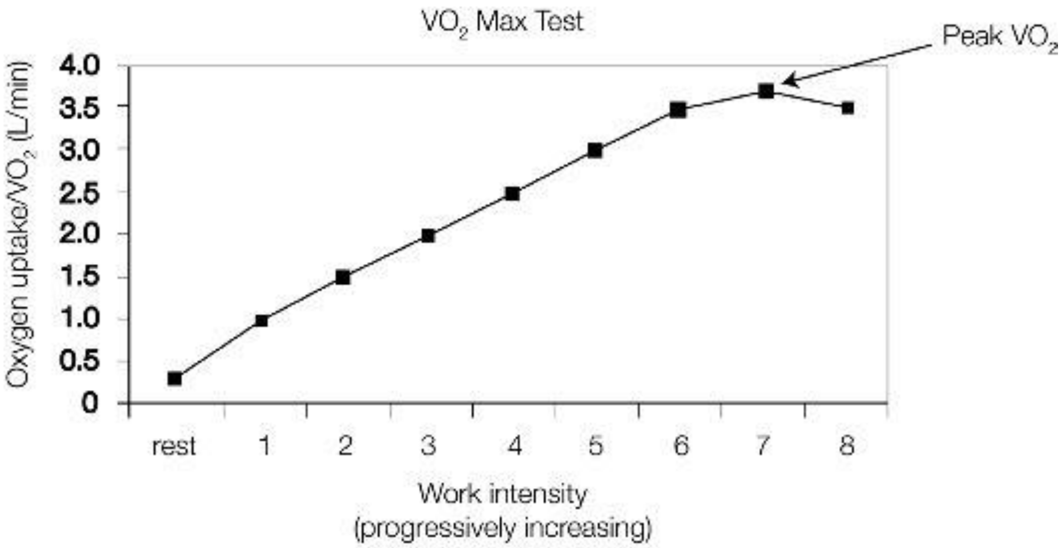


Figure 1.1.16: Maximum Oxygen Consumption (VO_2 max)

Table 1.1.5: Typical VO_2 max values of tested athletes at the AIS. Source: Adapted from Pyke (2001), p. 81.

Sport		Approximate mean of VO_2 max (L/min)	Approximate mean of VO_2 max (ml/kg/min)	Typical range VO_2 max (ml/kg/min)
Running	Male	4.9	75	65-80
	Female	3.5	65	55-70
Rowing	Male – heavy	5.5	60	55-70
	Male – light	4.8	65	55-70
	Female – heavy	3.9	52	45-60
	Female – light	3.4	52	45-60
Cycling – track	Male	5.8	80	65-85
	Female	3.5	63	55-70
Kayaking	Male	4.8	60	55-65
	Female	3.1	50	45-55
Soccer	Male	4.6	60	55-65
	Female	3.1	50	45-55

The VO_2 max is an important indicator in determining a person's capacity for the aerobic resynthesis of ATP, with elite endurance athletes having higher values than other sports performers (see Table 1.1.5). Untrained sedentary individuals would have a VO_2 max of approximately 40ml/kg/min, while values exceeding 70ml/kg/min or beyond are only achieved by superbly conditioned endurance athletes.

It should be noted that exercise intensities approaching VO_2 max can only be achieved through the dominant use of anaerobic glycolysis (lactic acid system) with the subsequent formation and accumulation of lactic acid. Therefore, if VO_2 max values are similar between athletes, the fractional % of VO_2 max that can be sustained for a prolonged period of time (without lactate accumulation) will ultimately determine success.

Onset of Blood Lactate Accumulation (OBLA) and Lactate Threshold

Firstly, some background on blood lactate:

- When anaerobic glycolysis (the lactic acid energy system) is used to resynthesise ATP, it forms the byproduct called lactic acid
- The lactic acid produced in the muscle during anaerobic glycolysis quickly converts into lactate and hydrogen and moves from the muscle into the blood circulation – there are now lactate and hydrogen (H^+) ions in the blood
- Blood lactate concentrations can be measured with a "lactate analyser" by taking a small pin prick of blood from the fingertip or earlobe of an athlete
- The concentration of blood lactate is usually expressed in millimoles (mM) per litre (L) of blood
- Lactate is always being produced in the body and blood lactate levels only represent the balance of lactate production and lactate removal at that time
- Blood lactate concentrations in the range of 1-3mmol/L are common at rest and during submaximal exercise; concentrations in excess of 15mmol/L may be seen in elite athletes following intense exercise
- A blood lactate concentration of 4mmol/L indicates the Lactate Threshold and the Onset of Blood Lactate Accumulation (OBLA)
- The accumulation of lactate (4mmol/L and above) and the corresponding increase in hydrogen ions (H^+) are considered markers to muscular fatigue during exercise.

The maximum intensity of steady state exercise (%VO_2max) that a person can sustain without the accumulation of blood lactate has historically been termed the anaerobic threshold. However, this term is no longer considered accurate and shouldn't be used. Because there is no single threshold point where aerobic metabolism "stops" and anaerobic processes "begin", sports scientists (and various textbooks) will instead use one of the following terms:

- Onset of Blood Lactate Accumulation (OBLA)
- Lactate Threshold (LT)
- Lactate Inflection Point (LIP).

Generally speaking, a Year 12 PE student could use any of the terms defined in Table 1.1.6 to describe the highest intensity of exercise that can be sustained without the rapid accumulation of lactate and hydrogen (H^+) ions which will mark the onset of muscular fatigue.

Table 1.1.6: Terms to describe the highest intensity of exercise without lactate accumulation.

Term	Abbrv	Definition	What they refer to:
Onset of Blood Lactate Accumulation	OBLA	A blood lactate concentration of 4mmol/L indicates the Onset of Blood Lactate Accumulation.	*The highest intensity of exercise that can be sustained without the rapid accumulation of lactate and hydrogen (H^+) ions which will mark the onset of muscular fatigue.*
Lactate Threshold	LT	An exercise intensity that causes blood lactate concentrations to rise sharply above the pre-exercise level (usually by 1-2mmol/L).	
Lactate Inflection Point	LIP	A point beyond which a given exercise intensity cannot be maintained by the athlete – usually located in a zone between the LT and OBLA.	

In the Essentials Workbook, we will use the terms lactate threshold or OBLA.

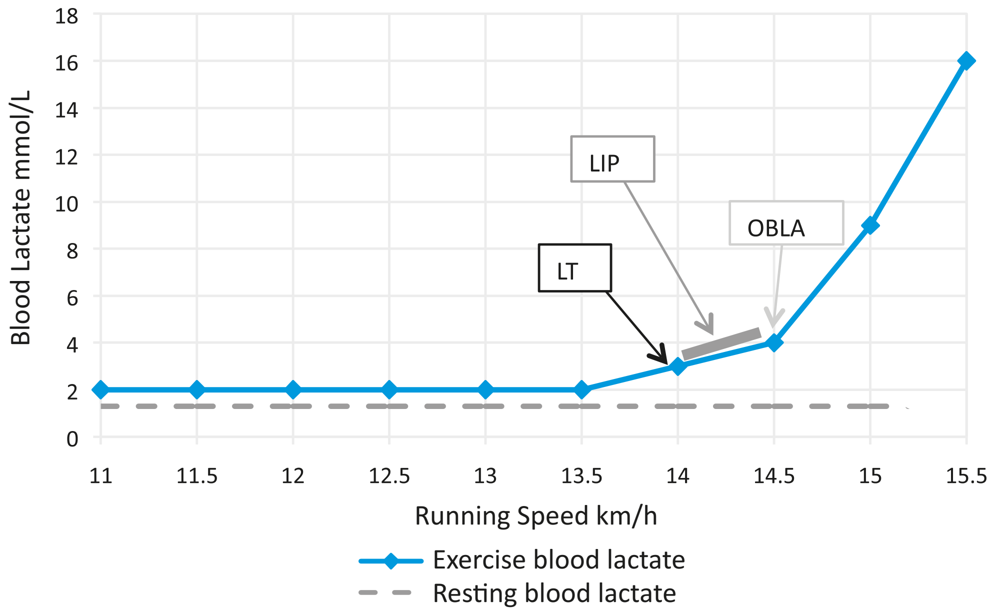


Figure 1.1.17: Blood lactate concentration during exercise of increasing intensity.

A person's Lactate threshold has a large impact on their athletic endurance performance because it determines the maximum exercise intensity they can sustain for an extended period of time without the accumulation of blood lactate and H^+ ions associated with muscular fatigue. Generally speaking, individuals with higher LT values (usually expressed a %VO_2 max) are the better endurance performers. It is probably considered a more important variable in athletic success than VO_2 max itself.

Table 1.1.7: Lactate threshold guidelines.

LT Guidelines	Untrained	Trained
% HR max	70	85%
% VO_2 max	50-60	70-85
Perceived exertion	A 'little uncomfortable' – can talk while exercising, but would not wish to carry out a conversation.	

Through training, VO_2max and LT can be improved.

Focus Questions

13. Explain the terms:

(a) VO_2 max

(b) LT

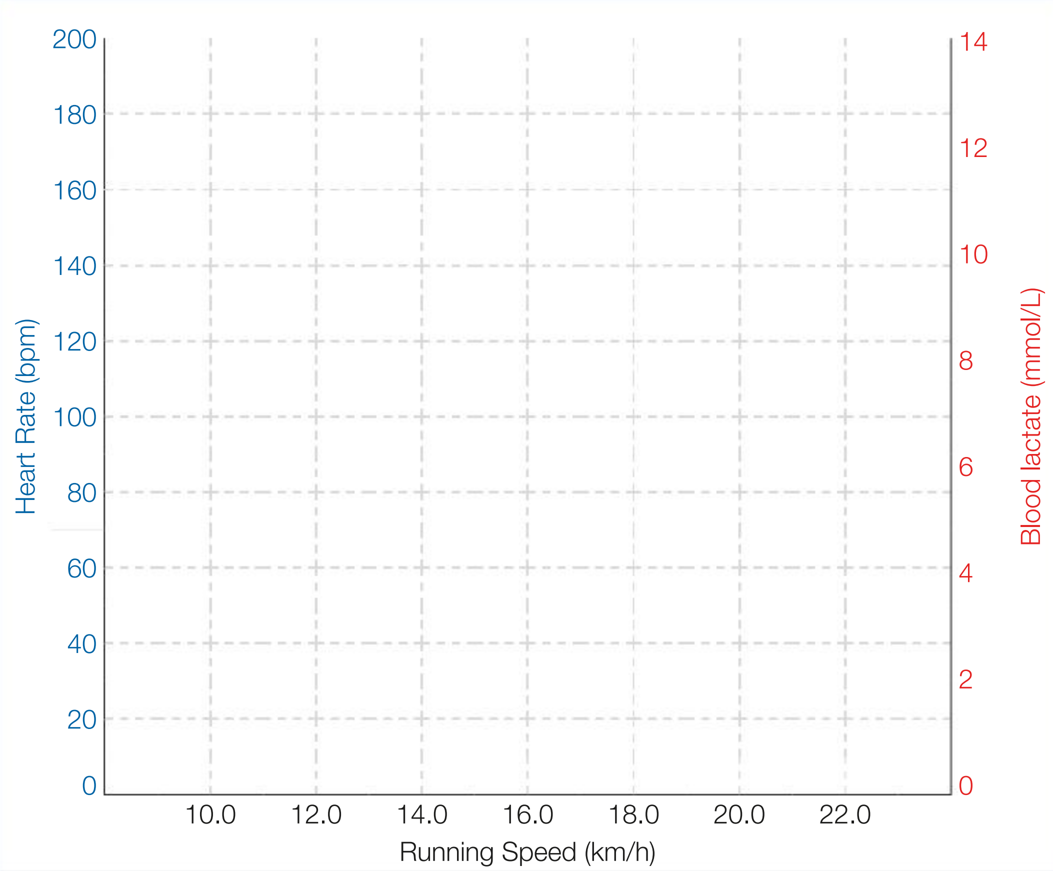
(c) OBLA

14. The table below contains data of an athlete's Heart Rate (bpm) and their lactate accumulation measured whilst running on a treadmill at different speeds (km/hr).

Running Speed (km/hr)	Heart Rate (bpm)	Blood Lactate (mmol/L)
10	88	1.8
11	96	2
12	103	2.2
13	114	2.2
14	125	2.9
15	135	3
16	148	3.5
17	156	3.7
18	164	4.0
19	177	6
20	188	8
21	195	11
22	200	14

Use the data in the table and the graph provided to plot the graph and answer the questions that follow:

Focus Questions



(a) On the graph above, mark the OBLA (lactate threshold).

(b) Identify the running speed where OBLA occurs.

....

(c) Explain how long could the runner maintain a pace of 20 km/h during a race?

....

....

....

(d) What Heart Rate (bpm) should the athlete hold during the race to maximize their performance in a 3000m track race?

....

....

....

Oxygen Deficit

The period when the aerobic system is desperately trying to catch up to the oxygen demands on the body is called the **'oxygen deficit'** – the difference between the oxygen required for a given task and the oxygen actually consumed by the body. During this period the anaerobic systems play a larger role.

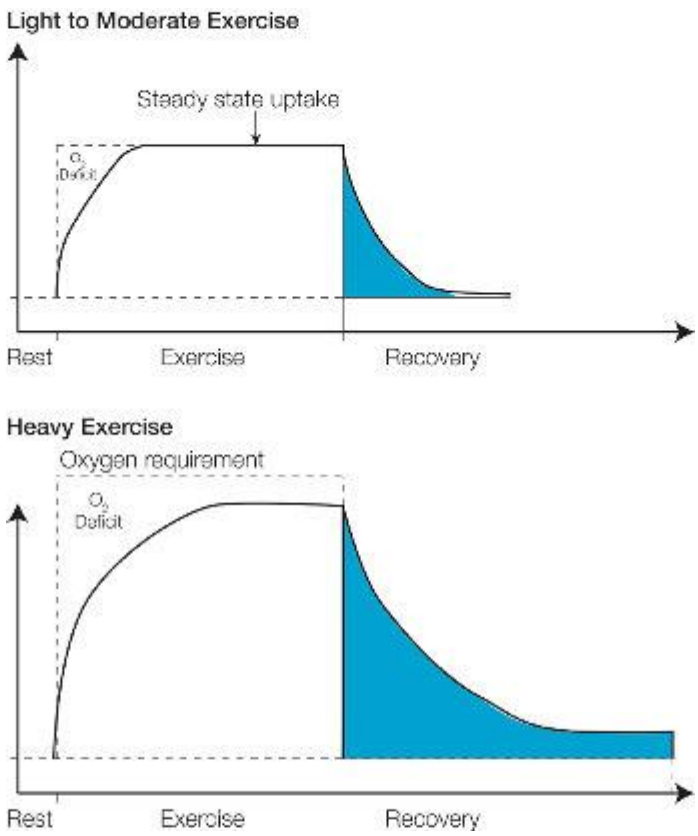


Figure 1.1.18. : Oxygen consumption graph. Source: Adapted from McArdle, Katch & Katch (1991).

Reminder

Note: In Figure 1.1.18, the cardio-respiratory system is able to obtain a steady state (where O_2 supply matches demand) during 'light to moderate' exercise, but this can't be achieved during 'heavy' exercise.

Excess Post-Exercise Oxygen Consumption (EPOC)

Once the exercise session has finished, recovery can begin. Oxygen consumption will remain elevated for some time following exercise to allow the body to slowly return to pre-exercise levels. The volume of oxygen consumed after exercise (above that normally required at rest) is termed the **excess post-exercise oxygen consumption** (EPOC) – it has been traditionally termed the 'oxygen debt'.

The EPOC is a result of the following:

- Replenishing of ATP-CP stores
- Removal of blood lactate
- Increased activity of the heart and respiratory muscles
- Restoration of myoglobin and haemoglobin oxygen supplies
- Other factors including:
    - the release of hormones during exercise (i.e. adrenalin)
    - the increase in core temperature raising the metabolic rate.

The intensity of the exercise affects the oxygen deficit and therefore the extent of the EPOC. The lighter the exercise intensity the smaller the oxygen deficit, as the cardio-respiratory system is better able to respond to a rise in oxygen demand. Likewise, there is a corresponding decrease in the time required for complete recovery post exercise.

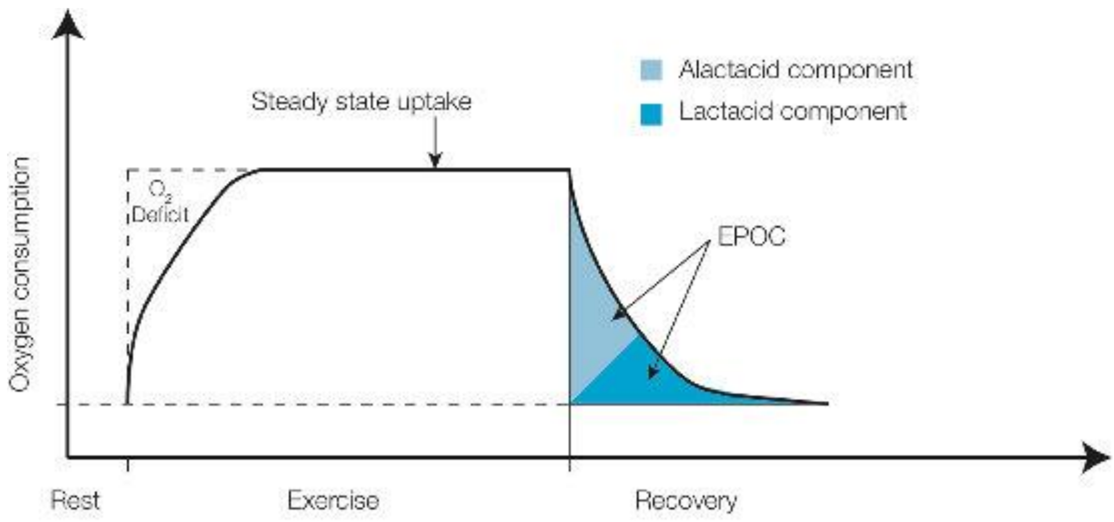


Figure 1.1.19: Excess post-exercise oxygen consumption (EPOC).

EPOC (Alactacid Component)

The first part of the EPOC has traditionally been termed the alactacid or fast component involving the restoration of ATP and CP stores and the replenishment of O_2 for myoglobin and the surrounding tissues.

This whole process takes approximately 2-3 mins, with 50% of ATP-CP replenished in 30 seconds and 100% in approximately 3 minutes.

EPOC (Lactacid Component)

The second component of the EPOC has traditionally been termed the lactacid or slow component and is involved with lactic acid removal and some slight glycogen replenishment.

Lactate removal may require up to 90 minutes for full recovery, and 15 minutes for 50% removal.

Following exercise, the EPOC recovery processes are achieved mainly through the aerobic energy system. It should also be noted that both processes occur immediately and simultaneously after an exercise session, but the alactacid recovery is rapid and occurs at a greater speed.

Warm Down

Continuous activity post-exercise (at about 55-60% VO_2 max) will speed up the removal of lactate twofold. (Refer to Figure 1.1.20.) Why an active recovery?

- It prevents blood pooling in the extremities
- It allows the skeletal muscles to oxidise some of the lactic acid for energy (70%)
- An elevated heart rate keeps blood circulation to the liver high, assisting with the conversion of lactic acid back to glycogen (20%).

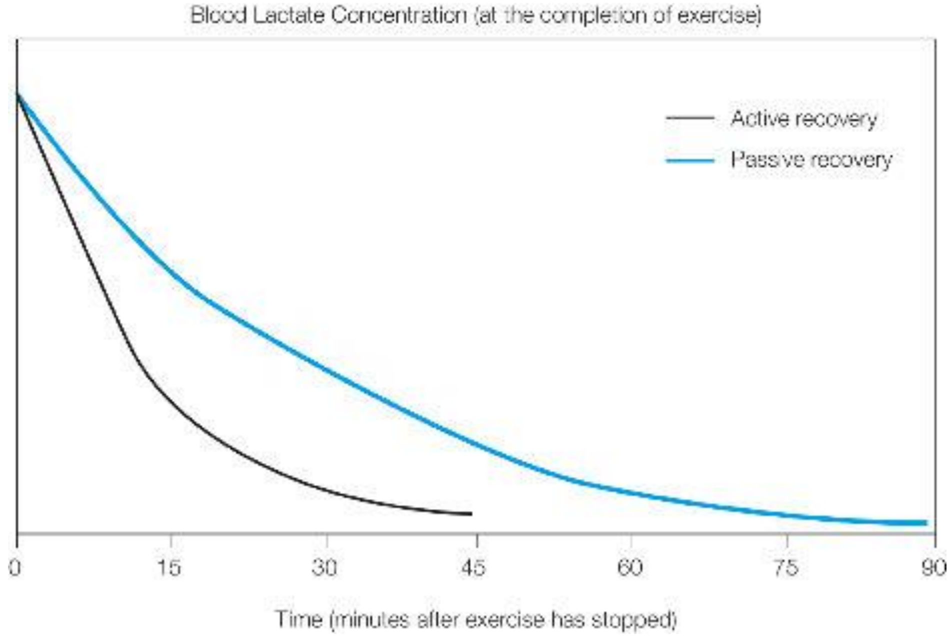


Figure 1.1.20: Lactate recovery times

Focus Questions

15. Explain the terms:

    (a) Oxygen deficit

    (b) EPOC

16. With specific reference to 'energy systems', consider why it is beneficial for a 5000m runner to:

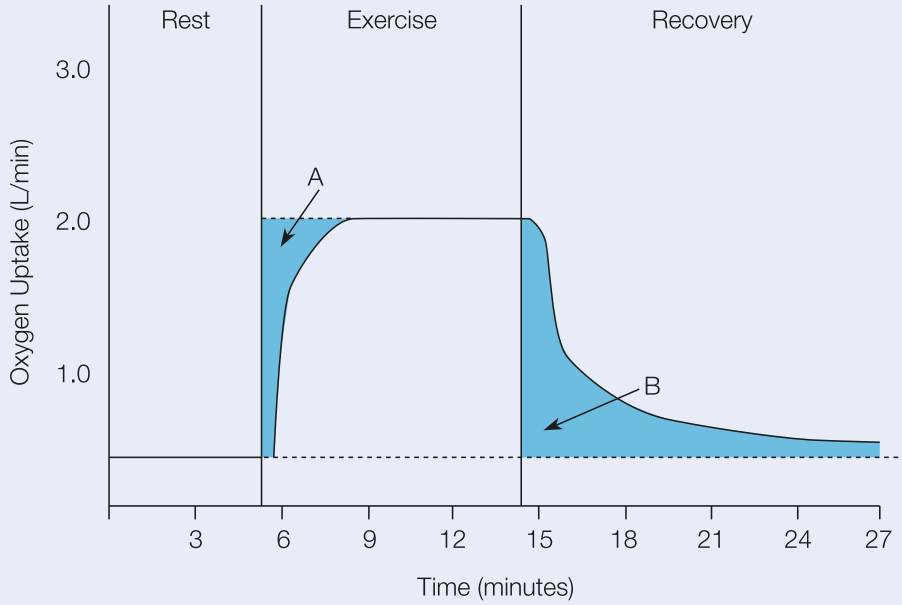
    (a) Perform a warm-up prior to the start of the race?

    (b) Remain at or below their lactate threshold (OBLA) for the majority of the race?

    (c) Participate in low-level physical activity after the race?

Focus Questions

17. Refer to the graph showing oxygen consumption during rest, exercise and recovery:



(a) Circle the athlete's resting VO_2?

2.0L/min 500ml/min 3.5L/min

(b) What is the highest VO_2 reached in the test?

(c) What do the areas marked A and B represent?

(d) What would be the predominant energy system used at the following time periods? Explain your answer?

(i) Minute 6 to 8?

(ii) Minute 10 to 14?

(iii) Did the athlete reach their VO_2 max in this test? Explain your answer.

The Interplay of Energy Systems

Contribution of Energy Systems in Specific Activities

At any one time, all three energy systems will be functioning. It is the intensity of exercise (how quickly ATP is required) and the duration of exercise (how much ATP is required) that will determine which energy system(s) will be dominant in any activity. As exercise intensity increases there is a greater reliance on the more powerful anaerobic systems and as the duration of exercise increases, the dominant energy system will become more aerobic in nature.

Figure 1.1.21 shows the relationship among the energy systems in terms of rate of energy release and capacity of energy release. It can be seen that the ATP-CP system can supply energy at a fast rate but has a low capacity. By contrast, the oxygen system produces energy at a much slower rate, but has an almost unlimited capacity. Together, the three energy systems are well suited to cope with the high, often sustained, and usually diverse energy demands placed on them during sporting contests.

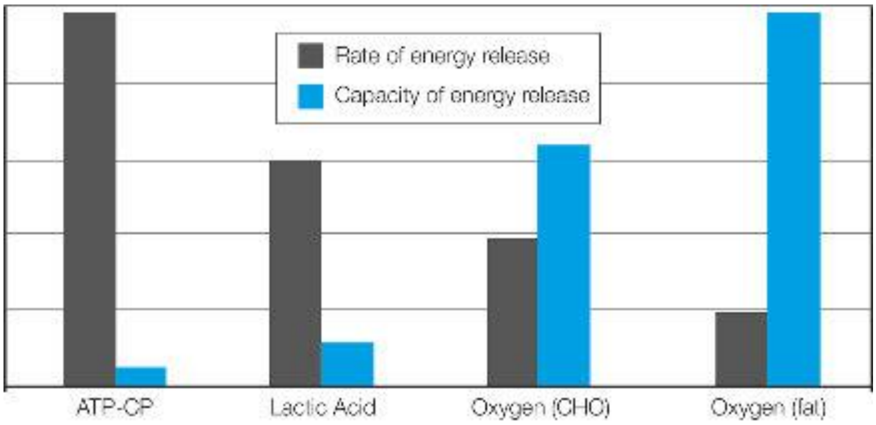


Figure 1.1.21 Rate and capacity of energy release.

Recent evidence suggests that the aerobic energy system contributes to high intensity exercise to a much greater extent than previously believed. For example, Figure 1.1.22 shows the aerobic (oxygen) energy system contributing up to 50% of energy requirements for a 60 second exhaustive effort.

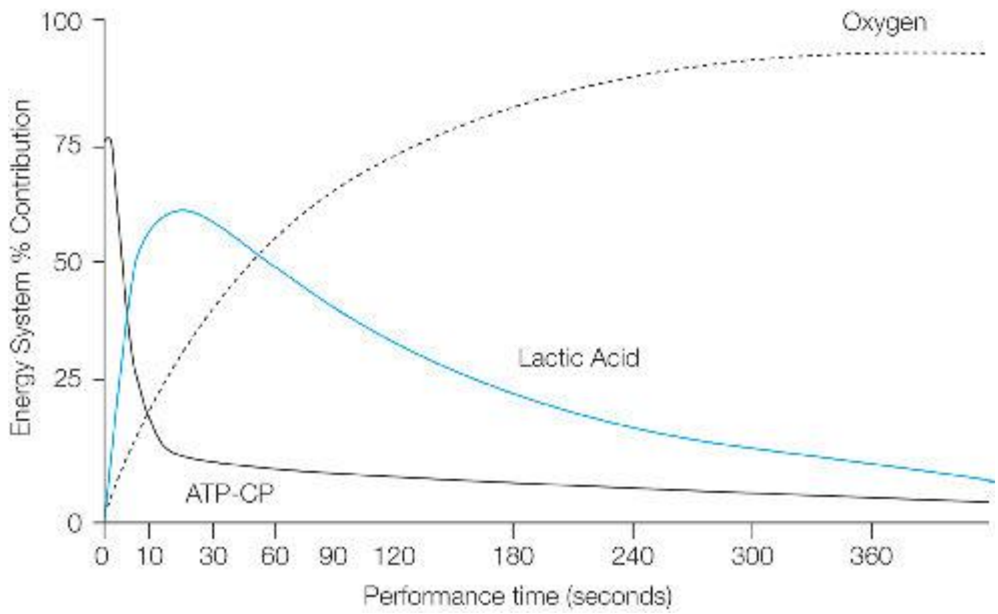


Figure 1.1.22: Contribution (%) of each energy system as a function of time during all-out exercise. Source: Energy Systems: Revaluating high intensity energy contributions (2001). Paul Gastin, Sports Science Coordinator VIS, Peter Le Rossignol, Exercise Physiologist, Deakin University

Interplay of Energy Systems

Example 1: In a 6 second dash to escape from a vicious dog, the subject running at high speed will utilise predominantly the ATP-CP system. **Yet** the other two systems will contribute something even if extremely little; hence words like the following should be used:

The ATP-CP system will be the *dominant* energy system OR

The *majority of the energy* for ATP resynthesise will come from the ATP-CP system.

And not the following:

For the first 6 seconds the body used ATP-CP system to resynthesise ATP.

The previous response isn't as accurate because it implies 100% ATP-CP usage. Figure 1.1.22 shows all three energy systems contributing to varying degrees, even in a 6 second maximal effort.

Note that if the subject is still running at high speed after 60 seconds, the contribution of the ATP-CP system has drastically fallen, being replaced as the dominant energy source by both the lactic acid and oxygen systems. (Refer Figure 1.1.26)

Figure 1.1.23: 6 seconds

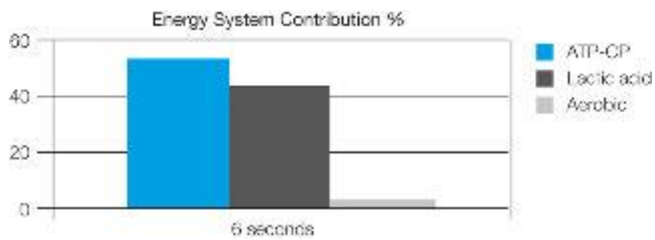


Figure 1.1.24: 6 seconds maximal work

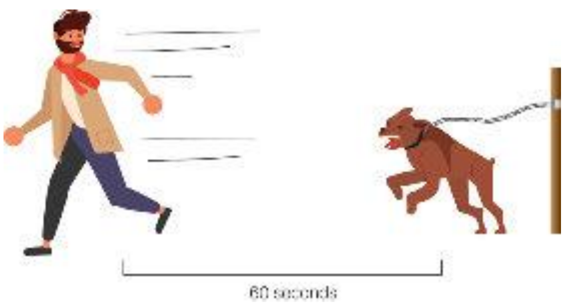


Figure 1.1.25: 60 seconds

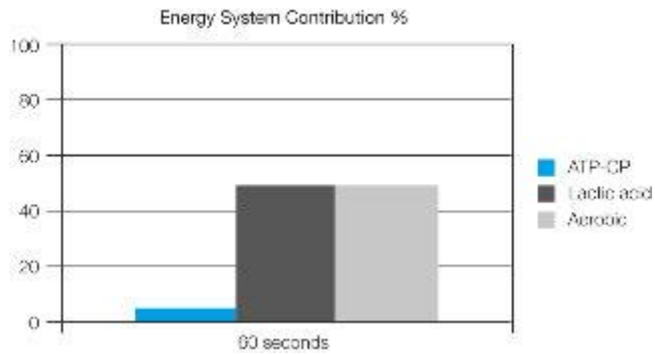


Figure 1.1.26: 60 seconds maximal work

Example 2: 200m sprint at the elite level.

Intensity: Maximal

Time: 20 seconds

Summary: The intensity suggests anaerobic systems as the dominant source of energy. While the duration points to more anaerobic glycolysis (lactic acid system), after 10 seconds the majority of the CP stores have been exhausted.

Figure 1.1.27 : Sprinting (200m)

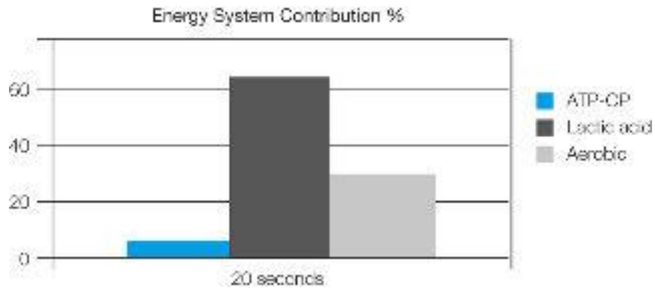


Figure 1.1.28: 20 seconds maximal work

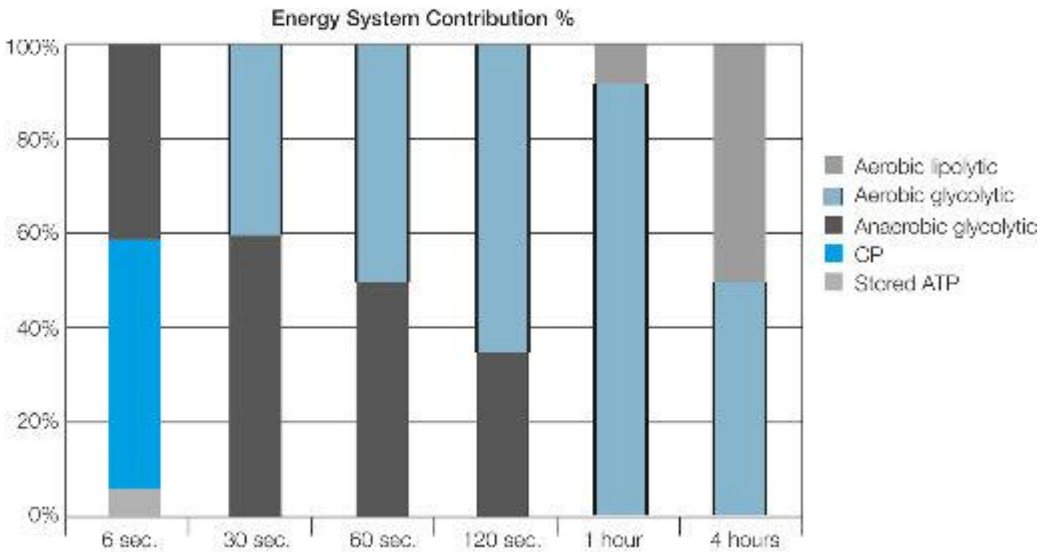


Figure 1.1.29: Contributions of the different energy systems to all-out exercise of varying durations. Source: Adapted from Bangsbo et al. (1990), p. 539.

Using Heart Rate to Predict Energy System Contribution

It is exceedingly difficult to measure the exact contributions that energy systems are making during any activity without sophisticated equipment in a laboratory setting. However, in Year 12 Physical Education, using heart rate monitors (Polar, Garmin, SMART watches, etc.) to record heart rate during exercise is quite common and a practical, valid and reliable way to determine exercise intensity. Accurately measured exercise intensity in turn, can be used to provide an estimate of energy system contributions.

Predicting energy system contributions from heart rate data is valid because previous research has demonstrated there is a linear relationship between heart rate and oxygen uptake (VO_2). This is because heart rate is the main determinant for the increase in oxygen delivery to the muscles during exercise.

Therefore, because heart rate can be used to accurately measure exercise intensity, it can also be used to predict oxygen uptake and accordingly, estimate the overall energy system contributions during exercise at different intensities.

The table below (Table 1.1.7) illustrates the link between recorded Heart Rate Values with Exercise Intensity, O_2 Demand, and the subsequent (predicted) Dominant Energy Pathway. In the table, heart rate data assumes a 20-year-old athlete with an estimated maximum heart rate of 200 bpm (based on the formula: 220-age).

Table 1.1.7

Heart Rate Values	Exercise Intensity	O_2 Demand (O_2 uptake)	Dominant Energy Pathway
<75% HR_{max} (e.g. <150 bpm)	Low	Low	Aerobic
	Submaximal exercise in a steady state **Aerobic** dominant		
75-85% HR_{max} (e.g. 150-170 bpm)	Moderate-High	Moderate-High	Aerobic/Anaerobic
	Exercise intensity at or close to LT/OBLA **Aerobic** (lower HR zone) or **Lactic Acid** (upper HR zone) may be dominant		
>85%+ HR_{max} (e.g. >170 bpm)	High-Maximal	High-Maximal	Anaerobic
	Exercise intensity high and O_2 demand > O_2 supply **Lactic Acid** / **ATP-CP** dominant *Note: HR not the best indicator to monitor ATP-PC contribution(s)*		
Rapid rise in HR (e.g. 130-140 bpm)	Increasing	Increasing	Anaerobic
	Exercise intensity rapidly increasing: O_2 demand > O_2 supply (O_2 Deficit) **Lactic Acid** dominant		
Rapid fall in HR (e.g. 140-130 bpm)	Decreasing	Decreasing	Aerobic
	Exercise intensity rapidly decreasing: O_2 supply > O_2 demand (EPOC) **Aerobic** dominant		

Focus Questions

18. (a) Using the information from this chapter and other resources as required, complete the following table:

Energy Systems	ATP-CP	Lactic Acid System	Oxygen System
Alternate names			
Type			
Fuel			
ATP production – capacity			
Duration that maximal energy production can occur			
ATP production – speed			
By-product of energy production			
Limiting factor			
Recovery time			

(b) What factors determine which energy system is the dominant source of energy production?

(c) State the dominant energy system used in each of the following activities:

(i) Marathon (2½ hours)

(ii) 50m sprint (5 seconds)

(iii) 400m sprint (45 seconds)

Focus Questions

(d) Complete the following table by identifying the dominant energy system(s) for each of the following examples and explain your answer:

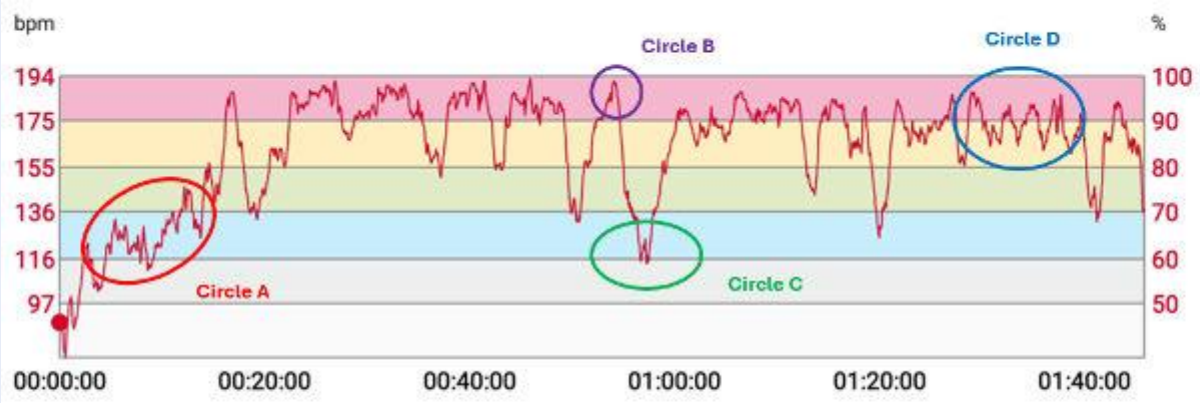
Activity	Dominant Energy System(s)	Explanation
High jump – Olympic athlete achieving a personal best		
Volleyball player – who has just performed a quick succession of spike and block combinations in an extended rally		
A brisk walk for 1 hour		
1500m swimming freestyle race (completed in 15 min.)		
An athlete immediately after running a 45-second 400m		

(e) Most team sports involve a complex combination and interaction of the three energy systems. Using a sport of your choice, explain the interplay of energy systems in regards to that sport.

In conjunction with your teacher, you may wish to look at a major practical you have studied this year. Consider the different skills performed in the sport and the different energy requirements between playing positions.

Focus Questions

(f) The graph below shows the heart rate (HR) response in beats per minute (bpm) for a 20-year-old tennis player during a three-set competitive match. Four HR periods (Circle A, B, C, and D) are marked on the graph.



Using data from the graph, complete the table below to answer the questions on the HR trend and subsequent exercise intensity, O_2 demand, energy pathway, and subsequent energy system contributions during the circled HR periods (Circles A, B, C, and D).

	Circle A HR Period	**Circle B HR Period**	**Circle C HR Period**	**Circle D HR Period**
HR Value(s) bpm				
Exercise Intensity				
O_2 Demand				
Dominant Energy Pathway				
Dominant Energy System				
Likely activity in tennis game				

Energy contributions and fatigue

The effect of fatigue on our performance is usually felt as a general sensation of tiredness accompanied with a decrease in muscular performance with continued effort. The exact cause of fatigue is often difficult to quantify, because a fatigued athlete may have been working at a maximal intensity but short duration (anaerobically) or at a lower intensity but for an extended period of time (aerobically). Therefore the causes of fatigue will be different in each of these scenarios.

Figure 1.1.30 A high intensity sport such as soccer is associated with high levels of fatigue from accumulated by-products.

Figure 1.1.31 A lower intensity sport such as a marathon is associated with high levels of fatigue from the depletion of fuels.

According to Wilmore et al (2008), muscular fatigue is defined as the inability to maintain the required power output to continue exercising at a given intensity. Furthermore, muscle fatigue is distinguished from muscle injury, in that fatigue is quickly reversible by rest.

The cause of fatigue can be very complex and involve both physical factors and perhaps even psychological factors as well. The exact cause of fatigue will depend on the intensity and duration of the exercise.

Muscular fatigue associated with energy pathways are the result of either (or combination) of:

- Fuel depletion
- Metabolic by-products.

Fuel depletion

As summarised in Table 1.1.4 the fuel supplies used in the three energy systems are limited and once they are depleted, that particular energy system will no longer be able to contribute significant energy to the rebuilding of ATP, and a decrease in performance will take place.

Fuel depletion: Creatine Phosphate

The ATP-CP energy system is used to power maximal intensity but short duration exercise. The fuel for this energy system is creatine phosphate (CP) and the stores of CP within the muscle fibres are very limited and last <10 seconds of maximal exercise. When CP is no longer available, the intensity of the activity is reduced, with ATP being rebuilt at a slower rate as the lactic acid or aerobic energy systems become dominant.

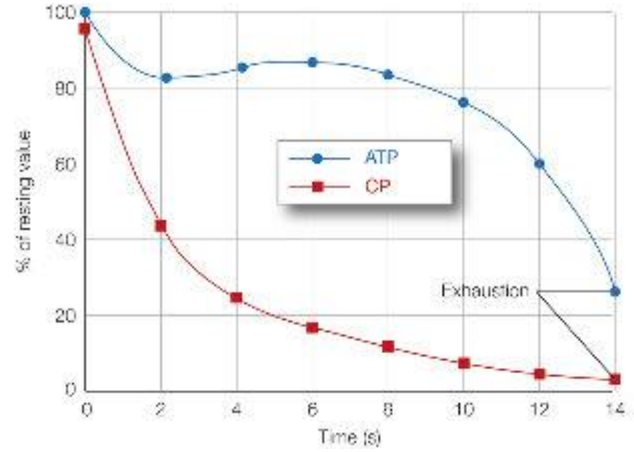


Figure 1.1.32: Changes in muscle ATP and CP during 14 seconds of maximal sprinting. Although ATP is being used at a fast rate, the energy from CP is used to rebuild ATP but at exhaustion, both ATP and CP levels are low.

Fuel depletion: Glycogen

In events lasting more than 10 seconds, muscle glycogen becomes the primary fuel to rebuild ATP via either the lactic acid system or the aerobic system. Unfortunately, glycogen stores are limited to what can be stored in the muscles and liver, which is estimated to be around 375g or 6,000 kJ of energy (refer to Focus Area 3.1) – which would usually be equivalent to the energy required to fuel 90 minutes of running.

Marathon runners often deplete their glycogen stores and report "hitting the wall" at around the 30km mark of a race (which approximates 90 minutes). At this point in time, the body must then begin to rely on fat as the major fuel source. However, because fat requires more oxygen to break down than glycogen, the body cannot cope with the increased oxygen demands of fat breakdown and the oxygen demands of exercise, so the exercising muscles must significantly reduce their work output (exercise intensity) to cope = fatigue.

Figure 1.1.33: "Hitting The Wall" is characterised by a massive reduction in exercise intensity.

During a marathon, the term "hitting the wall" is used to describe the point where exercise intensity suddenly and significantly drops. This is the point where muscle glycogen is depleted and fat becomes the dominant fuel source. In cycle racing, the same condition is referred to as "bonking". Both terms describe a condition which is characterised by a massive reduction in exercise intensity, the athlete feels "flat" and unable to continue. In any event lasting longer than 90 minutes. The depletion of glycogen may be a limiting factor in an athlete's performance. However, it should be noted that muscle glycogen stores can be manipulated through training and nutrition (pre competition, during competition and post competition) to maximise performance (refer to Focus Area 3.1: Nutrition and performance).

Assessment Task 1

Reference material:

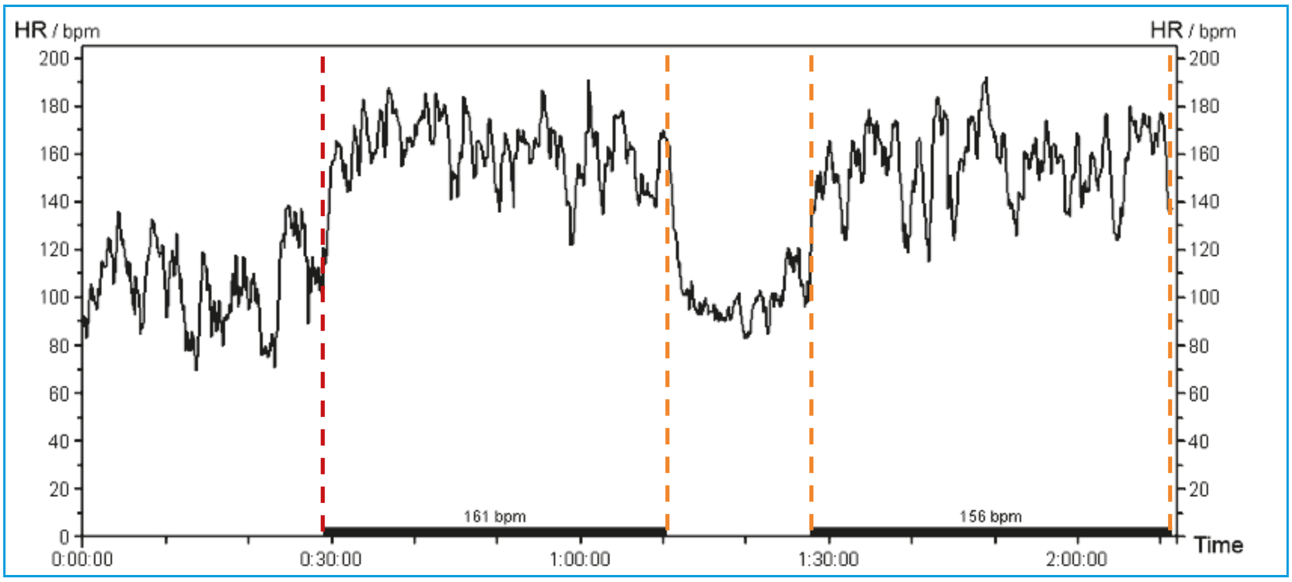
1.1 Application of energy sources affecting physical performance

3.1 Energy sources affecting physical performance

A common approach to assessment tasks requiring knowledge and understanding from Focus Area 1.1 and 3.1 is an analysis of the interplay of energy systems. Students will often be asked to use data recorded during a particular sport/activity, and then use this data to estimate exercise intensity, and subsequently predict and compare energy system contributions to either the student, their peers or an elite performer.

Application of Knowledge 1.1

The graph below shows the heart rate (HR) response in beats per minute (bpm) for a 20-year-old professional soccer player during an official 90-minute competitive match. The dark line in the X-axis represents the duration of each half (45 minutes) along with the average recorded HR (bpm) of each half.



Source: Energy expenditure estimation during official soccer matches graph adapted from Barbosa Coelho et al 2010.

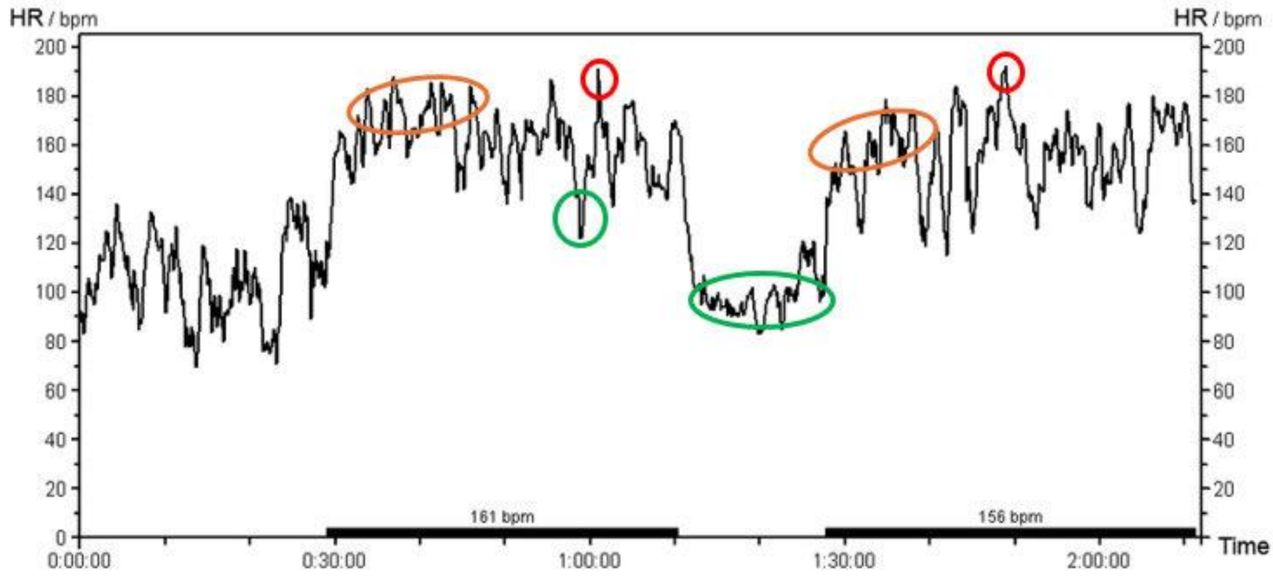
Using data from the graph, explain the **interplay of energy systems** for the soccer player whilst considering:

- Energy system contributions
- HR graph data
- Game play (i.e. positional play)
- Fatigue.

Suggested response

Soccer is a high-intensity intermittent sport characterised by short-duration high-intensity activities (such as sprints, jumps, and ball disputes) interspersed with lower-intensity activities (such as standing, walking, and low-speed jogging). The interplay of energy systems states that all energy systems will contribute to the energy demands of all these activities at any time. However, the dominant energy system will be dependent upon the intensity and duration of the activity undertaken at precisely that moment in time.

See the suggested response for energy system contributions, HR graph data, game play and fatigue in the table on the next page:



Source: Energy expenditure estimation during official soccer matches graph adapted from Barbosa Coelho et al 2010.

Energy System	HR Graph Data	Game Play	Fatigue
The ***ATP-PC*** energy system is dominant in maximal efforts of short duration: • 90-100% effort • < 10-seconds	Spikes in HR graph shows heart rate >95% HR_{max} (190^{+} bpm). Examples highlighted on the HR graph with RED CIRCLES.	The ATP-PC system is dominant when a midfield player sprints 40m at maximal intensity to receive a through ball.	Decreased speed may follow a maximal sprint due to PC depletion after 10-seconds. Rest required to recover PC: • 50% - 30 seconds • 100% - 3 minutes
The **Lactic Acid** energy system is dominant during repeated high intensity sprints (>85%) which are above Lactate Threshold.	Repeated spikes in HR graph where heart rate >85% HR_{max} (170-180 bpm) interspersed with short recoveries. Examples highlighted on the HR graph with ORANGE CIRCLES.	The Lactic Acid system is dominant during a midfield player's repeated sprints to make position after the team has either gained or lost possession of the ball.	Decreased speed following repeated sprints due to the accumulation of Lactate and H^{+} ions, the byproducts of anaerobic glycolysis. These increase muscle acidity, impeding muscle contraction.
The **Aerobic** energy system is dominant during lower intensity efforts (<85%) which are below Lactate Threshold.	Intermittent drops in the HR graph where heart rate decreases significantly to <85% HR_{max}. The 15-minute halftime shows an extended low intensity where heart rate approximates 50% HR_{max} (100 bpm). Examples highlighted on the HR graph with GREEN CIRCLES.	The aerobic energy system is dominant during short recovery periods that may include standing, walking or jogging when game play is at the other end of field.	The aerobic system reduces fatigue during the EPOC process. E.g. The 15-minute half time will allow for the rebuilding of the PC molecule (3 minutes). In addition, 50% removal of lactate and H^{+} ions accumulated during the first half.

Assessment Task 2

Reference material:

1.1 Application of energy sources affecting physical performance

1.2 Application of the effects of training on physical performance

A common approach to assessment tasks requiring knowledge and understanding from Focus Areas 1.1 and 1.2 is an analysis of the interplay of energy systems and an analysis of key fitness factors relevant to the activity. Students will often be asked to use data recorded during a particular sport/activity to estimate exercise intensity and subsequently identify energy system contributions to either the student, their peers or an elite performer. Secondly, they will often be asked to observe (or record and observe later) a game and analyse fitness factors that are key to success in the activity or movement.

Application of Knowledge 1.1 and 1.2

Using data collected from a Year 12 touch football game, compare, analyse and evaluate the physiological demands of two different positions by considering the following:

- using heart rate evidence, analyse and evaluate the interplay of energy systems when playing in the midfield ((Figure 1.1.34a) vs on the wing (Figure 1.1.34b) in a Year 12 game.
- using movement analysis data, describe and analyse the key fitness factors required during the game.

Suggested Response

Activity Analysis

A game analysis of touch football using heart rate data will enable periods of the game to be matched with the dominant energy pathway to illustrate the interplay of energy systems.

Generally, a game analysis to assess fitness factors would be achieved through the collection of relevant research data, game observation/videotaping or a combination of all methods. An example of an observational table format can be found in 1.6 *Analysis of Movement Concepts and Strategies* Table 1.6.10.

Touch is a high-intensity intermittent sport characterised by short-duration, high-intensity activities interspersed with lower-intensity activities (such as standing, walking and low-speed jogging). The interplay of energy systems states that all energy systems will contribute to the energy demands of all these activities at any time. However, the dominant energy system will depend upon the intensity and duration of the activity undertaken precisely at that moment in time.

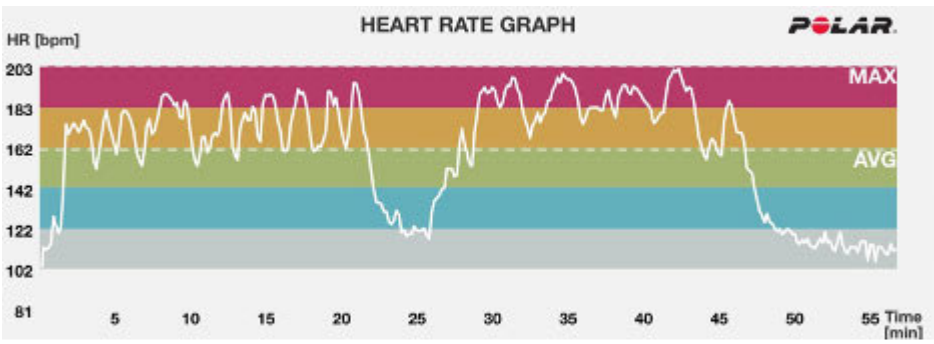


Figure 1.1.34a: Midfield position – Game Max HR 203 bpm (Lactate Threshold HR 172 bpm - predicted).

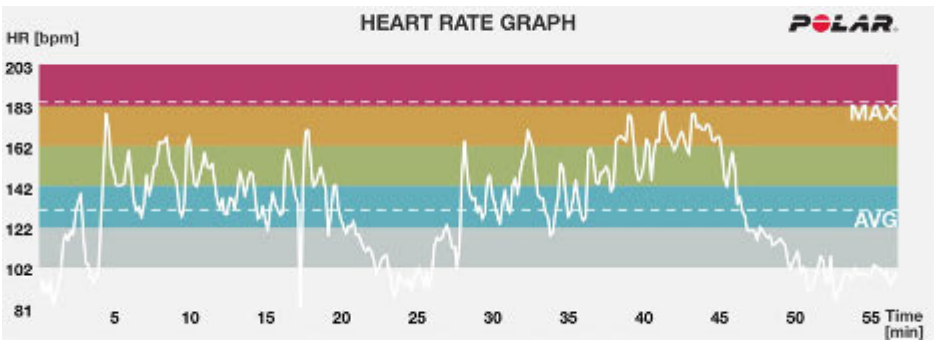


Figure 1.1.34b: Wing position – Game Max HR 185 bpm (Lactate Threshold HR 172 bpm - predicted).

See the suggested response for energy system contributions from heart rate graph data in the next table:

Possible considerations could include

Definitions **Concepts**	**Differences** **Findings** **Observations**	**Implications** **Game play**
ATP-CP energy system is dominant in maximal efforts of short duration • 90-100% • <10 seconds Looking for rapid increases or spikes in HR to indicate a sudden increase in intensity.	• Both positions have examples of steep spikes in HR. • Spikes in HR tend to start from a much lower base in the wing position. • Increases in heart rate for the midfielder reach up and past 85% of max HR. • Few examples of the HR peaking over 85% for the wing position.	• Any sudden or rapid spike in HR indicates a period of oxygen deficit (see page 19 oxygen deficit). So, ATP-CP would be contributing more at these periods, especially if short in duration and not repeated in quick succession. • The lower average HR for the wing position during the game means more opportunity for CP resynthesis between sprints. • Low ceiling for spikes with wing position would suggest short sprints or changes in intensity. The much higher ceiling with the midfielder would suggest more sustained higher intensity movements which indicates a greater contribution from the lactic acid system than when playing on the wing.
Lactic Acid System (Anaerobic glycolysis) dominant during repeated or prolonged high intensity movements. • looking for prolonged HR's reaching above 85% max HR, Lactate Threshold (172bpm for 17yr old) • looking for repeated HR spikes >85% max HR where ATP-CP system is depleted.	Midfield position has HR above 85% HR max a lot more than the wing position. • Only 4 brief incursions above 85% for the wing position. • Midfielder spends most of the 2nd half above Lactate Threshold (>172 bpm). • Midfield position produces rounder spikes in HR (more prolonged). • Near Max HR in midfield position	• HR that persists above OBLA (>172 bpm) indicates a sustained demand for high levels of energy. This would be predominantly coming from both the aerobic and anaerobic glycolysis systems. Too prolonged for ATP-CP to dominate. • Midfield position has a greater reliance on the anaerobic glycolysis system to provide energy than the wing during the game. • Rounder spikes in midfielders HR rate indicates more sustained effort at higher intensities (Lactic Acid system needed more during these periods). • Approaching HR max in places would suggest VO_2 max is being reached. Operating at these intensity levels is only possible with Lactic Acid system dominance. • Periods where there are groupings of HR spikes in quick succession would see a greater contribution from the Lactic Acid system.
Aerobic System dominant during submaximal intensity (<85% max HR)	• Submaximal intensity for most of the game for wing position. • Obvious drop in intensity during the ½ time break. • Drop in intensity after sudden spikes often below 85% max HR,	• Aerobic system dominant during the half time break as the intensity dropped considerably. Good for replenishment of CP stores and continued removal of lactate from system. • Energy during the short recovery periods between the peaks in the HR would be dominated by the aerobic system. • Much lower intensity throughout the match for the wing position, very little Lactate Threshold incursions occurring. This is good for ATP-CP replenishment.

Fitness Factors

There are a range of fitness factors key to successful performance in the game of touch football. Possible considerations for the key fitness factors involved in successful touch performance are outlined in detail in **Suggested Response 1.2** on pages 79-80. This response looks at possible observational data that could be collected during a game of Touch and how to interpret the data.

Focus Area 1: In Movement

1.2 Application of the effects of training on physical performance

- Analysis of the demands of physical activity
- Measurement and monitoring of fitness and energy components relevant to participation and performance
- Training principles and methods specific to fitness factors and to physical activities
- Chronic adaptations related to training methods

Analysis of the demands of physical activity

A game analysis enables the coach and athlete to prepare for the specific physiological demands of competition by identifying:

- The major energy system utilised during the event
- The major fitness factors and movement patterns involved.

Generally, a game analysis is achieved through observation, videotaping, statistical recording, heart rate monitoring, GPS analysis or a combination of all five. Intermittent team games are best suited to a ‘games analysis’ involving these techniques (refer to 1.6: Analysis of movement concepts and strategies).

An activity analysis is important to establish links between the training undertaken by an athlete, and the actual performances they achieve in competition. This is related to the training principle of **specificity** - where training demands must match the game demands to maximise performance (refer to Focus Area 1.2: Training principles and methods). An activity analysis will determine useful information for a coach and athlete in regard to:

- Skill requirements
- Movement patterns
    - Muscle groups used
    - Force of contraction
    - Speed of contraction
    - Direction of movements
- Fitness factors
    - Strength, power & speed vs muscular and cardiovascular endurance
- Energy systems
    - Aerobic vs anaerobic
    - Work: Rest ratios
- Biomechanical requirements
- Team strategy/tactics etc.

An analysis of continuous events such as competitive swimming, running and cycling may provide important information about biomechanical techniques, etc., but generally the analysis is more focussed on physiological data because in these events it is generally quite easily collected with the use of heart rate monitors, GPS and blood samples (thumb prick test for lactate measurements) etc.

An analysis of team sports usually utilises all of the above techniques (physiological data) but also requires a greater detail on the type, intensity and direction of movement patterns as these are important features of intermittent team sports such as soccer and netball etc.

How to analyse a particular activity

To establish the dominant energy systems, there are three questions to ask:

1. What is the intensity of the activity?

- Maximal – Anaerobic energy systems will be dominant (ATP-CP and Lactic Acid)
- Sub-maximal – Aerobic energy system will be dominant.

1

2. What is the time frame of the activity?

- 0-10 secs of maximal intensity, then the ATP-CP energy system will be dominant
- Up to 60 secs of high intensity, then then lactic acid energy system will be dominant
- Prolonged 1-2 mins (or longer) at lower intensity, then the aerobic energy system will be dominant.

3. What is the work-rest ratio?

- Total work time and total rest time
- Average work and rest time.

A **work-rest ratio** is used to analyse the energy demands in a competition.

- It is calculated by analysing an activity or sport and breaking the activity into its work (exercise) components and its rest (stationary, walking or slow jogging) components
- A work:rest ratio of 1:2 indicates that for every 1 × 'unit' of work there are 2x 'units' of rest.

Work:rest ratios provide information about the intensity of the game and the likely causes of fatigue. They also provide information to develop strategies to deal with fatigue to maximise performance i.e. the rotation of interchange players in the AFL etc.

Example 1: Olympic kayaking over 2km (Figure 1.2.2) equates to a time of approximately 4 minutes to complete. Therefore, the duration points towards the aerobic system.

Figure 1.2.1 – Repeated short intense (100%) efforts during a soccer game with a low work:rest ratio (minimal recovery) can increase the chance of fatigue.

Figure 1.2.2: Kayaking 2000m.

The intensity is high, but because of the duration (4 minutes) it can't actually be maximal. Maximal effort over this period of time would result in massive amounts of blood lactate accumulation and muscle fatigue would occur very early on in the race. Therefore, the dominant energy system is aerobic.

However, it should be noted that all energy systems will contribute to the energy demands of the kayaker at various times throughout the event (energy system interplay). For example, a quick sprint start, or explosive finish will be predominantly ATP-CP; working hard mid race to surge and lose a competitor would see the paddler's heart rate increase to an intensity above their lactate threshold and this would see some blood lactate accumulation.

Example 2: A professional soccer game consists of two halves of 45 minutes.

However, it is not appropriate to simply state that a total time frame of 90 minutes activity means the aerobic energy system is dominant.

Soccer, as with most team sports, is characterised by short bursts of intermittent high intensity exercise interspersed with varying amounts of active recovery (walking, jogging, etc.).

Figure 1.2.3: Soccer is a high intensity intermittent sport with little recovery for a midfield player.

To analyse the energy demands of a soccer midfielder, you must look at the specific skills, tasks and work-rest ratio that the midfielder would undertake throughout the 90 minutes to establish the dominant energy system(s) at that time (see Table 1.2.1).

Table 1.2.1: Team player (soccer midfielder) will use all three energy systems to varying degrees throughout a game.

Energy System	Game Play Examples for Soccer
ATP-CP system	Maximal Intensity efforts < 10 seconds • 10m sprint to a 50:50 contest • Maximal jump to out header an opponent from a corner kick.
Lactic acid system	Repeated high intensity efforts • Repeated short intense activities with a low work:rest ratio (minimal recovery) • With repeated high intensity sprints, CP stores will be depleted and unable to replenish (this requires 3 minutes), with a subsequent reliance on the lactic acid system.
Aerobic system	Lower intensity efforts: • Jogging to follow an opponent • Active walk recovery following strenuous efforts during EPOC (excess post-exercise oxygen consumption) • Ability to last 90 minutes and cover in excess of 10km per game for a midfielder.

In the above example, it should also be pointed out that an energy system analysis would provide different information when looking at different playing positions within the same sport. Using the above soccer example, consider comparing the goalkeeper (energy largely anaerobic and lots of recovery), with the midfielder's obvious aerobic requirements.

1

Focus Questions

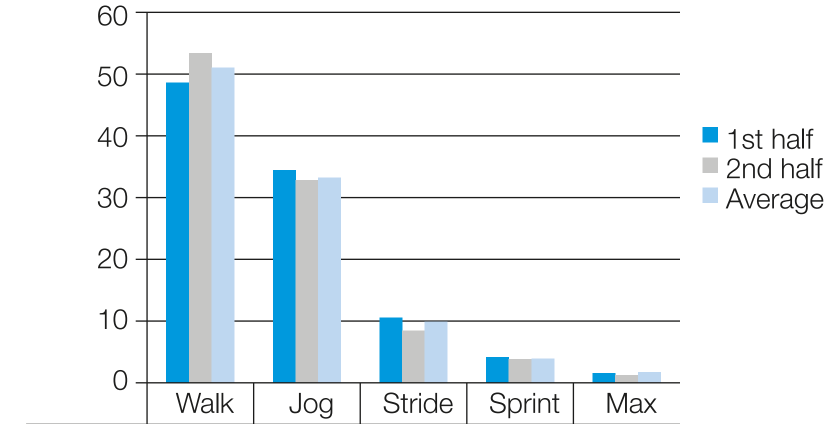
1. The data below was collected from a soccer game tracking a midfielder playing for the entire 90 minute game.

Table: Distances (km) covered by a soccer midfielder in a 90 minute game

	Walk	Jog	Stride	Sprint	Max
1st half	1.37	2.54	1.43	0.79	0.44
2nd half	1.46	2.73	1.33	0.59	0.34
Game totals	2.83	5.27	2.76	1.38	0.78

Total game distance = 13.02 km Overall average speed = 8.5 km/h

Work Intensity (% of time) by a Soccer Midfielder in a 90 Minute Game



	Walk	Jog	Stride	Sprint	Max
1st half	48.8	34.2	11	4.4	1.8
2nd half	53.3	32.9	8.6	3.9	1.3
Average	51	33.5	9.8	4.2	1.5

Source: Data collected by Glen Urbani.

Using data from the diagram and table above explain (using specific examples) how the interplay of the energy systems will lead to the midfielder successfully competing for the full 90 minutes.

Measurement and monitoring of fitness and energy components relevant to participation and performance

What are the Major Fitness Factors?

To identify the major fitness factors of a sport or activity, you must first become familiar with what each component is (see Tables 1.2.2 and 1.2.3).

Table 1.2.2: Health-Related factors – believed to offer some protection against 'lifestyle diseases.

Health-Related Factors	Description
Cardio-respiratory endurance	The capacity of your heart, blood vessels and lungs to function efficiently (delivering oxygen) during vigorous sustained activity.
Flexibility	The range of movement (ROM) possible at a particular joint or series of joints. Flexibility is affected by the following factors: • Structure of joint • Resting length of muscle • Muscle temperature • Injury/Disease • Gender • Soft tissue (skin, ligaments, etc.)
Muscular endurance	The capacity of a muscle to repeatedly exert a force or to hold a fixed or static contraction over a period of time.
Muscular strength	The maximum force that can be generated by a muscle or group of muscles in a single maximal contraction (1 RM). Muscular strength is affected by the following factors: • Cross-sectional area of the muscle • Angle of pull • Length of muscle • Age of person • Gender of person • Number of fibres (motor units) recruited • Speed of contraction • Shape of muscle (fusiform, pennate or radiate) • Type of contraction
Body composition	The make-up of the body, taking into consideration the relative proportions of fat mass and fat free mass, which includes components like bone and muscle – often expressed as a % body fat.

Table 1.2.3: Skill-Related factors – include all the components in Table 1.2.2 (but to a higher level of conditioning) and the additional factors that are based around improved performance.

Skill-Related Factors	Description
Agility	The ability to change direction quickly and accurately while maintaining balance.
Balance	Maintaining body equilibrium while static or dynamic.
Coordination	Accurate movement of body parts, to produce smooth, controlled actions.
Muscle power	The maximum force that can be exerted (strength) in the shortest possible time (speed). Hence it is a combination of Speed × Strength.
Speed	How quickly a body part can be put into motion (moved) – speed of muscle contraction.
Reaction time	Time it takes to respond to a stimuli.

To identify fitness factors ask yourself some questions:

How fast is the activity?

Figure 1.2.4: Speed and power.

Figure 1.2.5: Aerobic endurance.

Do you use maximum force?

Figure 1.2.6: Strength.

Figure 1.2.7: Muscular endurance.

Do you need to evade opponents?

Figure 1.2.8: Agility to evade an opponent is shown by this lacrosse player and football player.

Focus Questions

2. (a) What fitness factor is being used by the following athletes?

	Fitness factor(s)
A weight trainer in the gym performs a 10 RM Bench Press (i.e. they fatigued at 10 repetitions) lifting 70kg?	
A marathoner jogging 15km?	
A basketball slam-dunk?	
A diver from the 3m springboard performing a 'pike' position?	
A soccer player dribbles around two opponents in a cluttered goal box?	
A five-set tennis match at the Australian Open?	

(b) Compare the fitness components required for a game of volleyball (or other suitable sport) at the elite level and the recreational level. Is there a difference? Explain your answer.

Monitoring of fitness relevant to performance

Why conduct tests? (Purpose and benefits):

Strengths and Weaknesses

The tests used should be those that test the relevant fitness factors of the sport or activity. Determining any weakness provides a focus for the future; strengths must also be identified so that they can be maintained. A list of the strengths and weaknesses of an individual will give the coach an idea of where this individual will be best suited to play in a team sport.

To Gauge the Effectiveness of a Training Program

After a period of time (ideally about 12 weeks for noticeable chronic adaptations to occur), a follow-up fitness test would indicate whether or not there has been any improvement in the conditioning of the athlete. Failure to generate any real improvement in fitness may suggest that the training program needs modification.

Motivational Tool

Targets can be set by coaches for the athlete to strive for (rewards or incentives may be offered). Results from the tests are definitive indicators of improvement for the athlete to see for themselves, so it acts as an internal motivator (intrinsic), spurring the athlete to continue, confident in knowing that the program is effective.

What Tests to conduct?

Relevance

Is the test specific to the demands of the sport? The tests conducted should be specific to the sport in terms of:

- energy systems
- fitness factors
- muscles used.

Example: When conducting tests on a long jumper, it is obviously more beneficial to test leg power than arm power; you should test the alactacid system and not the aerobic system. It may also be argued that the 'standing long jump' may be more specific to the action of long jump than the 'standing vertical jump'.

Validity

Is the test measuring what it is intending to measure?

Example: It's all well and good to work out what the relevant energy systems and fitness factors of an activity are; but if the tests you use aren't actually assessing these things then they are not valid (a test must measure what it claims it is measuring). Refer to Focus Area 1.6: Collecting valid and reliable data.

Reliability

How reliable are the results?

Example: For the results to be compared with previous tests conducted by the individual or by other testing institutions, then the testing procedure must be the same each time. All variables except the one being assessed must remain constant. Failure to adhere to this means that any difference measured in pre and post tests may be the result of measurement error rather than a change in fitness level.

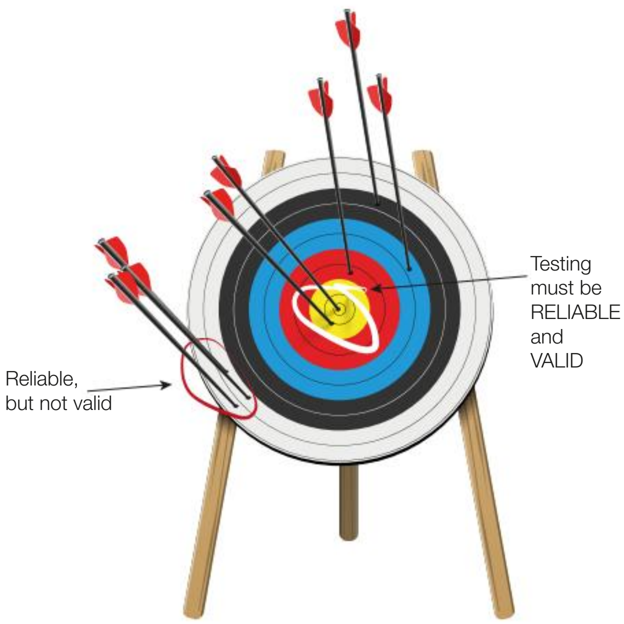


Figure 1.2.9: Fitness tests must be valid and reliable.

When a fitness test is conducted on an individual, it is essential that any differences between a pre-test and a post-test score is the result of a change in fitness status – NOT the result of a measurement error or variation in the testing technique.

Other Factors

It is also important to be able to recognise the relevance and appropriateness of a range of tests in terms of specific groups, available time, expertise of the tester and available equipment, etc.

For example:

- The 1500m swim is an inappropriate test of aerobic fitness if the individual can't swim!
- If measuring body composition, sometimes the Body Mass Index (BMI) is the 'best' you can do if the facility has no skin fold calipers and no underwater weighing equipment.

To ensure that the subject completes the test accurately and in their quickest possible time it is very important that the individual has been thoroughly briefed on the requirements of the test.

Types of Tests

Tests Based on Energy Systems

Students should be able to identify dominant energy systems within a sport or activity and subsequently identify an appropriate test to measure this energy system.

Alactacid Tests

These tests are of maximal intensity and no greater than 10 seconds in duration.

- Phosphate recovery test (5-7 seconds of exercise duration).

Lactacid Tests

The lactic acid system is more active (dominant) over approximately 60 seconds, so the duration of many of the tests for this energy system is between 30 and 60 seconds. This ensures that the lactic acid system is dominant during the testing period.

- 400m sprint (how fast a subject can complete 400m – approximately 60 seconds).

Aerobic Tests

There are two types of aerobic tests:

1. *Maximal tests* – aimed to work the subject to their maximum by gradually increasing the demands (intensity) of the activity. The tests are conducted within the confines of a laboratory because the subject is connected to a device that captures their expired air. The test is concluded when the subject's oxygen consumption peaks. These tests are very accurate, but they require maximal effort, specialised equipment, highly trained personnel to conduct the test and they are restricted to a laboratory environment.

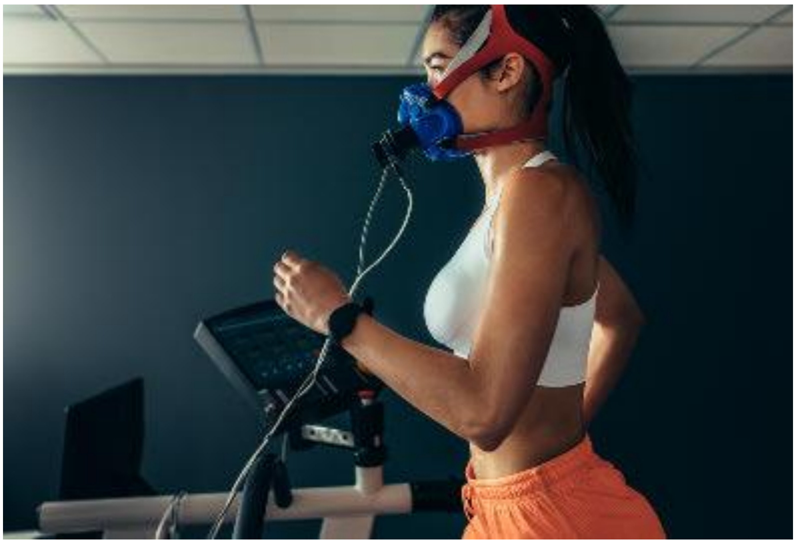


Figure 1.2.10: Maximal treadmill test to determine VO_2 max.

VO_2max = volume of air breathed in × O_2 consumed

Volume of air breathed in = 60 L.min

O_2 breathed in = 21.3%

O_2 breathed out = 15.0%

Therefore: VO_2 max = 60 × (21-15)/100

Therefore: VO_2 max = 60 × 0.06

Therefore: VO_2 max = 3.6 L min

Therefore: VO_2 max = 3600 mL min

Subject mass = 55kg

VO_2 max = 3600/55

VO_2 max 65.45 mL kg min

2. Predict VO_2 max. – these tests are more related to what is conducted during Year 12 PE lessons, as they don't require equipment to the same degree as the maximal tests.

   These tests predict VO_2 max by using heart rate during the activity or recovery heart rate at the end. Others include recording the level of achievement and comparing this to norms for the exercise (i.e. 20m shuttle run - beep test).

Procedures for Actual Tests

The procedures for the completion of the actual fitness tests can be found in many secondary physical education textbooks.

An athlete or coach must be able to recognise the major fitness factors within any given sport or sporting action and then match these identified fitness components with an appropriate test to measure the individual's proficiency in that particular component of fitness.

Students should be able to identify the testing procedures and protocols of some of the following major tests:

Note

The fitness tests in ***bold italics*** are briefly described and included as a fitness battery within this chapter.

They have been chosen simply because they are popular tests within many school Physical Education programs. They are described to reinforce theoretical concepts and should not be considered exclusively above other fitness tests.

Students should be able to recognise the relevance and appropriateness of a range of tests in terms of specific groups, available time, and expertise of the tester and available equipment, etc.

Identifying Testing Procedures and Protocols

Apply and understand some basic measurements of a range of tests assessing the following:

- alactacid and lactacid power
- muscular power
- agility
- flexibility
- aerobic power.

Recognise and identify the use of fitness testing batteries such as the SASI Sports Search and ACHPER Australian Schools Fitness Test, etc.

Muscular Power

- standing long jump (broad jump)
- ***vertical jump***
- softball throw
- basketball throw

Local Muscular Endurance

- Maximum push ups
- *Maximum sit ups*
- **Crunch test (2 minutes)**
- Flexed arm hang test
- Wall sit test

Agility

- **Illinois agility test**
- Semi agility test
- Vic fit agility test
- 5m agility test
- Flexibility
- **Sit and reach test**
- Shoulder hypertension test
- Trunk hyperextension test
- Bend twist and touch test

Aerobic fitness

- Physical work capacity (PWC 170)
- Astrand bicycle ergometer test
- Coopers 12 minute run
- 1.6km run
- Harvard step test
- **20m Shuttle Run (Beep test)**
- Treadmill test
- Yo-yo test
- Queens college step test
- Physical work capacity (PWC 170)

Anaerobic Power and Speed

- Margaria stair running test
- ***30m sprint***
- 40m sprint
- Phosphate recovery test
- 400m run
- Repco peak power test

Body Composition

- Skin folds (BF %)
- ***Body mass index (BMI)***

Fitness Test Batteries

Fitness-testing batteries involve the grouping of different fitness component tests to give an individual's fitness profile. Examples of organisations that utilise this principle include:

- 'SASI Sports Search'
- 'Tri skills'.

A disadvantage of using fitness test batteries is that at times the tests may not be specific to the sport or sporting activity that the athlete is competing in.

Focus Questions

3. (a) Explain the following terms (in reference to fitness testing):

Relevance

..

..

Validity

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..

Reliability

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..

(b) Refer to table below to answer the following questions:

Test	Fitness Component Measured	Athlete A		Athlete B	
		Score	Rating	Score	Rating
Multistage 20m fitness test (beep test)	i	Level 11 Shuttle 1	Excellent	Level 9 Shuttle 2	Good
Hand grip dynamometer	ii	43kg	Excellent	47kg	Excellent
Crutches in 60 seconds	iii	48	Excellent	42	Good
Vertical jump test	iv	47cm	Average	58cm	Excellent
50m sprint test	v	7.4 sec	Good	7.0 sec	Excellent
Illinois agility run	agility	15.8 sec	Excellent	16.1 sec	Good
Sit and reach test	vi	29cm	Good	35cm	Excellent

(i) Using the table above indicate the fitness factor being assessed for the letters indicated below:

i	
ii	
iii	
iv	
v	
vi	

Focus Questions

(ii) Both of these athletes (previous page) play for the local soccer team. One player is a goalkeeper and the other is a midfielder. Identify which athlete (A or B) is most likely to play each position and validate your choice using data from the table:

4. Please read the following scenario:

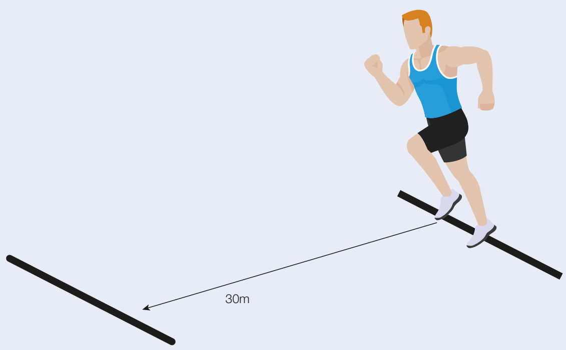
Fitness Testing Laboratory

30m Sprint

Equipment: Stopwatch, 30m measuring tape, 4 markers and flat area.

Procedure: Measure 30m distance with markers. Subject uses a standing start behind the line. The starter (on starting line) raises their right arm and gives the command 'Ready...GO!' On the command 'Go', the starter simultaneously lowers their right arm to signal to the timer to start the stopwatch. The timer (at the finishing line) stops the watch as the subject's chest crosses the line. The better of two attempts is recorded.

Classification		
	Men	*Women*
Excellent	<4.0 sec	<4.5 sec
Good	4.2 – 4.0	4.6 – 4.5
Average	4.4 – 4.3	4.8 – 4.7
Fair	4.6 – 4.5	5.0 – 4.9
Poor	4.6 +	5.0 +
Circle your score and rating		



(a) What fitness factor does this test measure?

(b) What is the dominant energy system being used here?

(c) At the completion of this test, have you incurred an Alactacid or Lactacid acid debt? Why?

Focus Questions

(d) Collate your class results. Generally, how do the sexes compare on speed? Explain two factors that might explain these differences?

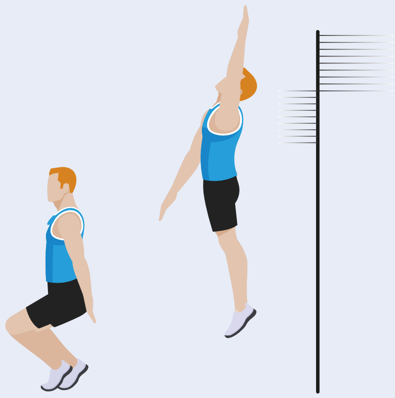
Standing Vertical Jump

Equipment: Vertical yardstick, a flat surface.

Procedure: Subject stands with feet flat on floor and both arms fully extended overhead. Adjust the height of the yardstick so that the tips of the middle fingers are touching the bottom peg. Turn to a side-on position to the yardstick. From a standing position, flex the knees and then jump as high as possible, touching the pegs with the fingers of one extended hand at maximum height.

Have three attempts (3 minute rest between attempts). Record the greatest distance (height) gained between the standing height and height of jump (in cm) – the subject's vertical jump.

Classification		
	Men	*Women*
Excellent	65cm +	58cm +
Very Good	55 – 65cm	47 – 58cm
Average	45 – 54cm	36 – 46cm
Marginal	35 – 44cm	26 – 35cm
Poor	<34cm	<25cm
Circle your score and rating		



(e) What fitness factor does this test measure?

(f) What type of muscle fibres would be desirable in this test? Why these types of fibres?

(g) Explain the dominant energy system providing the necessary energy?

Focus Questions

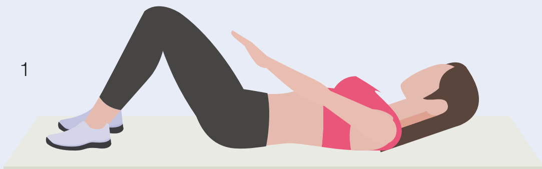
Crunch Test (in 2 minutes)

Equipment: Gym mat and a flat area.

Procedure: Assume a supine position with hands on your thighs. Draw your feet back towards the buttocks until they are flat on the floor (knees bent). The angle of your legs to your thighs should be approximately 90°. A crunch is counted when you have curled your back and raised your trunk 35° only.

Repeat this procedure as many times as possible in 2 minutes. Your partner counts out loud to assist the performer and lessen the risk of losing count. The score is the number of crunches completed in the 2 minute time period. Resting is permitted but only on your back with hands in the proper position.

Classification		
	Men	*Women*
Excellent	100	90
Very Good	90	80
Good	75	70
Average	60	50
Poor	40	30
Very Poor	30	20
Circle your score and rating		

1


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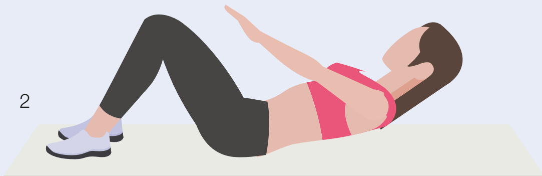


(h) What fitness factor is this laboratory testing?

(i) Explain the dominant energy system providing the necessary energy?

(j) Explain why you cannot keep doing crunches at your maximum pace for a long period of time?

Sit and Reach Test

Equipment: Flexibility box (or ruler).

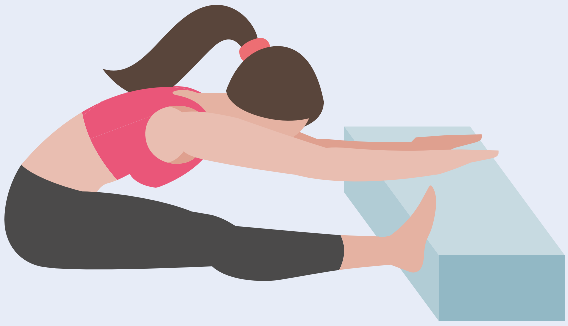
Procedure: Sit on the floor with the knees together and the feet flat against the flexibility box (or a bench turned on its side). With a partner holding the subject's knees straight, they reach forward with the arms fully extended and hold this position for 5 seconds. Measure the distance the fingertips reach on the flexibility box (or with a ruler). A score of '–'cm would indicate they can't touch their toes (without bending their knees) whilst a '+'cm score would indicate they can reach past their toes.

This test should be performed only after a warm-up that elevates heart rate.

1

Focus Questions

Classification		
	Men	*Women*
Excellent	9cm +	12cm +
Very Good	7 – 8.9cm	10 – 11.9cm
Average	5 – 6.9cm	8 – 9.9cm
Poor	2 – 4.9cm	5 – 7.9cm
Very Poor	<2cm	<5cm
Circle your score and rating		



(k) What fitness factor is this test measuring?

....

(l) What two areas of the body is this laboratory testing in particular?

....

....

(m) Suggest two reasons why females generally out-perform males in this test?

....

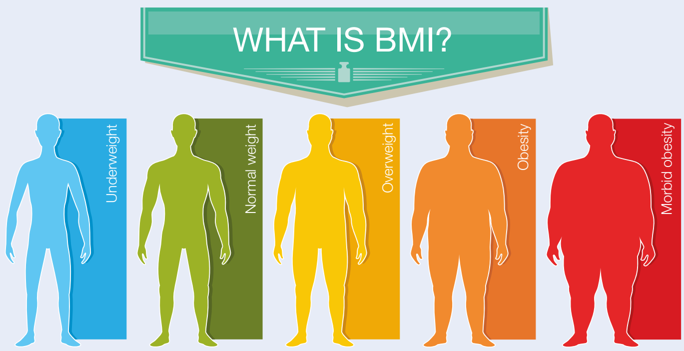
....

Body Mass Index (BMI)

Equipment: Scales, stadiometer (or tape measure).

Procedure: The BMI is used to assess weight relative to a person's height. BMI = weight (kg)/height^2 (metres).

Classification		
	Men	*Women*
Underweight	<18	<19
Average	19 – 25	20 – 25
Overweight	26 – 30	26 – 30
Obese	30 +	30 +
Circle your score and rating		



(n) What fitness factor is this test measuring?

....

(o) Explain one advantage and one disadvantage of using the BMI to predict this fitness factor?

....

....

....

....

....

....

Focus Questions

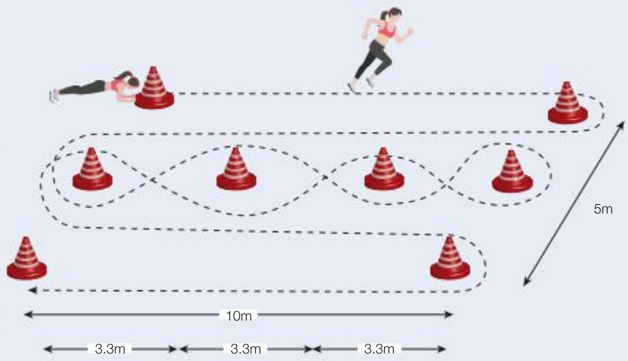
Illinois Agility Run

Equipment: Stopwatch, 30m measuring tape, 8 markers and flat area.

Procedures: Measure 2 parallel lines 10m apart. Place 4 witches' hats 3.30m apart as per diagram. Place 2 witches' hats 2m each side of the first line to indicate start and finish. Divide into pairs. One person is to complete the course and the other is to time and record results. Ensure you are warmed up sufficiently. The first subject to be tested lies down flat on their stomach in a push-up position just behind the start line.

On the word 'Go', the first subject runs to the end line and back, then in and out of the markers to the end line and back, and then to the end line once more and back to the finish. During the run, each line should be crossed and the markers can't be touched or jumped.

Classification		
	Men	*Women*
Excellent	<15.5 sec	<17.4 sec
Very Good	15.6 – 16.7	17.5 – 18.6
Average	16.8 – 18.6	18.7 – 22.3
Marginal	18.7 – 19.7	22.4 – 23.4
Poor	<19.8	<23.5
Circle your score and rating		



(p) What fitness factor is this test measuring?

....

(q) Consider two athletes (X – 100m sprinter and Y – AFL midfielder). Which athlete would you expect to perform better in the Illinois run? Justify your answer?

....

....

....

20m Shuttle Test (Beep Test)

Equipment: Music recording (CD player/app etc.), 30m measuring tape, 4 markers and flat area.

Procedures: Measure 2 parallel lines 20m apart. Place witches' hats to indicate start and finish. Divide into pairs. One person is to complete the test and the other is to record results. The first subject to be tested listens to the introductory remarks on the tape, which tell them how to complete the test and judge the pace.

Subjects begin by walking to the end line, aiming to reach it on the 'beep'. They turn and return to the start line on the next 'beep'. Gradually the tempo increases and the subjects are eliminated from the test when they fail to make the pace on two occasions. Record the level and shuttle number with the estimated O_2 uptake levels below.

There are many cardiorespiratory tests available, some of which require an athlete to push their body above lactate threshold levels (as in the 20m Shuttle Run as described above) or alternatively, there are more submaximal tests where an athlete generally exercises below lactate threshold level intensities (i.e. the Cooper's 12-minute run).

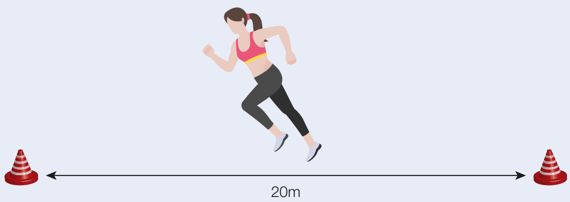
Level	Oxygen Uptake (ml/kg/min) Predicted
4	26.8 – 29.5
5	30.2 – 32.9
6	33.6 – 36.4
7	37.1 – 39.9
8	40.5 – 43.3
9	43.9 – 46.9
10	47.0 – 49.9
11	50.0 – 53.9
12	54.0 – 57.9
13	58.0 – 60.9
14	61.1 – 64.0
15	64.6 – 67.5
16	68.0 – 70.9

Table 1.2.4: Predicted VO_2 max. Source: Adapted from Davis, et. al. (2002), p. 156.

Focus Questions

The choice of test used to measure cardiorespiratory fitness really comes down to the training principle of specificity - does the test duplicate the athlete's physical demands in competition? With this in mind, the Cooper's 12 minute run test may be a good choice for a 10km distance runner to match their event demands of straight-line running at or slightly above OBLA. Alternatively, an AFL player who plays a high intensity intermittent sport would be advised to use the 20m Shuttle Run or the Yo-Yo Intermittent Test which matches a player's change in running direction and an exercise intensity above OBLA.

Classification		
	Men	*Women*
Excellent	>55	>44.5
Good	49.8 – 54.5	40.8 – 44.3
Average	44.9 – 49.7	37.1 – 40.7
Below Average	40.1 – 44.8	33.5 – 37.0
Circle your score and rating		



(r) What fitness factor is this test measuring?

(s) After their 'best' effort, an athlete reached level 12/shuttle 1 on the beep test. What caused the athlete to fatigue and prevent them from keeping up with the 'required' pace of the test? Explain your answer.

(t) Briefly explain how you would conduct the beep test (as described above) to maximise reliability and validity.

Training Principles and methods specific to fitness factors and to physical activities

Processes

It is probably every athlete's dream to produce their peak performance on that one big occasion in their athletic career – to kick the winning grand final goal, serve out the 5th set of a grand slam or to stand on the gold medal winning dais at the Olympics. Training is the process used to reach this 'peak' condition for a specific competition.

Peaking

Peaking is defined as the 'process of achieving an optimal performance on a specific occasion. Ideally, peaking will occur on the very day, even the very minute, of an important competition. Peaking requires a thorough knowledge of training and its effect on an individual athlete so that the training programme will produce the required response' (The Oxford Dictionary of Sports Science and Medicine).

Periodisation

A training program should be broken up into different sections or phases. During each phase of training, different physical demands from the event or game are emphasised. This is termed 'periodisation'. There are three main phases to a training year:

Table 1.2.5: Sample of the different phases within a yearly training program for a football side (senior – club standard).

Phases of the Training Year	Alternative names
Preseason phase	Preparatory phase
Competition phase	In-season phase
Off-season phase	Transition phase

January-March	April-September	October-December
Preseason Phase	Competition Phase	Off-Season Phase

Preseason Phase

The preseason phase is generally concerned with developing a general fitness base or platform from which the competitive season's fitness can be built upon. There are two sub-phases of the preseason:

- General preparation – the aim of this phase is to build a solid foundation of fitness and basic skills for the year. Typically, this phase sees training completed at a low to moderate intensity to accommodate for a higher volume of training.

  e.g. AFL players will gradually develop their aerobic fitness base with longer, lower intensity continuous running and gradually build up to more demanding fartlek and longer slower interval training as the sub-phase progresses. The basic elements of individual skill and team play will also be introduced to improve player and team cohesion.

- Specific preparation – In this phase of training the content of training sessions will become more sport-specific. This is achieved with a steady increase in training intensity and a gradual reduction in training volume.

  e.g. AFL players will tend to reduce the volume of their running but increase the speed by introducing shorter, faster interval training, interval skill drills and sprint training to develop the more specific game related fitness required for competition. There is also an increasing emphasis placed upon skill and strategy which will continue into the competition phase of the training year.

Competitive Phase

The competitive phase is where the regular competition is held, often on a weekly basis over many months before a final series begins. There are two sub-phases of the competitive phase:

- *Pre-competitive* – maintaining preseason fitness, main emphasis now on tactics and skills
- *Competitive* – Continue to maintain fitness (perhaps over a period of several months).

Because competition places heavy demands on an athlete, it is important that they avoid overtraining and incorporate a mini-taper before competition day. This is generally achieved by scheduling lighter, less intense training sessions near the end of the week, so that the player can be in ‘peak’ performance on competition day.

Off-Season Phase

This phase is a working holiday away from the chosen sport – so it is more correctly referred to as the **‘transition’ phase**. The individual must prevent a loss of their fitness while taking a ‘break’ from the stresses of regular training and competition. This phase tends to be much more individually based and self-motivating. It may involve light aerobic work 2-3 times per week or some strength training in an attempt to maintain a reasonable fitness level. Major weaknesses or injury rehabilitation could also be individually addressed during this period.

Table 1.2.6 Sample of the sub-phases within a yearly training program for a football side (senior – club standard).

January-March		April-September		October-December
Preseason Phase		Competition Phase		Off-Season Phase
General Prep.	Specific Prep.	Pre-Competitive	Competitive	Transition

Macrocycles

Macrocycles break the year up into manageable sections of 4-6 weeks in duration. Mini goals can be set during this period allowing the athlete to achieve success more regularly than if the focus is over the length of an entire season.

Table 1.2.7: Sample of the macrocycles within a yearly training program for a football side (senior – club standard).

January-February				March-September				October-December	
Preseason Phase				Competition Phase				Off-Season Phase	
General Prep.		Specific Prep.		Pre-Competitive		Competitive		Transition Phase	

Macrocycles

Microcycles

Microcycles are a collection of all the training sessions for the week. Therefore, 4-6 microcycles make up a macrocycle.

Table 1.2.8: Sample of the microcycles within a yearly training program for a football side (senior – club standard).

<table>
<tr><td colspan="15">January-February</td></tr>
<tr><td colspan="15">Preseason Phase</td></tr>
<tr><td colspan="8">General Preparation</td><td colspan="7">Specific Preparation</td></tr>
<tr><td colspan="4">Macrocycle</td><td colspan="4">Macrocycle</td><td colspan="4">Macrocycle</td><td colspan="3">Macrocycle</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Microcycle

Although Year 12 students would not be expected to construct a detailed yearly periodisation plan in this course, the following example of an annual training plan for Australian Rules Football shows the complexities of a detailed conditioning plan. As a general rule in elite sports today, success does not happen by chance.

Table 1.2.9: Example of an annual training plan for team-based athletes (Australian Rules Football). Source: Woodman & Pyke (1991), pp. 32-9.

Annual Training and Competitive Plan

Months	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Competitions												
Periodisation	Preparation		Special prep.	Pre-session competition	Competition						Finals	Transition
Macrocyles	Conditioning	General Basic		Specific Basic				Unloading		Taper	Peak	
Endurance	Aerobic Capacity		Max Aer Power	Anaerobic Alactic Power		Anaerobic Alactic Capacity				Maintain		
Strength	General	Maximum		Power	Maintain							
Flexibility	Develop				Maintain							
Speed	Develop running speed			Develop movement speed								
Technique (skill)	Maintain basic Remedial		Improve Basic	Acquire Variants	Maintain/Develop Rhythm and Co-ordination							
Tactics (team play)			Maintain elementary Acquire advanced		Acquire Advanced		Consolidate and Synchronise					
Psychology	Assess basic skill Devel. Indiv. rograms		Specific mental skills		Compensation & Motivation Development			Refine and Maintain			Spec. finals preparation	
Testing	■		■	■				■				
% Training time: Conditioning / Skill / Tactical	70 / 30 / –	60 / 40 / –	50 / 30 / 30	40 / 30 / 30	30 / 40 / 30	20 / 40 / 40	20 / 40 / 40	20 / 30 / 50	20 / 30 / 50	30 / 30 / 50	20 / 20 / 60	
Training load												

In-season competition games; Pre-season compeition games; Semi-finals; Grand finals; —— Volume; - - - - Intensity; Test dates

The Typical Training Session

To achieve maximum training effects, each training session should be planned to meet the goals of the microcycle. Below is an example of a typical structure for a team-based training session.

Team Briefing (5 minutes)

Discuss previous game or performance and set goals for the session.

Warm-Up (15 minutes)

- Rationale behind the warm-up is to prevent injury by thoroughly preparing the working muscles and joints for the more intense activity to follow.
- The warm-up is of lower intensity than during the conditioning phase and includes easy aerobic activities like jogging (to increase blood flow to the muscles, and therefore muscle temperature) followed by active range of motion exercises. This cycle may then be repeated at a higher intensity and include more game-specific movements and stretches prior to the conditioning phase.

Conditioning Phase (60 minutes)

The intensity now increases as the specific fitness components for the chosen sport are trained.

Training principles must be adhered to during this phase to ensure training benefits. The general order of conditioning tasks is as follows:

- Speed and power usually done early when athletes are fresh
- Individual and team skill drills with tactics and strategies
- Specialised fitness/skill work.

Cool Down (10 minutes)

Easy aerobic exercise to remove blood lactate that may have accumulated during training is the main aim of this phase. To do this, the blood must continue to be pumped around the body at increased levels (slow muscular contractions ensure little more lactate is formed and help move the pooling venous blood back to the heart for oxygenation). Finally, the training session may be completed with some stretching.

Note

The above sample training session is for illustrative purposes only. Not all of the listed activities will necessarily be used in every training session. The times for each section are guides also.

Focus Questions

5. (a) Explain the following terms:

Peaking

Taper

Periodisation

(b) You are the coach of a team sport, briefly describe to your athletes the main training focus in each phase of a yearly training program; pre-season, competition phase and off-season.

(c) An individual training session consists of three main components. Briefly describe the purpose of each one.

Training principles

To ensure maximum benefits are obtained from a training programme, the following training principles need to be implemented.

Progressive Overload

For fitness to improve, the body must be exposed to a training load that it is normally unaccustomed to in everyday activities. This ‘overload’ will put the body under stress. If the overload is regularly repeated, the body will adapt until it can cope with the stress (training load) comfortably – a training adaptation is said to have occurred.

If the training load remained at this level, no further improvements in fitness would occur. The theory behind ‘progressive overload’ is to progressively challenge the body so that it will continue to make physiological changes to cope with the new demands placed upon the body.

Figure 1.2.11 shows this concept over a three-week period, where each week the duration of the activity increases by 5-10% from the previous week. The last week is of lower intensity, allowing the body to recover and make the physiological adaptations.

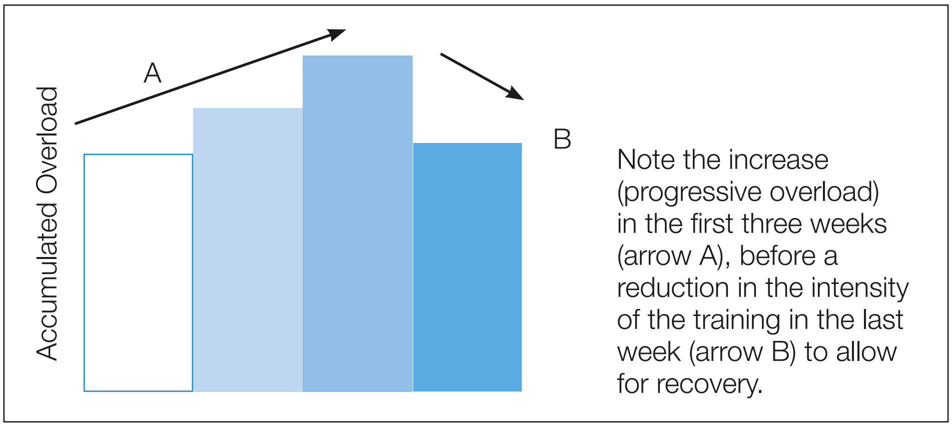


Figure 1.2.11: Progressive overload.

Methods to overload the body’s systems may include:

- changing work interval distance
- changing work interval time
- changing rest interval time
- changing rest interval type
- changing the number of repetitions
- increasing the number of sets per week
- increasing the amount of resistance
- increasing the range of motion

Note

It is recommended to only alter one variable at a time to avoid too much overload and subsequent injury or overtraining. As a guide, aim to increase loading by no more than 10% per week.

Specificity

Fitness is specific. This means the adaptations from training will be directly related to the type of training undertaken. Therefore, it is essential that an athlete replicate the characteristics of physical activity in training to match that of the event. This is in regard to:

- skills performed
- fitness components used
- predominant energy systems
    - muscle groups:
    - type of contraction
    - speed of contraction
    - force of contraction
    - angle of contraction.

In a practical sense, this means that if you wish to maximise your performance as a runner, you will need to train by running! There will be little transfer of training to your running performance if you train by bicycling.

Furthermore, if you wish to run quickly, you will need to train by running quickly! For example, it is generally no good training with a long, slow distance run of 20km (at a pace of 12km/hr) if you wish to set a PB of 4min 30secs over 1500m (at an equivalent pace of 20km/hr). Likewise, running for 60 minutes at a 'steady state' in a straight line is not specific to prepare a player for the demands of an intermittent, high intensity team sport such as Australian Rules Football – where higher intensity 'interval' running with changes of direction may provide more specific chronic adaptations to match their performance requirements.

Variation

A training stimulus that is regularly repeated will lose its effect over time. In other words, the same training session week in and week out over an extended period of time will not see fitness improve – it may maintain current fitness levels at best. However, physical fitness can be achieved in a variety of ways; so by periodically manipulating training variables (intensity, time and type of training) to alter the program, fitness gains will continue (but remember specificity!)

In addition, variation may be needed psychologically to ensure the athlete remains focused and motivated. A disinterested athlete's performance during training can drop and result in reduced training effects.

Individuality

No two subjects will respond in the same way to an identical training stress. We are all individuals and coaches must take this into account. Some factors that may need to be considered are:

- current fitness level
- maturation
- psychological needs
- gender
- injury.

Recovery

It is not simply the case that if some training and overload is good, then more must be better. In order for the body to adapt to training stresses, there must be an appropriate recovery period (24-48 hours) following training. Recovery doesn't necessarily mean inactivity, however. For example, elite athletes may train up to ten times per week or more, but still incorporate the recovery principle with a 'hard/easy' approach to their training sessions.

Likewise, body builders in heavy resistance training may train every day by carefully structuring their program to alternate different muscle groups throughout the week, i.e. Monday – biceps, Tuesday – triceps, Wednesday – biceps, Thursday – triceps, etc. This way each muscle will still have 48 hours recovery before the next training session.

An athlete may also incorporate recovery weeks in their training program to allow the body to adapt and recover from the accumulative effects of training or competition (refer Figure 1.2.11).

Diminishing Returns

If a subject has a low level of initial fitness, their fitness will increase markedly with only 2-3 training sessions per week. As they become better conditioned and closer to their 'genetic potential' (the best performance they could achieve naturally) their fitness gains will decrease, and they will have to work a great deal longer and harder for smaller improvements in fitness.

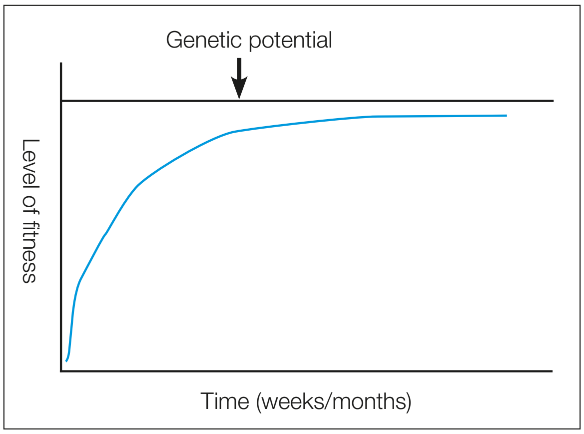


Figure 1.2.12: Diminishing returns over time to training.

Frequency

Frequency refers to the number of training sessions needed per week. As a general rule of thumb, the more often the body is stressed, the more rapidly it will adapt to the training load. Factors that may need to be considered include:

- Recovery time (24-48 hours)
- Fitness level of individual
- Nature of activity:
  - Aerobic training (min 3 × per week)
  - Anaerobic training (min 3 × per week increasing to 4 × week).

Duration

For training adaptations to occur, training must be long term (conducted over a minimum of 6 weeks).

- Aerobic training generally requires about 12 weeks.
- Anaerobic training (strength and power) generally requires about 8 weeks.
- Flexibility training generally requires a smaller number of sessions.

'Aerobic fitness programs should run for not less than 12 weeks, while anaerobic fitness programs should run for 8-10 weeks' (Davis 2002, p. 197).

Intensity

Intensity refers to how hard the training session is. Generally, intensity may be measured in:

- Exertion level (perceived exertion)
- % of HR max or % of VO_2 max
- % of one repetition maximum (1RM).

For example:

- ATP-CP is targeted at **95-100% HR max** (although HR isn't always a good indicator in alactacid work)
- Lactic acid is targeted at **85-95% max HR max**
- Aerobic system is targeted at **60-85% HR max**.

Note: the % of VO_2 max can also be used.

Reversibility

The principle of reversibility is commonly referred to as the 'use it or lose it' syndrome. In other words, the body will quickly enter a detraining state (loss of fitness) when training ceases. All fitness factors will decrease when the training stress is removed, but aerobic fitness is generally lost quicker than strength gains.

This training principle is the main argument for the inclusion of the 'transition phase' in a yearly training program (instead of the traditional 'off season') so that an athlete does not lose all the fitness they worked hard to achieve throughout the season.

Focus Questions

6. (a) Explain how the following principles of training will allow an athlete to get the most from their training:

Progressive overload

Recovery

(b) At first glance, the principle of 'specificity' and 'variation' may appear to contradict each other. Explain the difference between these two principles and explain how a coach may apply both principles using a specific example.

(c) Explain to a group of athletes what may happen if they ignore the principle of 'reversibility' throughout the off-season. What would you recommend be done in this part of the training year?

Training Methods

Continuous Training

Continuous training involves training over an extended period of time (20 min–2 hours), during which time the activity is continuous and of a 'constant effort' and so the HR generally remains stable. The intensity of the activity depends on the needs and wants of the individual.

Continuous training is used to develop aerobic fitness. There are two levels of continuous training:

- Low intensity training: at this level the athlete is at the lower end of the aerobic training zone (60-75% HR max). The activity is very much sub-maximal and the duration of training and distances covered tend to be long.
- High intensity training: at this level the athlete is pushing the boundaries of the aerobic training zone (75-90% HR max) and is aiming to work at their current highest steady state pace for a shorter period of time (15-45 minutes). This is often referred to as 'threshold' training because it is trying to lift the lactate threshold or OBLA (onset of blood lactate accumulation).

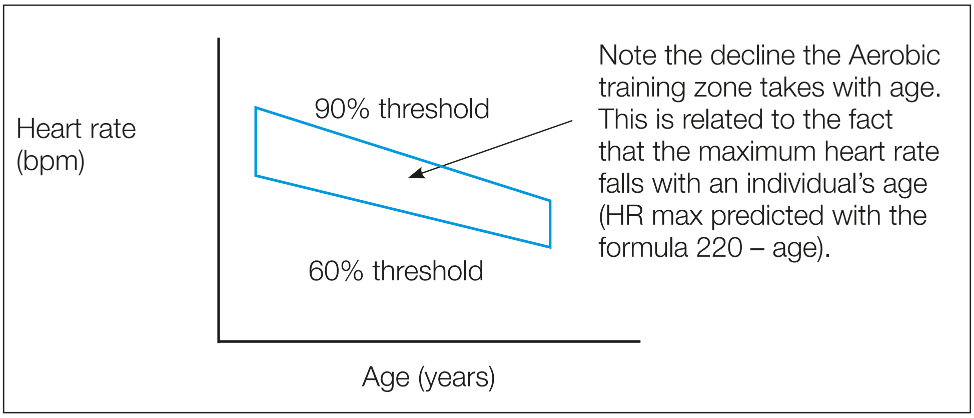


Figure 1.2.13: General aerobic training zone (note the variation in prescription for the high intensity training zone of 90% HR max – this higher training threshold would only be 'aerobic' (under lactate threshold) for very well-trained athletes.

It should be noted that a person's level of fitness is important when following target HR zones for training. Poorly conditioned people will receive training effects from sustained training at lower intensities, whereas fitter people require a higher threshold to stimulate training adaptations. For example, the American College of Sports Medicine states that lower intensity values – i.e. 55% of HR max – may be most applicable to individuals who are quite unfit (position stand – Medicine & Science in Sports & Exercise Volume 30). Likewise, highly conditioned endurance athletes may be able to train at 90% HR max and still be working below their lactate threshold.

The generally accepted aerobic training prescription is remembered by the acronym **FITT:**

Frequency: training must be at least 3 times per week and more for elite athletes.

Intensity: 60 – 90% HR max (HR max **predicted** with the formula 220 – age)

Time: Minimum of 20 minutes per session (duration is dependent on the intensity)

Type: Aerobic exercise (able to elevate the HR for an extended period of time).

The benefits of continuous training include the following:

- Low intensity, continuous training is a good initial preseason technique, although the low intensity is below many of the demands placed on athletes in competitive sporting activities. Low intensity, continuous training is also used as a recovery session following strenuous sessions. In addition, many highly trained endurance athletes will use very long duration/low intensity continuous training (60% HR max) to improve the body's ability to 'burn' fats.
- High intensity continuous training increases the lactate threshold and better mimics the intensity demands of many competitive sporting activities.

Interval Training

This form of training involves alternating periods of activity (exercise) with periods of recovery.

Interval training may be used to develop aerobic power, lactacid power or alactacid power (depending on length of work intervals and recovery times).

When designing a program for interval training the following factors must be accounted for:

Table 1.2.10: Interval training variables.

Repetitions	Interval Time	Work Intensity	Work to Rest Ratio	Rest Interval	Sets

- *Repetitions* – The number of work periods in a set. The number of repetitions tends to be greater when training anaerobically and less when training aerobically.
- *Interval time* – The time it takes to complete each work interval. The prescribed interval time will be dependent on the energy system. Training must ensure that the correct system will be dominant.

Target energy system	**Interval time**
ATP-CP	< 10 seconds
Lactic acid	approx. 10-45 seconds OR < 10 seconds with minimal rest time
Aerobic system	approx. 45 seconds – 4 minutes

Sometimes, the work interval may be expressed as a 'work distance' (such as 400m instead of time - seconds/minutes). However, the distance selected must ensure the individual finishes within the correct time span.

- *Work intensity* – How hard the athlete must work when performing each repetition. Based on the energy systems:

Target energy system	**Intensity**
ATP-CP	95% + max. HR
Lactic acid	85-95% max. HR
Aerobic system	60-85% max. HR

The intensity of the work interval is generally inversely proportional to the length of the work interval; i.e. shorter intervals are conducted at higher intensity than longer intervals.

- *Work-Rest ratio* – The ratio of work-rest is determined by the energy system that is being targeted. Hence, this form of training can train all three energy systems:

Target energy system	**Work-Rest**
ATP-CP system	1:5+
Lactic acid system	1:3
Aerobic system	1:1

- *Rest interval* – This is related to the work-rest ratio (energy system), i.e. 1:5 for the ATP-CP system means that the rest period must be 5 × that of the interval time.
- *Sets* – The number of times a group of repetitions must be repeated.

Interval training may be prescribed as short, intermediate or long intervals depending on the energy system the coach wishes to address.

- *Long interval training* – predominantly aerobic, but as each successive interval becomes harder (with the incomplete removal of blood lactate) anaerobic lactacid energy may also contribute in the latter phases.

Table 1.2.11: Guidelines for a long interval training plan with sample (800m runner).

	Repetitions	Interval Time	Work Intensity	Work to Rest Ratio	Rest Interval	Sets
Guidelines	3-12	2-5 mins	75-85%	1:1	2-5 mins	1-2

- *Intermediate interval training* – Greater lactacid demand as the duration of work is decreased but the intensity of work increased. This form of training is used to develop both aerobic and anaerobic lactacid endurance. Because blood lactate concentrations can become elevated during intermediate intervals, it is sometimes referred to as 'lactic acid tolerance' training. Athletes may consider these sessions psychologically (and physically) very difficult to complete.

Table 1.2.12: Guidelines for intermediate interval training.

	Repetitions	Interval Time	Work Intensity	Work to Rest Ratio	Rest Interval	Sets
Guidelines	3-12	30 secs-2 mins	90-95%	1:3	1-6 mins	2-3

- *Short interval training* – designed for athletes to generate power. Short work intervals and longer recovery periods allow for the recovery of CP (there would be an increased reliance on lactacid energy in the later repetitions without sufficient recovery).

Table 1.2.13: Guidelines for a short interval training.

	Repetitions	Interval Time	Work Intensity	Work to Rest Ratio	Rest Interval	Sets
Guidelines	10-30	5-15 secs	95-100%	1:5+	30 secs-3 mins	2-3+

The benefits of interval training are:

- Interval training may be useful for any sport that has an anaerobic component (e.g. sprints, middle distance running or fast paced, intermittent team games)
- It allows an athlete to train at a higher intensity for longer
- By manipulating the variables of work and rest, any energy system may be trained
- Because interval training is highly structured, it is easy for coaches to monitor an athlete's progress and it is difficult for an athlete to hide or coast (so long as the prescribed work and rest intervals are monitored).

Focus Questions

7. (a) Refer to the table below detailing sample interval training programs to answer the following questions:

	Repetitions	Interval Time	Work Intensity	Work to Rest Ratio	Sets
X	10	5 secs (35m) run	100%	1:5	3
Y	8	1 min (100m) swim	90%	1:3	2
Z	3	3 mins (1000m) run	80%	1:1	1

(i) What is the dominant energy system(s) being developed by each of the following interval prescriptions. Briefly justify your answer.

Program X

Program Y

Program Z

(ii) How long (in minutes) would the athlete in program X rest for between work sessions? Why is the work- rest ratio considerably higher for program X compared to the other two programs?

(iii) Explain which program (X, Y or Z) is an athlete likely to find the most 'difficult' to complete? Give a reason for your answer.

(b) A sedentary 30-year-old wishes to 'get fit' and comes to you for some advice. What recommendations would you provide for this person to follow to develop their aerobic fitness?

Fartlek Training

'Fartlek' is a Swedish term meaning 'speed play'. Fartlek training may be considered a blend of continuous and interval training (i.e. a continuous activity that incorporates random variations of speed (exercise intensity).

For example, after running for 2 minutes, you might then implement a surge of speed for about 20 seconds, before returning to the initial intensity. These variations in intensity are generally very informal, with the individual athlete or terrain deciding on when and where the intensity will increase and for how long. On the other hand, the training session can be more formal – for example, an athlete may be required to perform 20 seconds of speed work every 2-3 minutes of running. Fartlek training can be easily applied to many disciplines – running, cross-country skiing, cycling, etc.

The benefits of Fartlek training:

- Fartlek training may be used to develop the aerobic and anaerobic energy systems
- Fartlek training is an excellent form of training to introduce more intensive workouts to an athlete. For this reason, it is often used in the specific preparation period of the training program.
- The deliberate attempt by the athlete to work at a higher intensity for periods throughout the run result in some temporary accumulation of blood lactate – simulating competition demands.
- Generally, it is an interesting workout that motivates an athlete because it is often performed in undulating, natural environments (e.g. forest).

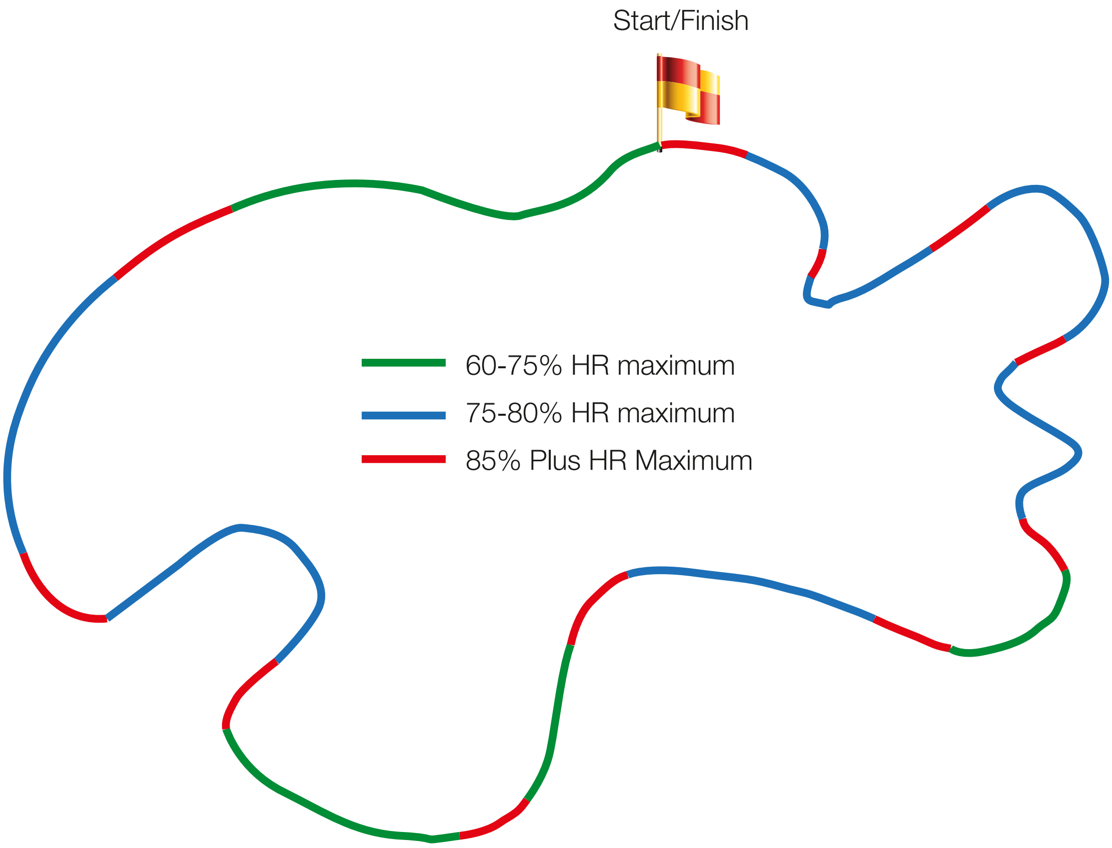


Figure 1.2.14: Fartlek training is often performed in natural, undulating environments e.g. Forest.

Table 1.2.14: Comparison of features of several training modes. Source: Adapted from Rushall & Pyke (1998), p. 216.

Training Method	Energy System	Blood Lactate Levels	Load On Athlete	Recovery Time	Appropriate Training Phase
Low intensity continuous	Aerobic	3mmol/L	Low	24-36 hrs	General preparation recovery, transition
High intensity continuous 'threshold' training	Aerobic/ Lactacid	<3-5mmol/L	Moderate/ High	24-36 hrs	Specific preparation
Fartlek	Aerobic/ Lactacid	3-6mmol/L	Moderate	24 hrs	Specific preparation, competition, transition
Long interval training	Aerobic/ Lactacid	6-10mmol/L	Moderate/ High	36 hrs	Basic preparation, specific preparation
Intermediate interval training 'Lactic Acid tolerance' training	Lactacid/ Aerobic	>10mmol/L	High	48 hrs	Specific preparation, pre-competition, competition
Short interval training	Alactacid	4-6mmol/L	Moderate	36-48 hrs	Specific preparation, pre-competition, competition

Note

Resting levels of lactate are approximately 1mmol/L blood; OBLA considered to be 4mmol/L and above.

Aerobic Floor Classes

These are hybrid aerobic classes that incorporate continuous training to train the aerobic system, with additional callisthenic exercises.

The classes may develop cardiovascular fitness while also improving local muscular endurance (with forms of resistance training). The stretching involved in the classes can improve flexibility.

Resistance Training

Resistance training involves lifting a form of resistance (free weights, pin loaded, body weight, etc) in an attempt to improve muscular strength, power or endurance.

Two forms of resistance training exist:

- Weight training
- Resistance calisthenics'.

Weight training – This form of training involves lifting of weights; the mass lifted and the number of times lifted depends on the fitness component that is being focused on.

Table 1.2.15: Weight training guidelines.

Fitness Component	Load (% 1RM)	Frequency (per week)	Reps	Sets	Speed	Rest
Strength	90	3	2	8	Slow	3-4 mins
Power	60	3	7	5	Fast	2-4 mins
Endurance	50	3	20 +	3	Medium	2 mins

Load – Mass lifted

RM – Repetition maximum is the maximum weight that can be lifted a set number of times (i.e. 1 RM is the maximum weight that can be lifted once only)

Reps. (repetitions) – Consecutive lifts, i.e. 2 reps = 2 lifts

Sets – Grouping a number of reps with a rest period

Note

The above guidelines quoted are a guide only – it is recommended you obtain specific figures that relate more to the training program you are planning.

As a general rule of thumb, however, when training for muscular strength the load is high and reps low, while when training for muscular endurance the load is low and reps high.

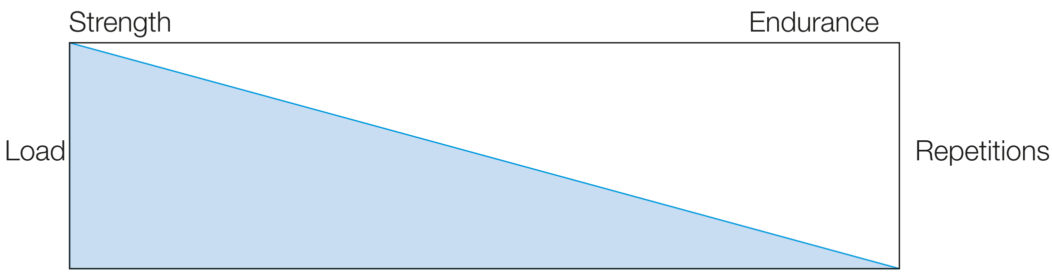


Figure 1.2.15: High load/low reps = strength; Low load/high reps = endurance.

The different types of muscular contractions possible mean different weight training programs also:

- *Isotonic training*

  Using a set mass (load), moved through the range of movement possible at the particular joint, the muscle actively alters its length – in Figure 1.2.16, the bicep muscle shortens (concentrically) as the weight is lifted up and then lengthens (eccentrically) as the load is controlled back down.

  Isotonic training is cheap and easy to conduct because free weights can be made or bought cheaply. However, this technique doesn't fully overload the muscle in the mid-range of the lift due to weaknesses in the muscles 'strength curve' at sections **A** and **B** limiting the load lifted.

- Isokinetic training

  This form of resistance training does allow the mid-section of the lift to be trained at maximum, as the load varies throughout the lift to ensure maximal resistance throughout the entire range of motion – sections A, B and C (Figure 1.2.16).

  The speed of the muscles' contraction is maintained by the machine (Cybex & Kin Com, etc.). However, equipment to do this is extremely expensive and out of reach for many schools in South Australia.

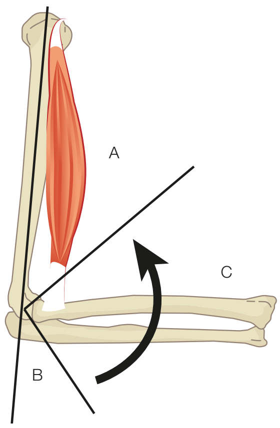


*Figure 1.2.16: Muscle weaknesses in the 'strength curve' at sections **A** and **B** limit the load that can be lifted.*

Figure 1.2.17: Isotonic 'resistance training' involves 'concentric' and 'eccentric' muscle contractions.

- *Isometric training*

  Muscle contracts against a resistance without changing length, i.e. a flexed arm hang held as long as possible involves an isometric contraction of the bicep (Figure 1.2.18). Static strength gains are specific to the joint angle trained.

Figure 1.2.18: Flexed arm hang is an example of isometric training.

Focus Questions

8. Describe a sport or activity where the athlete would benefit from training that incorporated isometric contractions:

- *Resistance callisthenics*

  This style of resistance training uses the body and/or gravity to generate a load or resistance, i.e. push-ups.

Plyometric Training

This form of training is associated with muscular power, as the training involves quick, powerful repeated contractions, including jumping, bounding, skipping or hopping (Figure 1.2.19). Plyometric exercise is very dynamic, and to avoid potential injury, subjects should:

- be very familiar with the requirements of each exercise
- be skilled in the correct techniques
- achieve this knowledge of technique through practice first at low intensity
- start a training session with low intensity activities, and building up to the higher, more skilled activities.

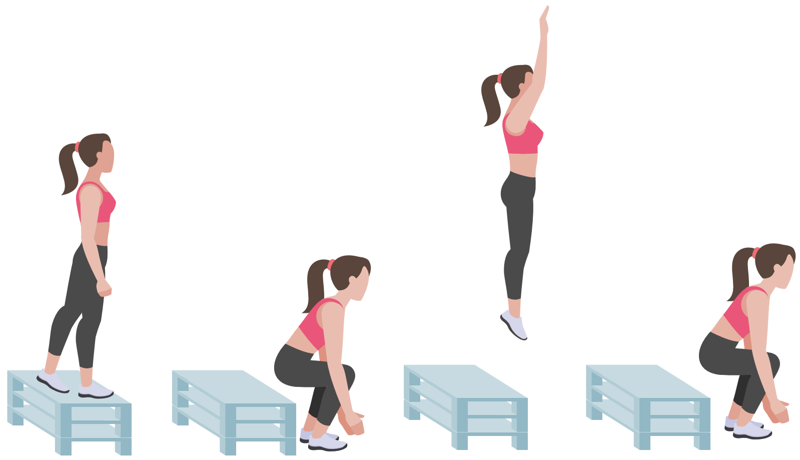


Figure 1.2.19: Plyometric Training – any jumping exercise where a landing is followed by a jump.

Circuit Training

Circuit training involves the use of stations within an activity to train a variety of fitness factors. The type of fitness gain will depend on the activities at each station. There are essentially three types of circuits used:

- *Fixed load circuits* – Each individual doing the circuit training does the same load at a particular station. For example, perhaps 30 push-ups are required, so the subjects all must try to achieve 30 push-ups before moving to the next station.

  Progressive overload is possible by simply increasing the load at each station the next time around (once a subject can achieve 30 push-ups, they progress to 35 the following session). The circuit is usually repeated 2-3 times.

  This style of training is not individualised, so all subjects complete the same load, regardless of ability.

- *Individual load circuits* – This method of conducting a circuit allows for individual needs but requires pre-testing to be conducted to find out the athlete's initial load – usually ½ maximum to begin with.

  Once the initial load has been established, the individual begins the circuit by trying to achieve their individual load, with the aim of progressively increasing their performance at each station. The circuit is usually repeated 2-3 times.

- *Fixed time circuits* – Subjects get one minute to complete as many repetitions as possible at each station. Progressive overload is achieved by trying to improve the number of repetitions at each station. The circuit is usually repeated 2-3 times.

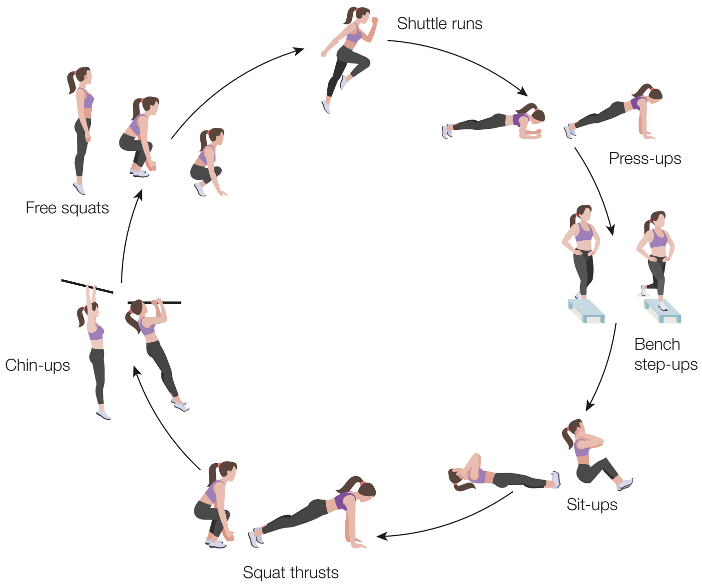


Figure 1.2.20: Circuit training involves a series of 'stations' arranged into a 'circuit' for athletes to complete in a predetermined order.

Fitball Training

This form of training is based around the exercises that you can complete using a fitness ball. The exercises rely on stability being maintained throughout the movements, and the exercise should be ceased if the stability is lost.

The exercises help train:

- Flexibility in a dynamic setting
- Balance
- Core stability
- Strength in agonist muscles
- Flexibility training.

The need for flexibility will vary from sport to sport, depending upon the specific nature of the activity undertaken (i.e. gymnastics versus running). However, good flexibility is a requirement for all athletes. There are some guidelines that should be followed during any form of flexibility training:

- There shouldn't be any pain while stretching.
- Stretching work should be 3-5 times per week, minimum.
- All forms of flexibility training are more effective following a full body warm up that increases blood flow to the muscles, raising muscle temperature and increasing muscle pliability.

During a training session, flexibility training is usually carried out in the warm-up and cool-down. There are three main recognised techniques for training flexibility:

- *Static stretching* – This form of training involves taking a muscle to its full range of motion and holding the stretch statically (with no movement) for a period of time, ranging from 15 seconds to 2 minutes. Static stretches should only be done at the very end of a training session and/or competition because they are not considered suitable to maintain the high heart rates required for a muscular warm up prior to training and/or competition.
- *Ballistic stretching* – This form of stretching involves swinging or bouncing the muscle into the end range of motion. This form of stretching can be very dangerous because it carries a high risk of muscle tear (through the 'stretch reflex'). However, many sports are ballistic in nature, and so many athletes such as gymnasts and dancers perform these stretches. But they should only be done following a complete and thorough full body warm up (including static stretching prior).

- *Proprioceptive Neuromuscular Facilitation (PNF)* – This form of flexibility training is the most effective at improving flexibility levels for the athlete. It involves taking a muscle to the end of its ROM for a static stretch, and then contracting the muscle isometrically for a short period of time (approx. 6 seconds) against a resistance (usually a partner/towel etc.) before relaxing the stretch and taking the muscle further into a static stretch.

Focus Questions

9. (a) To ensure physiological adaptations are maximised with all forms of training, the principle of overload should be implemented. Discuss ways that overload could be achieved in each of the following methods of training:

(i) Continuous training

(ii) Interval training

(iii) Fartlek

(iv) Fixed time circuit

(v) Plyometrics

(vi) Isotonic resistance (weight) training

Focus Questions

(vii) Isometric resistance (weight) training

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(b) Explain the basic differences you would expect to see in a resistance-training program for muscular endurance, muscular strength and muscular power.

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(c) With the assistance of your teacher or coach, describe a static, ballistic and PNF stretch for the hamstring muscle group. Repeat the process for a different muscle group.

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Chronic adaptations related to training methods

Chronic adaptations related to training methods refers to the changes or 'adaptations' that occur in the body over an extended period of time, as a result of repeated training sessions.

If a training method is regularly repeated, the body will slowly 'adapt' to the stress or 'overload' placed upon it during this training session and over time, the body will make changes to better handle the training session. Therefore, the chronic adaptations to training are often termed the 'training effect'.

The specific chronic adaptations that occur in the body are a direct result of the training that has taken place (i.e. the training method used). The frequency, intensity and time of the training session will in turn influence the rate and type of chronic adaptations developed.

For a full description on the chronic adaptations related to training methods, refer to Focus Area 3.3: The effects of training on physical performance.

Assessment Task 3

Reference material:

1.1 Application of energy sources affecting physical performance

1.2 Application of the effects of training on physical performance

A common approach to assessment tasks requiring knowledge and understanding from Focus Areas 1.1 and 1.2 is a performance improvement/self-improvement portfolio task. Students will often be asked to undertake a personal journey of improvement with a focus on a chosen sport/physical activity. They will reflect on their current performance(s) and capabilities to identify a relevant Fitness Factor for improvement, with a focus on the specific physiological areas related to their chosen physical activity. Students will apply their contextual knowledge and understanding from Focus Areas 1.1 and 1.2 by designing and implementing strategies, such as plans, programs, approaches, and/or training principles to improve their identified physical activity.

Application of Knowledge

At the end of an AFLW season, a 20-year-old midfielder sets herself a Personal Fitness Goal to “improve stamina” prior to the start of the next competitive football season.

Propose a 6-week fitness training program explaining how the following considerations may help structure an effective training program to achieve her goal:

- Activity Analysis
- Goal Setting
- Fitness Testing
- Training Methods
- Training Program
- Training Principles
- Other relevant strategies.

Suggested Response

Activity Analysis

A game analysis will enable the specific AFLW game demands to be matched with training in regard to the dominant energy system(s) used during a game, and the major fitness factor(s) and movement patterns involved.

Generally, a game analysis would be achieved through the collection of relevant research data, game observation/videotaping, HR recording or a combination of all methods.

Possible considerations may include:

Game Analysis		**Considerations**
Fitness Factor	Cardiovascular Endurance used in AFLW games during low intensity activities such as walking, jogging etc.	• AFLW game last 68 minutes (4 × 17 minutes plus time-on) • Research shows AFLW players cover up to 6474 ± 1013 m per game
Energy Systems	All energy systems interplay throughout an AFLW game. The aerobic energy system is relevant to ‘stamina’ and cardiovascular endurance. Repeat sprint ability is a critical aspect in AFLW performance, as the game requires players to repeatedly chase in defence and sprint to create space in offence.	Aerobic energy system dominant during low intensity periods where recovery (EPOC) from fatigue may occur: • Rebuilding CP (alactacid – fast component) • Removing Lactate and H^+ (lactacid slow component) • Multi-Intensity running: • Replicate intermittent higher-intensity running followed by brief lower-intensity recovery periods • Replicate low Work-Rest ratios (e.g. 1:1) to duplicate the fatigue levels experienced during AFLW games
Movement patterns	Wide variety of movement patterns used in an AFLW game: Spatial Awareness - direction of movements (curved, straight, forward, backward, sideways movements, etc).	• Multi-Directional running to mimic unpredictable movements used in a game: • Replicate game - specific movement patterns

Goal Setting

SMART goal setting will provide a framework for achieving her personal fitness goal because it makes goals more specific, measurable, achievable, relevant, and time-bound.

Possible considerations may include:

Specific	A specific goal will clarify exactly what needs to be achieved. Instead of the vague goal to 'improve stamina', a specific goal may identify a specific fitness factor, which can then be clearly and accurately measured via a fitness test. For example, 'stamina' is more accurately referred to as cardiovascular endurance - which can be accurately measured using a variety of different fitness tests. Therefore, the goal to increase cardiovascular endurance is more accurate for the AFLW player. In addition, the goal can now be explicitly measured; by measuring 'reach level 10.2 in the Beep Test' is more specific, and provides a clear target to aim for, which can enhance focus and motivation.
Measurable	Measuring progress is essential for motivation, accountability and knowing whether you've achieved your goal. The specific goal to 'reach level 10.2 in the Beep Test' is easily measured and progress can be tracked objectively - allowing for periodic adjustments to be made progressively to the program, as required.
Achievable	Setting achievable goals means setting targets that are realistic but challenging. Unrealistic goals will likely lead to frustration, failure, and demotivation. Assessing current abilities, resources, and constraints, will provide goals that stretch your limits without overwhelming you. For example, if your pre-measure fitness test was level 8.2 in the beep test, then setting a goal to reach level 10.2 may not be achievable in six weeks.
Relevant	Goals should be relevant to your overall performance objectives. For instance, research data reports that elite midfield AFLW players are often required to run long distances (6474 ± 1013 m). There is also research evidence that reports high-speed running and maximal accelerations diminish as the game progresses, which is likely indicative of fatigue. Therefore, the goal of improving cardiovascular endurance (via measurement if the Beep Test) is relevant to AFLW performance.
Time-Bound	Setting a timeframe for achieving goals creates accountability and often encourages a well-structured training program to achieve the goals within the deadline. By establishing specific time frames, such as six weeks to 'reach level 10.2 in the Beep Test' it is more likely an athlete will remain motivated and complete their training program.

Fitness Testing

There are a range of fitness tests relevant to an AFLW midfielder wishing to measure their cardiovascular endurance. One common test available to Year 12 Physical Education students is the 20m Shuttle Run Test (Beep Test). This test has been widely used for team sports like AFL, Soccer and Touch Football to measure an athlete's cardiovascular endurance capabilities.

Possible considerations may include:

20 Metre Shuttle Run Test (Beep Test)	
Protocol	Player shuttle runs back and forth between two lines positioned 20 metres apart, keeping pace with audio cues from a pre-recording. The test consists of multiple stages, each with progressively quicker audio cues, designed to increase running speed. Players continue running until they fatigue and can no longer maintain the required pace.
Relevance	The Beep Test is advantageous for AFLW midfielders for several reasons: • Midfielders frequently engage in high intensity running at an exercise intensity above their lactate threshold. The Beep Test closely simulates the demands of high intensity of running and the associated fatigue experienced during the later stages of the test. • The change of directional running back and forth in the Beep Test matches the movement patterns utilised during an AFLW game. • Research has shown that performance in the Beep Test correlates with match performance and playing intensity in team sports. AFLW midfielders who perform well in the Beep Test are likely to demonstrate superior cardiovascular endurance during matches, contributing to their overall effectiveness on the field.

20 Metre Shuttle Run Test (Beep Test)	
Validity & Reliability	Reliability - The Beep Test follows a standardised protocol with established norms and benchmarks. If carefully implemented, this test allows for a reliable comparison of an individual players' cardiovascular endurance and the monitoring of training progress, over time. For example, as a pre/mid/post-program fitness test. Validity - The Beep Test is sometimes used to indirectly predict maximal oxygen uptake (VO_2max) via the use of algorithms. However, the validity of the Beep Test to accurately estimate VO_2max is considered low.

Training Methods

Some of the dominant training methods that can be used to increase the aerobic endurance of an AFLW player are discussed in the table below:

Training Method	Description	Relevance to AFLW
Continuous	Low intensity running for an extended period of time (20+ minutes). This method of training is completed without breaks at a 'steady state' intensity where HR remains in the aerobic training zone (60-85% HR max). There is minimal accumulation of fatigue causing byproducts (lactate and H^+).	Useful to implement in the early stages of an AFLW cardiovascular endurance program to provide a low injury risk introduction to endurance running. Although it is specifically designed to improve the cardiovascular O_2 delivery system, its game specificity to AFLW is low.
Fartlek	Fartlek is a Swedish term for 'Speed Play' because it describes a blend of fast and slow running. This training method incorporates random but deliberate variations of running speed and is often completed over varied terrain and natural environments.	Useful to implement as an introduction to high intensity running. Random surges of fast running develop both the aerobic and anaerobic energy systems. Game specificity to AFLW is good because high intensity running results in the temporary accumulation of blood lactate, simulating game demands.
Interval (Long)	Interval training involves alternating periods of work (exercise) with periods of rest (recovery). Long interval training is useful to develop cardiovascular endurance with long duration work intervals (45 seconds - 4 minutes), performed at low intensity (<85% HRmax). The work-rest ratio is usually 1:1 as there are limited fatiguing by-products accumulated.	Long intervals stress the O_2 delivery system and improve cardiovascular endurance. Repeated intervals of exercise intensity (85%) simulate the AFLW game demands at Lactate Threshold. The short recovery periods (W:R 1:1) promote quick recovery in EPOC also simulating AFLW game demands.

Training Program

A sample six-week AFLW aerobic endurance training program utilising the identified training methods is proposed in the table below. Throughout the six-week period, training progress is monitored through regular self-assessment of performance during workouts and adjusted based on recorded heart rate, rate of perceived exertion (using a modified Borg scale (0 - 10)), fatigue and running pace.

Phase 1: Training Weeks 1 & 2 - Build aerobic endurance and condition the body with sustained running.		
2 × week	Continuous Training • Steady-state running 20-minutes • Moderate intensity	• 4.5km @ 70-80% HRmax (140 - 160 bpm) • Rate of Perceived Exertion (RPE) = 5 Moderate Activity
1 × week	Continuous Training • Long Slow Distance (LSD) 30-minutes • Low intensity (conversational pace)	• 6km @ 60% HRmax (120 bpm) • Rate of Perceived Exertion (RPE) = 3 Light Activity
End of Week 2 - Fitness Test (20m Beep Test) to monitor progress evaluate program in preparation for Phase 2.		

Phase 2: Training Weeks 3 & 4 - Gradually increase the intensity and volume of training.		
2 × week	Continuous Training • Steady-state running 30-minute • Moderate intensity	• 5km @ 70-80% HRmax (140 - 160 bpm) • Rate of Perceived Exertion (RPE) = 6 Moderate Activity
1 × week	Continuous Training • Long Slow Distance (LSD) 40-minutes • Low intensity (conversational pace)	7km @ 60% HRmax (120 bpm) Rate of Perceived Exertion (RPE) = 3 Light Activity
1 × week	Fartlek Training • 'Speed play' - fast & slow running • Varied terrain • 40-50 minutes	Warm Up & Cool Down - 2km @ Easy • Run 30 seconds @ 85% / Walk-Jog 1-minute • Run 1 minute @ 85% / Walk-Jog 2-minutes • Run 2 minutes @ 85% / Walk-Jog 4-minutes
End of Week 4 - Fitness Test (20m Beep Test) to monitor progress evaluate program in preparation for Phase 3.		
Phase 3: Training Weeks 5 & 6 - Increase the intensity of training to maximise endurance and running speed.		
2 × week	Continuous Training • Steady-state running 30-minute • Moderate intensity	5km @ 80-85% HRmax (160 - 190 bpm) Rate of Perceived Exertion (RPE) = 6 Moderate Activity
1 × week	Fartlek Training • 'Speed play' - fast & slow running • Varied terrain • 50-60 minutes	Warm Up & Cool Down - 2km @ Easy • Run 30 seconds @ 85% / Jog 1-minute • Run 1 minute @ 85% / Jog 2-minutes Repeat Fartlek 3x in WK 5 and WK 6
1 × week	Interval Training • Intervals 4x 1 km (4-minute) • Moderate-high intensity • 50 minutes	Warm Up & Cool Down - 2km @ Easy • 4x 1 km @ 85% HRmax • Work-Rest ratio 1:1
End of Week 6 - Fitness Test (20m Beep Test) to evaluate overall progress of the training program.		

Training Principles

Implementing the training principles of progressive overload, recovery, and specificity into the training program will be crucial for continuous improvement, injury prevention, and ensuring relevant and effective performance enhancement.

Progressive overload can be achieved by gradually increasing the intensity, duration, or frequency of training to continuously challenge the body and stimulate improvements in stamina.

For example:

- **Increased distance:** The program started with a baseline distance that she was comfortable with and gradually increased the total distance run by approximately 10% each week.
  For example, she ran 4.5km in week one, but this increased to 5km in week three.
- **Increased intensity:** She started running with steady-state continuous running at 60% HR_{max} but slowly incorporated fartlek and interval training where she increased running up to 85% HR_{max} by week six.
- **Increase frequency:** She started with three running sessions per week and progressively added more sessions, up to four times a week, as her aerobic fitness improved.

Recovery is essential to allow the body to repair, adapt, and grow stronger. Adequate recovery helps prevent overtraining and injuries.

For example:

- **Rest Days:** These were incorporated into the program, with at least three rest days per week to allow her muscles to recover. For instance, she was programmed to run on Monday, Wednesday, Friday, and Sunday, with rest on Tuesday, Thursday, and Saturday. This generally allowed for 24-48 hrs recovery between runs.
- **Active Recovery:** The program prescribed low-intensity cool-down activities such as light jogging or walking, following the Fartlek and Interval training to promote blood flow, removal of fatiguing byproducts (lactate and Hydrogen) and aid recovery without putting too much accumulative fatigue on her body.

Specificity can be achieved by tailoring the training program to match the specific running demands of AFLW, focusing on the type of distances and running speeds required in a game for a midfield player.

For example:

- **Game-specific running:** Midfield players can cover a lot of distance during a game, and there is also intermittent high-intensity running, followed by short recoveries. Therefore, the program included longer distance runs (continuous running of 4-7km) in conjunction with fartlek and interval running, which combined intervals of speed with slower running recovery after every repetition.
- **Running drills:** Although not detailed in the program, incorporating running drills that mimic AFLW movement patterns and running intensity could include forward, backward and sideways shuttle runs and various agility drills to simulate the start-stop and change of direction nature of Australian Rules football.
- **Conditioning with ball work:** Although not detailed in the program, integrating football-specific drills that involve running with the ball, passing, and receiving under game-like conditions could enhance specificity further.

Other relevant strategies

Other relevant strategies to consider: Maintaining proper hydration, nutrition, stretching, sleep and fatigue management etc could all be utilised to support training adaptation and recovery.

Assessment Task 4

Reference material:

1.2 Application of the effects of training on physical performance

A common approach to assessment tasks requiring knowledge and understanding from Focus Area 1.2 is an observational analysis of the student's, peers or elite performers' gameplay. This is usually done through video analysis, real-time observation, or published movement analysis data.

Fitness data is usually obtained through published sources or standardised fitness testing protocols (see Topic 1.2 Measurement and monitoring of fitness and energy components relevant to participation and performance).

Application of Knowledge

Using data collected from an elite-level game and a Year 12 touch football game (Table 1.2.16 and 1.2.17), compare, analyse and evaluate the physiological demands of the game of touch football played at the elite level and at a Year 12 PE level by considering the following:

- Describe and analyse the main fitness factor requirements for both levels using movement analysis data (Tables 1.2.16 and 1.2. 17).
- Evaluate your level of fitness in the fitness components identified. With respect to your level of fitness identified in these components, explain the impact on your game performance.

Suggested Response

Possible considerations could include

Table 1.2.16 is a comparison of time (%) spent on each movement.

Table 1.2.17 looks at the number of times an individual movement or action is performed and the average time spent on each of those movements or actions. Keep in mind that in most situations, elite players will probably spend more time off the field (interchange is more frequent) than a typical Year 12 student playing in PE.

Table 1.2.16: Approximate time (%) spent on each movement by Year 12 and an elite player in a game of Touch football.

Movement	Year 12	Elite
Interchange (sitting)	0	49.5
Standing	14.6	1.5
Walking	45	14.5
Jogging	20	18.5
Running	7	7.9
Sprinting	2.4	1.6
Pass	1.8	1.2
Catch	1.4	1
Tap	0.2	-
Roll	0.8	0.6
Touch	1.2	0.75
Dive	-	-
Dummy half pick up	1.1	0.8
Evading opponents	1.6	1.2

Table 1.2.17: Repetitions and duration of each movement.

	Year 12		Elite Player	
Movement	**Repetitions**	**Average Duration (s)**	**Repetitions**	**Average Duration (s)**
Interchange (sitting)	0	0	12	99
Standing	70	5	9	4
Walking	180	6	58	6
Jogging	96	5	89	5
Running	56	3	63	3
Sprinting	19	3	19	2
Pass	44	1	29	1
Catch	34	1	23	1
Tap	3	2	1	2
Roll	20	1	15	1
Touch	31	1	18	1
Dive	1	1	1	1
Dummy half pick up	27	3	19	2
Evading opponents	13	3	10	3

Common responses based on example tables could include

Fitness Factor	Activities	Differences Year 12s v Elite players	Implications for Gameplay
Muscular Power: The maximum force exerted in the shortest possible time	Passing, diving, sprinting would require powerful movements	• Sprinting and dives are similar for both. • Less passing by elite players, but this could be due to less game time. • Sprints of short duration for both, so power important as need to generate force quickly.	• Power is a combination of speed and strength. • Quicker, longer passing to open up the defence more or have more options when attacking. • More powerful push off when starting to sprint means players are quicker to close down gaps in defence, or more likely to get through gaps in offence.
Speed: How quickly a body part can be put into motion	Sprinting	Sprinting is similar for both. Elite players sprint duration is shorter.	Greater speed: • More likely to evade defenders, not get run down if they receive or intercept a pass. • Defenders can run down opponents quicker, or close down gaps that are forming earlier, reducing the opponents' chances to score.
Agility: The ability to change directions quickly and accurately while maintaining balance	Evading opponents	Elite players have slightly less frequency of evasion. Yet significantly less on-field time would suggest a greater frequency by elite players when actually playing on the field.	• Ability to change direction quickly to evade opponent(s). • Allows defenders to change direction quickly in response to attacking players sudden movements. Increases potential to make the tag.
Cardio-respiratory endurance: Capacity of the cardio-respiratory system to deliver oxygen to working muscles during vigorous, sustained activity	• Running at high intensity • Recovery from sprinting and running at high intensity also requires a good cardio-vascular system.	• Both spend nearly 10% at high intensity running / sprinting. These periods of oxygen deficit will require recovery periods with elevated oxygen levels. • Seven percent of game time is running. The higher the intensity the more oxygen will be required.	• The more the aerobic system can provide the majority of the energy at higher intensities, the more fatigue can be delayed from lactate build up etc. A good cardio-vascular system delivers more oxygen to working muscles to allow this to occur. • The more oxygen available during submaximal periods the faster the replenishment and recovery of the two anaerobic energy systems. A more efficient EPOC process delays fatigue and allows the athlete to continue to perform at higher intensities for longer.

Fitness Testing

Common responses for fitness ratings could be

Fitness component	Standardised Fitness test (see pages 45-46)	Rating	Implication examples
Muscular power	Legs • Standing Vertical Jump • Standing broad jump Upper body (Arms) • Basketball throw	See classification norms in Topic 1.2	Good performance in the power tests means a more forceful movement is possible. This can improve performance in all explosive and powerful components of the game.
Speed	30m or 40m sprint test	Find published normative data for Australia online	Greater speed in movements means less opportunity for the defence to intercept a pass, or make a touch etc.
Agility	Illinois Agility test	Find published normative data for Australia online	Being able to change direction quickly and stay on your feet means greater opportunity to evade the touch of defenders.
Cardiovascular endurance	Multi-stage shuttle test (beep test)	Find published normative data for Australia online	A higher endurance rating in a test would mean you could operate at higher intensities for longer than your opponent before fatiguing. This would be an advantage especially if no or little substitutions. Greater ability to recover from anaerobic activity with a higher aerobic capacity. Faster CP replenishment and removal of lactate etc.

Review Questions

Multiple Choice (1-19)

1. A netball player made over 80 changes of direction (lead outs, turns and pivots) during the course of a game. Identify which fitness component is necessary for this position:
   (a) Flexibility
   (b) Muscular endurance
   (c) Agility
   (d) Balance
2. Soccer midfielders require a well-developed aerobic capacity. This was reinforced by match analysis data that showed:
   (a) The player sprinted a total of 1100m throughout the match
   (b) The player made 35 sprints of less than 30m throughout the match
   (c) The player had high levels of lactate present in the blood
   (d) The player covered a total distance of 10500m
3. A match analysis on a player showed game time of 5 minutes; an average work period of 10-second maximal exercise; and a work-rest ratio of 1:3. This would indicate that:
   (a) Lactate would quickly accumulate in the blood
   (b) CP stores would fully replenish following each work bout
   (c) Aerobic glycolysis is dominant
   (d) Exercise intensity could be maintained
4. Which of the following activities would rely predominantly on muscular power?
   (a) Tug-of-war
   (b) Discus throw
   (c) One-arm push-up
   (d) Chin up
5. Which two components of fitness are most required by a 100m sprinter?
   (a) Muscular power and flexibility
   (b) Flexibility and agility
   (c) Muscular strength and flexibility
   (d) Muscular speed and agility
6. The most obvious distinction between power and strength is that:
   (a) Power involves speed, strength does not
   (b) Only power involves 100% effort
   (c) FT fibres are preferentially recruited for strength, but not for speed
   (d) Power is more dependent upon muscle size
7. Which of the following fitness tests would be suitable for a 100m sprinter?
   (a) Vertical jump
   (b) 40m sprint
   (c) Illinois agility run
   (d) Multi-stage 20m shuttle test (beep test)

8. To improve an athlete's muscular power, a coach would use which of the following methods:
   (a) Plyometric training
   (b) Continuous training
   (c) Long interval training
   (d) PNF training
9. The table below shows two training programs (X & Y); Refer to this table to answer the next four questions:

Program	Frequency	Intensity	Time	Type
X	3 × week	60% Max. HR	30 mins	Walking
Y	4 × week	70% Max. HR	30 mins	Walking interspersed with jogging

   The above training programs (X &Y) can be best described as:
   (a) Fartlek training
   (b) Low intensity continuous training
   (c) Long interval training
   (d) Threshold training
10. After 4 weeks of training, the person moves from program X to program Y. As they change programs, the following occurs:
   (a) Frequency increases to improve anaerobic power
   (b) Exercise type changes to improve anaerobic performance
   (c) Time remains constant to improve aerobic endurance
   (d) Intensity has been increased to improve aerobic endurance
11. Assume the person training is 40 years of age. In program Y, the prescribed HR they should be working at would be:
   (a) 180bpm
   (b) 220bpm
   (c) 126bpm
   (d) 108bpm
12. The concentration of lactate in the blood during program X would most likely be:
   (a) Low (<3mmol/L)
   (b) Zero (0mmol/L)
   (c) At 'lactic acid tolerance' training levels (>10mmol/L)
   (d) At 'threshold' training levels (4-5mmol/L)
13. The advantages of circuit training over other forms of training include:
   (a) A wider range of fitness factors can be developed
   (b) There is no need for equipment
   (c) All athletes will complete the same amount of work
   (d) All of the above
14. Breaking a training year up into 'phases' to focus on different physical training demands is referred to as:
   (a) Periodisation
   (b) Peaking
   (c) Tapering
   (d) Microcycles

15. When designing a resistance-training program to improve strength, it should involve:
    (a) Heavy loads and high repetitions in each set
    (b) Light loads and high repetitions in each set
    (c) Heavy loads and low repetitions in each set
    (d) Moderate loads and high repetitions in each set
16. The best method of flexibility training to improve range of motion at a joint is:
    (a) Active range of motion
    (b) Static
    (c) PNF
    (d) Ballistic
17. A subject has been pedaling on a stationary cycle at 60% of their VO_2 max for 60 minutes. If the subject continued to exercise at the same intensity for a further 30 minutes, the energy supply would come preferentially from fats rather than carbohydrates because:
    (a) More ATP is formed per molecule of fat
    (b) Blood lactate would begin to accumulate
    (c) Glycogen stores would be in limited supply
    (d) There would be large reserves of protein in the body to supply ATP
18. An athlete is using the following sprint program:

Reps	Distance	Intensity	Time	Rest Period
10	50m	100%	6 seconds	90 seconds

    The dominant energy supply used to complete the first repetition would have been:
    (a) Aerobic
    (b) Lactic acid
    (c) ATP-CP
    (d) Lactacid-aerobic
19. Refer to the previous sprint program table (Question 18.) to answer this question. The dominant energy supply used to complete the 10th repetition would have been:
    (a) Aerobic
    (b) Lactic acid
    (c) ATP-CP
    (d) Lactacid-aerobic

Short Answer Questions

1. Refer to the table below outlining data collected during an elite badminton singles game to answer the following questions:

Facts related to game play at the elite level in **BADMINTON**	
Shuttlecock smashed at speeds of up to 280kph	150 of all rallies played involved full arm swings at maximum force
Games averaged 350+ changes in direction of 90 degrees	Games averaged 146 rallies with some 13.5 shots per rally
Games averaged 1 hour and 16 minutes	56% of total game time was active (athletes were playing)
Average distance covered per rally was 6.7 metres	Players completed 5-10 shots in 20 seconds
Players covered up to 6.5km per game	

(a) From the data presented in the table, provide evidence why agility is needed in the game of badminton.

(b) Select two different fitness components required for the game of badminton at the elite level (do not use agility). Provide data from the table to justify your selection.

(i)

(ii)

(c) Define each fitness factor you have named in part b. above.

(i)

(ii)

(d) Briefly describe an appropriate method of assessing the fitness of the badminton player in each of the fitness components that you named in part b.

(i)

(ii)

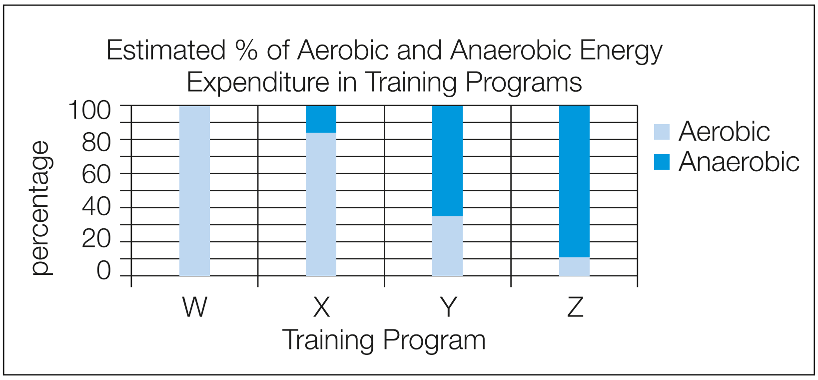
(e) With specific reference to information in the table, describe a situation during the game when each of the three energy systems would be dominant.

ATP-CP

Lactic Acid

Aerobic

2. The graph below compares the energy expenditure involved in four training programs – W, X, Y and Z.



(a) Indicate which training program (W, X, Y or Z) would best suit each of the following athlete's performance needs and briefly justify your selections:

(i) Elite Marathoner

(ii) Elite 100m Sprinter

(iii) A sedentary person undertaking a 12-week training program to complete the City-Bay 12km fun run.

(b) One training method that may be utilised extensively in program Z would be interval training.

(i) What are two benefits of interval training?

(ii) What are four variables that can be manipulated in an interval-training program?

(iii) Outline in point form one short-interval-training set you may expect to be used in program Z to use predominantly the ATP-CP system.

3. A group of four 4 × 100m sprinters want to run as a charity team in the 12km 'City- Bay Fun Run' 12 weeks after the 'track' season finishes.

Discuss the necessary changes in training they will have to be aware of with respect to the following training principles:

- Specificity
- Progressive overload
- Individuality

Focus Area 1: In Movement

1.3 How does biomechanics affect physical activity and movement

- Generating force
- Speed and motion in sport
- Achieving distance
- Achieving and maintaining equilibrium

Biomechanics

Biomechanics addresses the study of living organisms and factors that act on these bodies. In a sporting context, biomechanics often refers to the study and analysis of sporting techniques. The knowledge gained from such analysis is then used to improve sporting performance.

Example: The cyclist (Figure 1.3.1) whilst pedalling, experiences a force termed '*air resistance*' which acts against the forward motion of the rider and bicycle. The faster the bicycle and rider '*push*' through the air in front of them, the greater is their velocity and the greater is the air resistance. Testing the flow of air around and over riders in a wind tunnel, allows modifications to be made to the design of equipment (helmets) and posture on the bike to minimise the forces acting on the cyclist.

Figure 1.3.1 Wind tunnels can be used to improve aerodynamics whilst cycling.

Studying the various techniques used in sports like volleyball is another aspect of biomechanics. This might involve the use of video footage being analysed using specialised computer programmes or simply through observation. The aim again though is about improving performance. In this example, it would be through changing the technique of the spiker or blockers to maximise performance.

Figure 1.3.2 Spike during a volleyball game.

Generating Force

Sports in general involve movement or motion. A ball being kicked or hit around an oval is one example of movement, yet it can also be the movement of our own limbs or body as in the sport 'running'. Motion is to do with movement. So, if using the sport of golf as an example, for the ball to experience movement, certain factors must be present.

1. The golf ball must change position both in space and time.
2. A **FORCE** of some description must be applied to the ball.

In Figure 1.3.3 it is evident that the golf ball had changed position both in space (moved 100m) and time (travelled for 1.5 seconds).

The impact of the club head on the ball has applied a force. Therefore, both factors for motion have been achieved, so we can say the ball has moved or was in motion.

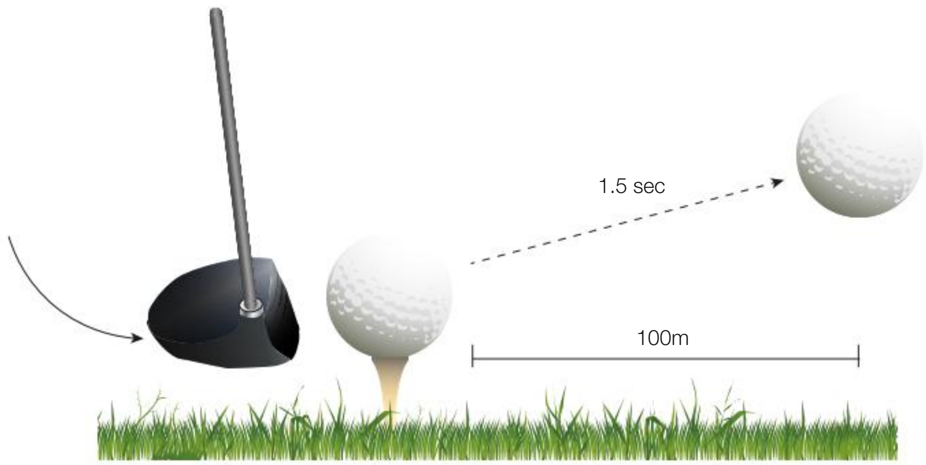


Figure 1.3.3 Moving golf ball due to force being applied to the ball.

Balanced and Unbalanced Forces

Before the golf ball can 'move' off the tee (Figure 1.3.3), the force applied to the ball needs to be an **unbalanced** force.

The ball in Figure 1.3.4 Is at rest or stationary on the tee prior to being hit because it is balanced. Although the **FORCE of GRAVITY** is pulling down on the ball (Figure 1.3.4) the tee is pushing up on the ball with the same amount of force, but in the opposite direction. The net result is the two forces are **BALANCED** (or they cancel each other out).

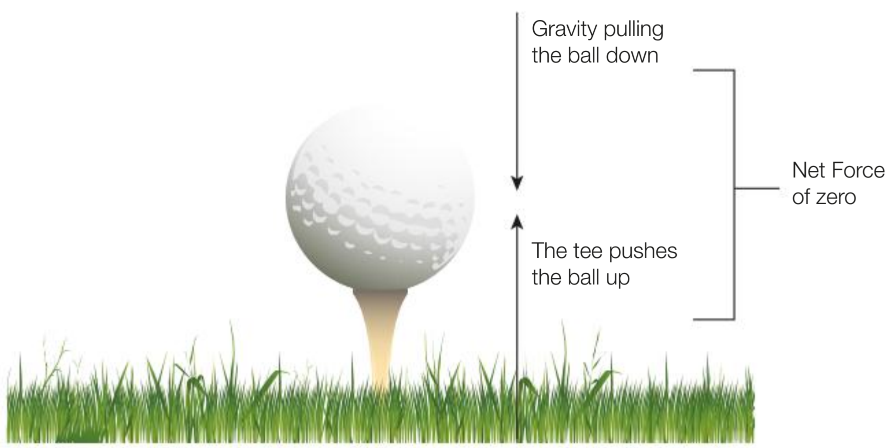


Figure 1.3.4: Forces acting on a stationary object.

However, if a golf club now applies a force to the golf ball (Figure 1.3.5), there is no equal force to cancel it out (or push back on the ball). As the force of the impacting club head is not balanced by another force, the impact is an **UNBALANCED** force. This means the ball's velocity will no longer be zero and it will change position both in space and time – the ball will be moving.

Figure 1.3.5: An unbalanced force acting on a ball.

Figure 1.3.6 The volleyball being spiked is an example of an unbalanced force acting on an object.

Sports that involve movement or motion are therefore all exhibiting examples of unbalanced forces. The volleyball moves quickly over the net after a spike for example, due to an **UNBALANCED** force. The motion of two women jumping up off the ground to block is another example of **UNBALANCED** forces at play.

A lot of the biomechanics of motion are explained by Newton's laws of motion. Sir Isaac Newton was a 17th century physicist and mathematician who among other things, devised three laws to explain motion. This section will look at how Newton's three laws explain the movement and behaviour of a golf ball. The aim is that you can then use these examples to apply the principles to a sport of your choice.

Newton’s 1st Law

‘Once in motion an object will want to stay in motion unless acted on by an unbalanced force. An object at rest will want to remain at rest unless acted on by an unbalanced force.’

Figure 1.3.7 Sir Isaac Newton.

In our golfing example, this means that the stationary ball on the tee (Figure 1.3.4) will remain at rest (or stay on the tee) unless acted on by an unbalanced force (being struck by the club head in Figure 1.3.3). Once struck by the club head, the ball will move off the tee in the direction of the applied force and in theory would stay in motion (in the air) until the ball is actually acted on by an unbalanced force. There are two unbalanced forces that slow the ball down until it eventually comes to rest on the ground. The two unbalanced forces that act on the ball are friction with the air (**air resistance**) and **gravity**.

Newton’s 1st Law is really about a concept called ‘**INERTIA’**. Inertia is the ‘resistance’ of an object to any attempt to change its state of motion. The more **MASS** an object has (or the more **‘MASSIVE’** it is) the more resistance it has to changes in its motion.

Figure 1.3.8: The mass (inertia) of an object determines the object’s resistance to any attempt to changes in its motion.

In the Figure 1.3.8 example, three balls have all been designed so they are the same size and shape. However, they all have a different mass. So if everything else remains constant (or stays the same), applying the same unbalanced force to the balls will result in different changes to their state of motion due to their different mass. The greatest resistance to a change in motion or inertia will be with the ball with the greatest **MASS**. In Figure 1.3.8 this will be the metal ball at 500g, compared to the much lighter table tennis ball. At only 2.7 grams, the table tennis ball has very little inertia or resistance to a change in motion. This means that you wouldn’t have to apply much force to the table tennis ball to move it off the tee. For example, a small gust of wind would blow the table tennis ball off the tee, but not the metal ball.

Figure 1.3.9: Medicine ball.

Extension activity

1. (a) Try throwing a medicine ball and basketball (same size) and record which travels further if using the same technique (assuming the same force is applied).

   (b) Discuss how much force was required to throw the two balls both a distance of 5 metres.

2. Remember the two balls are initially at rest (zero motion) and you are trying to change that motion from zero to something greater. So which ball has a greater resistance to change?

Focus Questions

1. In sumo wrestling, the aim is to push your opponent over or outside the wrestling area (straw ring). Using the concept of inertia, explain why a wrestler of greater mass has an advantage over one who is less massive in this sport (assuming similar skill and technique).

2. Once thrown, a javelin should remain in motion unless acted on by an unbalanced force. Identify one unbalanced force that will slow the javelin down once released.

3. In contact football codes (AFL, NFL), concussion injuries are making headlines in the media, as many past players are now having health issues related to the brain. In this image, player 27 is about to fall onto his back and hit his head on the ground. Explain, with reference to inertia why this type of fall can result in bruising the brain (concussion).

4. With reference to Newton's 1st law of motion, explain why it's very important for the race driver's health to wear a seat belt harness when they hit a solid object like this tyre barrier.

Law of conservation of angular momentum

In general, the inertia of an object is related to how big (large or great) the objects mass is, **BUT** what if the object is rotating?

An object that is rotating must be rotating about an axis, and the distance the object's mass is from this axis point is very important. This is referred to as the 'rotational inertia' of an object and it is dependent on the mass of the object, **PLUS** the distance this mass is from the axis (called the radius of rotation). The further the mass is from the axis, the greater the rotational inertia.

Throwing the Hammer (Figure 1.3.10), in this example (A) represents the radius of rotation (or distance of mass from axis) and (B) represents the mass of the object.

The longer (A), or the radius of rotation is, the greater the resistance to movement. This means slower rotation.

Figure 1.3.10: Man in the process of throwing Hammer.

In a science class, you may have experience 'rotational inertia' with the spinning chair experiment. This is a simple way to experience this concept. In Figure 1.3.11, moving the arms in and out changes the rotational inertia of the body. With the arms out in the first picture, some of the bodies mass now moves away from the axis of rotation (dotted line). This increases the bodies rotational inertia.

ANGULAR MOMENTUM is the product of an object's **ROTATIONAL INERTIA** and its **ANGULAR VELOCITY** (how fast it's spinning). **The LAW OF CONSERVATION OF ANGULAR MOMENTUM** states that 'the angular momentum of a system remains constant unless the system is acted upon by an external torque (force)'.

Angular Momentum = Rotational inertia × Angular velocity

So, in our spinning chair example (Figure 1.3.11) if angular momentum is constant, then the rate at which you spin (angular velocity) will depend on your rotational inertia. The lower the rotational inertia ('arms in'), the quicker the rate of spin.

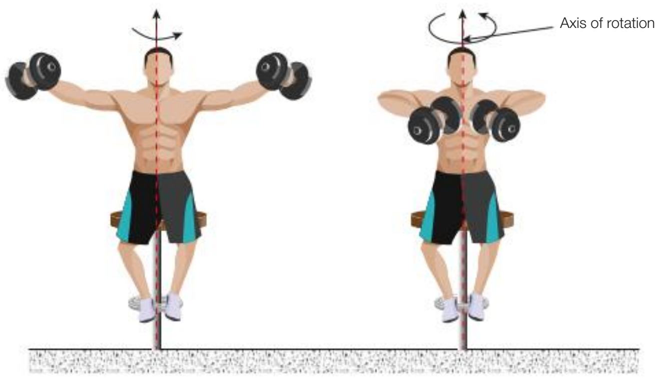


Figure 1.3.11: Rotational inertia demonstration on a 'frictionless' chair.

Rotational inertia	**High** (5 units)	**Low** (2 units)
Angular velocity (**rate of spinning**)	**Slow** (2 units)	**Fast** (5 units)
Angular momentum	10 units	10 units

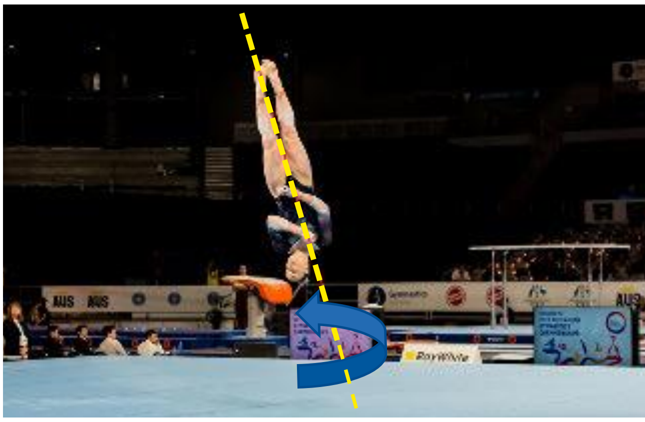


Figure 1.3.12: Low rotational Inertia.

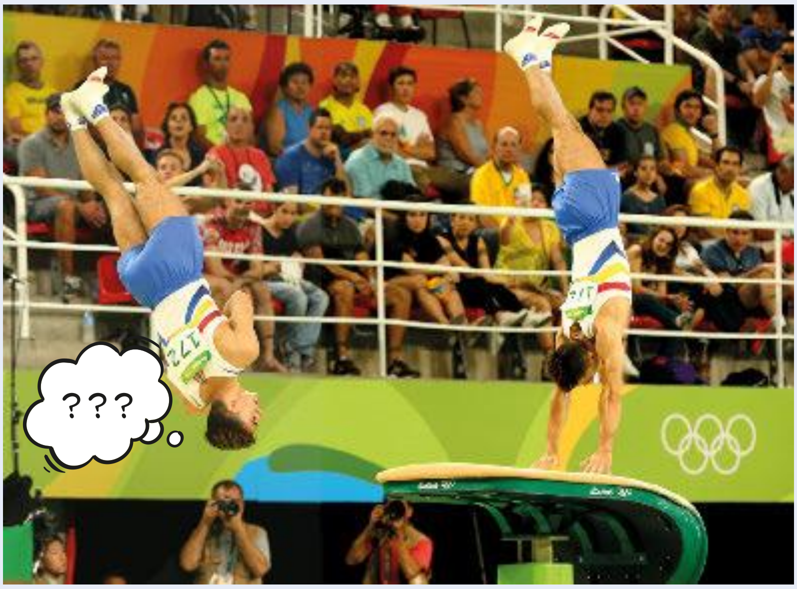
Figure 1.3.13 :High rotational inertia.

Gymnastics, diving and ice skating are all sports that you can readily see the law of conservation of angular momentum in action. In Figure 1.3.12 the gymnast has brought her arms in close to her chest as she spins. The axis of rotation is represented by the dotted line. Most of the gymnast's body mass is very close to the axis or rotation, so the rotational inertia is low and she spins or rotates quicker. In sports such as diving or gymnastics, where you haven't got a lot of time to complete a spin, the faster you can do the spin, the safer and more likely you are to successfully land the movement.

Figure 1.3.13 depicts a gymnast with much greater rotational inertia than the previous example. This is because the axis of rotation in this example is the bar on which the gymnast is swinging. So much of the body weight (mass) is now away from the axis of rotation, so there is an increase in the rotational inertia. With an increase in the rotational inertia, the angular velocity (rate of spin) of the gymnast slows down.

Focus Questions

5. In the image below, the gymnast is beginning to realise that he might not make the flip in time. Explain using the law of conservation of angular momentum what the gymnast needs to do in order to land safely on his feet.



Newton's 2nd Law

The second law of motion relates to the motion of an object when the **UNBALANCED** force causes a change in the velocity of the object. In the golf ball example earlier, how quickly or slowly the golf ball's **VELOCITY** changes is called it's **acceleration**.

VELOCITY is the speed of an object in a set direction. For example, zero velocity is when the golf ball is stationary on the tee. It isn't moving so the speed (velocity) is zero. However, when struck by an **unbalanced force** (the golf club) the ball moves. The speed of the motion and the direction of the motion can be recorded. So, a golf ball travelling at a speed of 5 ms^{-1} in an easterly direction is an example of a velocity.

In our golf ball example used previously, the acceleration of the ball is directly proportional to the force applied to it. This means (if everything else is constant) the more force you hit the ball with the faster it will accelerate. In a practical sense, greater acceleration means the further and quicker it will travel from the tee (Figure 1.3.14).

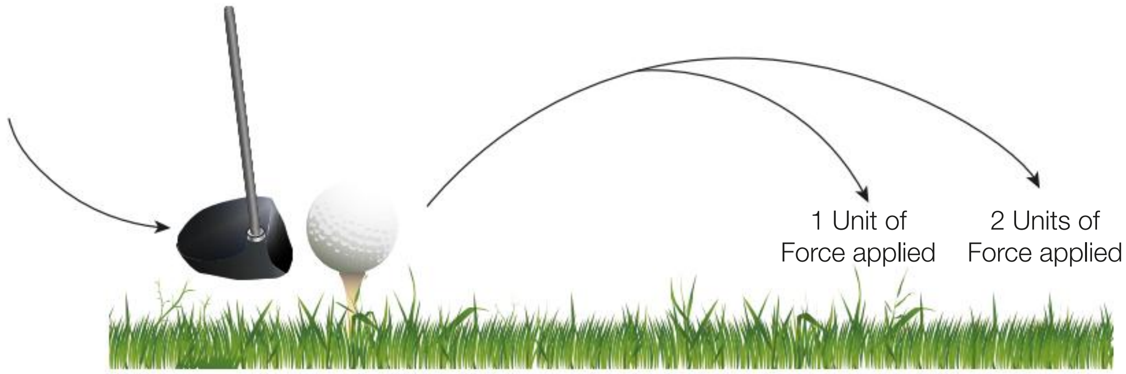


Figure 1.3.14 The acceleration of the golf ball is directly proportional to the force applied to it.

Newton's 2nd law also states the acceleration of an object is inversely proportional to the mass of the object. This means if you keep everything else the same, but just change the mass of the golf ball, then it's acceleration off the tee will be affected.

A heavier ball would accelerate less than a lighter golf ball (if struck with the same force). As an equation, Newton's 2nd law is often referred to as

F = m × a (or **F = ma)**

F = the force applied

m = the mass of the object

a = the acceleration

As the mass of the ball in many sports is fixed or regulated by a governing body, it's really just the F (force) and a (acceleration) that an athlete tries to change to improve performance.

In the golf ball example, the ball is approximately 45 grams, so assuming the 'm' in F = ma remains constant, the more force you generate in the club head at impact, the greater the acceleration of the ball will be.

However, in some sports you can manipulate the 'mass' part of the equation to improve performance.

In some forms of motor sport, the engine size is often regulated (set) so the 'F' (force applied) is constant (in theory). Race teams though can still manipulate Newton's equation (F = ma) to increase acceleration, by removing excess mass to lower / reduce the car's overall mass. This is because the acceleration of an object is inversely proportional to the mass of the object. So, if you make an object less massive, it will now have a greater acceleration if the force remains constant.

Figure 1.3.15 The interior of a Porsche racing car with only essential instruments and hardware to reduce the car's mass.

Newton's 3rd Law

Newton's 3rd law of motion also relates to hitting objects like in our golf ball example earlier. At impact, the club applies a force to the ball, the ball is pushing back with an 'equal and opposite' force.

This is because Newtons 3rd law states:

'that for every action there is an equal and opposite reaction'

This means that the size of the force acting on the first object equals the size of the force acting on the second object. So using our golf ball example, the ball exerts a force back on the club head of equal magnitude, just in the opposite direction.

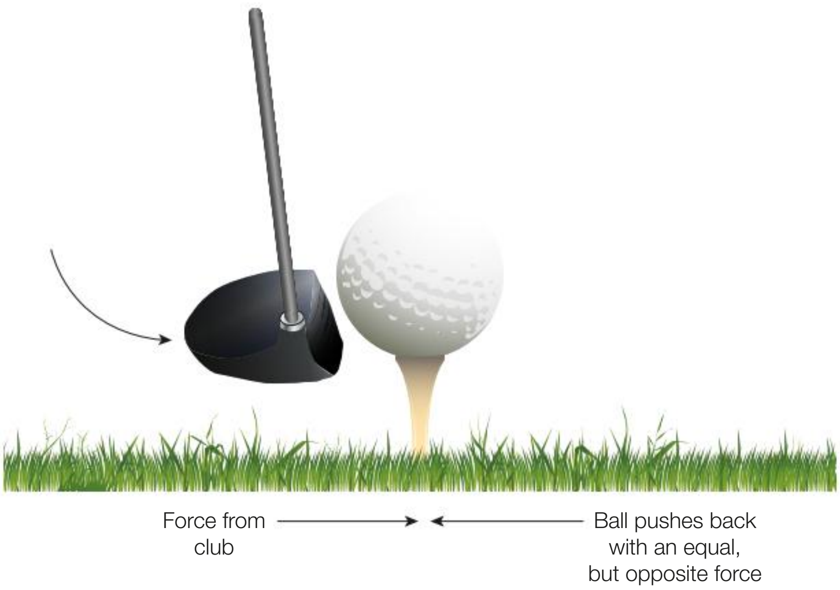


Figure 1.3.16: At impact, the club applies a force to the ball. The ball applies an equal but opposite force back.

With Newton's 3rd law, it is useful to identify the **action – reaction** force pairs when looking at athletic movements. For example, when the athlete in Figure 1.3.17 forcefully pushes against the ground, the ground exerts an equal & opposite force back on the athlete. The action- reaction force pair is the runner (foot) and the ground.

Figure 1.3.17

Focus Questions

6. If the canoeist pulls the paddle through the water with more force, explain with reference to Newton's 3rd law of motion what will happen to the forward motion of the canoe?.

7. With reference to Newton's 3rd law of motion, explain the action and reaction (opposite) forces occurring in the sprint start.

When a golf club impacts a golf ball. Both the club and the ball experience a force for a period of time. This is called an **Impulse**. The result of this impulse is a **change in momentum**, as an object's mass has either slowed down or sped up (change in velocity) when impacted. Essentially, an **unbalanced force** has **accelerated** an object. In this example the ball will speed up and the club will slow down.

Figure 1.3.18

Impulse refers to a change in momentum, so **impulse = change in momentum**.

Momentum can be transferred from one moving object to another. In our golf example, some of the momentum of the club head is transferred to the golf ball. This transfer of momentum is explained using the **Law of Conservation of Momentum**.

This law states that 'the total momentum after contact must be equal to the total momentum before contact.'

This means in our example: the golf ball gains momentum because the club head 'pushes' on the ball while the club head loses momentum due to the ball pushing back. The mass of the club and ball determine exactly how much momentum is transferred.

CHANGE IN MOMENTUM = mass of club (or golf ball) × change in velocity of club (or golf ball)

For example,

- If the golf ball has a mass of 40 grams and a change in velocity of 100ms^{-1}, then it has a

change in momentum of **+4kg ms^{-1}** (= 0.04kg × 100 ms^{-1}).

- While a golf club with a mass of 320 grams and a change in velocity of –12.5 ms^{-1} (decelerating) will have a change in momentum of **–4kg ms^{-1}** (= 0.32kg × -12.5 ms^{-1}).

The ball **GAINS** momentum and the club **LOSES** momentum. For more details on how the change in velocity values were calculated, please see Appendix.

Sequential Force

The force you generate when you serve a volleyball, for example, can be maximised if the contraction of muscles and the movement of body parts is in sequential order. This generally requires the larger, stronger muscle groups to move first. There is then a sequential acceleration of body parts as the lighter, but faster muscle groups in the extremities contract last (shoulder, arm, hand, then fingers). The result of this sequential movement or acceleration is 'force summation'. This means the forces generated by all the previous muscle groups are 'added' to the next. The force from the hip rotation for example is added to the force from the shoulder rotation, which is added to the force from the arm and then the hands etc.

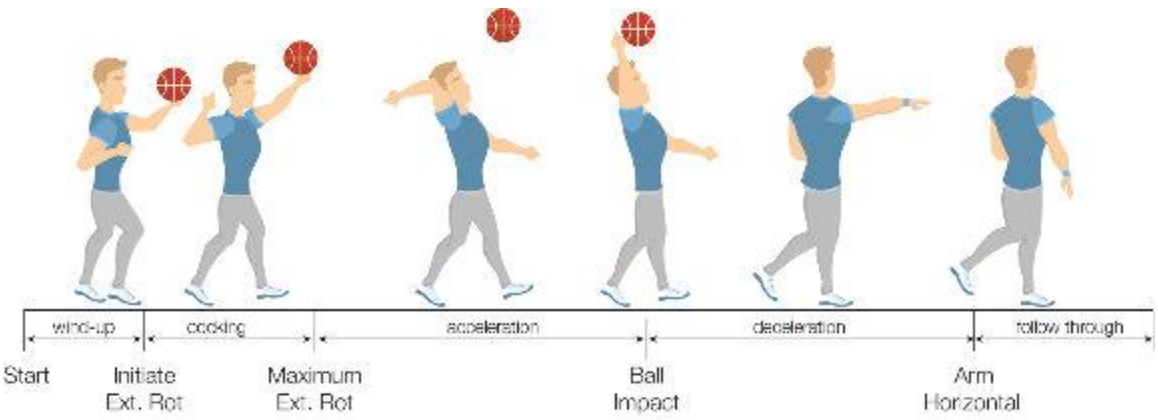


Figure 1.3.19: Sequential movements of a volleyball serve

Key points

1. To maximise the summation of forces, the 'next' body part or muscle group must begin when the previous one has reached their maximum output. Failure to do this results in less force, as there is 'less force' to add onto. Figure 1.3.20 demonstrates this concept with a soccer kick. In this example the right-hand side of the figure shows force generated in previous movements being 'added' onto at the highest possible level of generated force. The result is a final force greater than on the left.

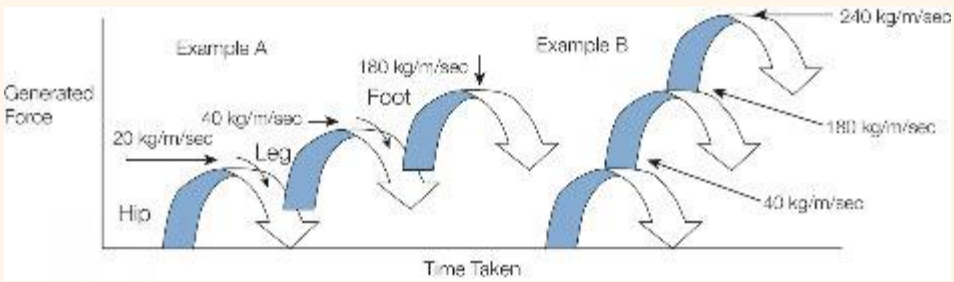


Figure 1.3.20: Force generated through the summation of forces when kicking a soccer ball.

2. Stability – To obtain maximum force, there needs to be stabilisation of some body parts so others can move. In the baseball pitch example (Figure 1.3.21) you can see the left leg is 'fixed' or providing stability for the pitcher. This allows the right hip and leg to rotate through in the initial stages of force summation.

Figure 1.3.21: The baseball pitcher stabilises on his left leg as the right leg and hip rotate through.

3. Larger muscle groups move first. Then a sequential acceleration of body parts as the lighter but faster muscle groups in the extremities contract.

Anthropometry

Anthropometry is the study of the measurements and proportions of the human body.

'The athlete's anthropometric dimensions, reflecting body shape, proportionality and composition are variables which play some (sometimes a major) role in determining the potential for success in a chosen sport' (Norton et al 1996, p289).

At the elite level, there are noticeable individual differences in anthropometric and physiological characteristics between sports. The physical make-up or structure of an athlete, especially height and limb length, have a definite advantage in many sports (Binthu Mathavan 2012).

In a sport like diving (Figure 1.3.22), faster angular velocities (ability to spin quicker) are an advantage. It allows divers to perform more spins in the same period of time, or finish a spin in time to successfully enter the water. Both factors result in a better performance and, consequently, higher points awarded.

If the divers are smaller and have smaller limbs, then they will have a reduced rotational inertia. Described earlier in this chapter during the **law of conservation of angular momentum**, a reduced rotational inertia means an increased angular velocity (faster spin or rotation).

Figure 1.3.22: Synchronized diving.

Figure 1.3.22 shows the two divers in a 'pike' position as the legs are straight during the turn. If the divers were taller than the two ladies in the photo, then the rotational inertia would be higher due to longer legs. This would mean they would take longer to spin completely around the rotational axis. Depending on how much time they have to complete the dive, this slower angular velocity could mean they aren't lined up correctly for the entry into the water. This would create a greater splash and reduce their entry score.

If the sport doesn't require spins or somersaults, then height and longer limbs can actually be advantageous. In the sport of rowing, longer limbs give a mechanical advantage by allowing a greater stroke length (provided they have the muscular strength to suit). A greater stroke length means the blade remains in the water for longer. This is important as it means the force generated by the rower is applied to the water over a greater period of time (this increases the **'impulse'**). Essentially, you're able to push more water back with each stroke. Then, thanks to Newton's 3rd law of motion, we know this will result in a larger reaction force. The water will push back on the boat in the opposite direction (propelling the boat towards the finish line quicker).

Figure 1.3.23: Rowers with longer limbs have the potential to generate a longer stroke length.

In addition, a smaller torso (upper body) when rowing would reduce air resistance as less surface area is trying to 'push' through the air. A shorter torso would also mean a lower centre of gravity, so stability would be increased.

Figure 1.3.24: Waterpolo.

Larger limbs (arms) in a sport like waterpolo allow for greater reach to stop or catch the ball.

Speed and motion in sport

Motion

As outlined earlier in the **'GENERATING FORCE'** section, movement or motion, in a biomechanical sense, involve two things:

1. A force being applied
2. A change in position, both in space and time

The shuttle in this badminton example is moving or in motion. This is because it changes location (position) when struck by the racquet (force applied) and that change in location takes time to occur.

Figure 1.3.25: Once struck (force applied), the badminton shuttle moves or is in motion.

Motion, or the state of motion of an object is defined by its velocity. Using the above badminton example, velocity is the speed of the shuttle with a direction.

- Zero velocity and the shuttle is at rest (no motion)
- 5ms^{-1} North and the shuttle is moving at a speed of 5ms^{-1} in a northerly direction.

Types of Motion

The different types of motion include:

- Translatory motion (linear motion)

  All parts in a body travel over the same distance at the same time.
- Rotary or Angular motion

  Movement around an axis of rotation.
- General or Combinational Motion

  Combination of two or more types of motion.

Speed vs velocity

The terms speed and velocity are often used interchangeably, yet they are different.

- Speed is measured by units of distance (usually metres) divided by time (usually seconds)
- Velocity is measured by displacement divided by time.

Velocity is essentially speed with a direction. Yet it's the rate at which an object (ie. shuttle) changes position. So it must finish at a different spot to where it started or there will be no change in position.

A race car that travels around a 4km track in 4 minutes **BUT** stops at the same spot they started has **zero** velocity.

The displacement = zero, thus velocity also = zero, as velocity is $= \frac{\text{Displacement}}{\text{Time}} = \frac{0}{\text{4 mins}} = \text{zero}$

However, the car does have an average speed (16.67 ms^{-1}), as speed is the total distance covered. NOT a change in position.

Figure 1.3.26: A race car starting and finishing at the same position has zero velocity.

Speed is a scalar quantity (just needs a number or magnitude to describe it) while velocity is a vector quantity, meaning you must also include a direction when you give the velocity of an object (magnitude + direction).

The 100m sprint (Figure 1.3.27) is a straight-line race. This means the finish line is not the same as the starting position. The runners are changing position and you can record the time it takes to change position (displacement).

$$\text{Velocity} = \frac{\text{Displacement (change in position in metres)}}{\text{Time taken (seconds)}}$$

$$\text{Velocity} = \frac{\text{100 m}}{\text{10 seconds}} = 10\ ms^{-1}\ \text{East}$$

Notice a DIRECTION has been added

$$\text{Speed} = \frac{\text{Distance travelled (in metres)}}{\text{Time taken (seconds)}}$$

$$\text{Speed} = \frac{\text{100 m}}{\text{10 seconds}} = 10\ ms^{-1}$$

Notice speed doesn't need a direction

Figure 1.3.27: The 100m sprint during the European Athletics Championships, Barcelona.

Focus Questions

8. In 2018 Kathleen Baker (pictured) broke the then world record in the 100m backstroke. She swam a time of 58.00 seconds. Calculate her average speed and velocity for the race.

Average Speed

Velocity

Momentum

An object that is in motion has momentum. So, in the netball example below (Figure 1.3.28), the ball and the moving players all have momentum. If using the ball as an example, we say that the ball has mass. So, momentum is better described as 'mass in motion'. This is a good description, as it contains the two factors that impact how much momentum an object has. That being MASS and VELOCITY.

The amount of momentum the netball in our example has will be dependant on two factors:

1. The mass of the netball
2. The velocity of the ball

Momentum (**p**) = Mass of object (**m**) × Velocity of object (**v**)

$$p = m \times v$$

If the netball has a mass of 400 grams or 0.4 kg, and the velocity of the ball is 20 ms^{-1} downward. Then the momentum of our netball is

$$p = 0.4\ kg \times 20\ ms^{-1}$$

The netball has a momentum of 8 kg ms^{-1} **Down**

NOTE – Momentum is a vector quantity also. That means we need a magnitude (an amount), **PLUS** a direction.

Figure 1.3.28: Shimona Nelson and Emily Mannix both have momentum as they move for the ball.

Momentum is directly proportional to both mass and velocity. This means if the mass of an object doubles (and velocity stays the same), then momentum would also double. If the velocity of an object doubles (and mass remains constant), momentum again would double.

Change in momentum

When two objects collide, they experience a **force** for a given period of **time**. In the rugby example (Figure 1.3.29), the defensive player has collided with the ball carrier as part of a tackle. The defender is trying to change (reduce) the runner's momentum when applying a tackle. The product of this **force** and **time** is the **IMPULSE**

$$\text{Impulse} = F \times t$$

Changing an object's momentum

The more momentum an object has, the more force you must apply to stop or reduce this momentum. Applying an unbalanced force changes the velocity of the object. To change momentum (i.e.. change its velocity) you need to apply this unbalanced force over a period of time.

The product of force and time as described earlier is **IMPULSE**. So, the magnitude of the impulse influences the magnitude of the change in momentum. For example, if the ball carrier in Figure 1.3.29 has 10 units of momentum, the defender would need 10 units of impulse to change that momentum to zero (stop the player).

With Impulse, the **Force** and **Time** components are inversely proportional to each other. So, if a tackling rugby player wants to maximise the force applied to the ball carrier, they must reduce the time period over which the force acts. In a practical sense this would mean not 'giving' when colliding with the ball carrier (falling backwards slightly). Rather, the defensive player becomes like a solid wall. This way the force acting on the ball carrier increases as the time period has decreased.

If the ball carrier has 10 units of momentum, then 10 units of impulse are needed to stop the player. If force is applied for 1 unit of time, then 10 units of force is applied to the oncoming player. Yet, look what happens in Table 1.3.1 when you increase the time over which the force was applied to the oncoming player.

Figure 1.3.29: Colliding rugby players.

Table 1.3.1: The impact on total force when changing the amount of time over which the force acts.

Impulse needed to stop players momentum	Force applied	Time period in which force acts
10 units	10 units	1 unit
10 units	5 units	2 units
10 units	1 unit	10 units

As can be see in Table 1.3.1, the force applied can be maximised if you reduce the time period over which the force acts. Conversely, if you want to reduce the force of a collision, you must try to increase the time period over which that force will act. Catching a cricket ball is a good example of this concept. To reduce the force of the ball colliding into your hands, you 'give' a little with the ball. This allows that force to be spread out over a longer period of time.

Boxing is another sport where this principle applies. The boxer on the left is 'riding' the punch (Figure 1.3.30). Meaning they are moving their head back with the punch. This means the force of the punch is being applied over a greater time period. Ultimately this reduces the actual force. For example, if the boxer can double the time period over which he is struck, then he halves the force acting on him. In Table 1.3.1. if you compare the force associated with 1 unit of time compared it to the force applied with the 2 units of time. You can see that the force applied is halved if you can double the time period over which it is applied.

Figure 1.3.30: 'Riding' with the punch.

Focus Questions

9. Explain with reference to time and force why using dynamic ropes that stretch when rockclimbing are safer than using static (non-stretch) if you fall of the rockface?

Inertia

The resistance to a change in the motion of an object is described as **INERTIA**. This concept was introduced earlier in 'generating force' and relates to Newton's 1st Law of motion.

'Once in motion an object will want to stay in motion unless acted on by an unbalanced force. An object at rest will want to remain at rest unless acted on by an unbalanced force.'

The more **MASS** an object has the greater the Inertia. This means the more massive players in the American football example below (Figure 1.3.31) are harder to stop once they are in motion, or they are harder to move or get around if they are standing in your way (blocking). The four or five players directly in front of the quarterback are usually those with the greater mass for this reason. Their large mass makes it harder for the opposition to push through the line and get to the quarterback before they can throw the ball.

Figure 1.3.31: Dallas Cowboys playing New York Giants in an NFL game.

Part of Newton's 1st law states that an object in motion will stay in motion unless acted on by an unbalanced force. We also know that an object with greater mass will have more inertia, so will be harder to slow down or stop. So, what exactly stops a ball or object. As with the momentum example earlier, an unbalanced force will stop an object's motion.

For example, the fastest badminton smash recorded during a competition was 426 km/h. If hit from one end of the court to the other you would have just over 0.1 second to react!

However, the shuttle doesn't have a lot of MASS. Therefore, the shuttle's resistance to a change in its motion isn't very high. As a result, the shuttle decelerates or slows very quickly.

What is slowing the shuttle down? Why doesn't it just keep moving forward like Newton's 1st Law of motion said?

Figure 1.3.32: The smash in Badminton can reach over 400 km/h.

The shuttle does follow Newton's 1st Law of motion, as in flight, the shuttle is acted on by unbalanced forces.

1. The force of gravity, 'pulling down' on the shuttle reduces its flight time by drawing it closer to the ground.
2. Air resistance created by the shuttle as it moves through the air. The drag force is opposite to the velocity direction of the shuttle, so this decreases it's velocity too. Air resistance is a special form of friction. Friction occurs when two solid objects move against each other, but in this case its an object and air molecules causing the friction. The front edge of the shuttle as it flies through the air is pushing through (or colliding with) air molecules. The **FASTER** the object moves, the **MORE** air resistance there is.

A soccer ball (Figure 1.3.33) being kicked will rise in the air, before falling to the ground, bouncing a few times and then come to rest (stop rolling).

As with the Badminton shuttle example, the unbalanced forces of Gravity and Air Resistance will act on the ball to slow it down. However, you can also add the Frictional forces now. As the ball rolls or slides over the grass, you have an opposing force to the balls forward motion.

Figure 1.3.33: Kicking a soccer ball.

Rotational Inertia

Inertia, as described previously, is directly related to its mass. However, if that mass is rotating then it's not so simple. Now you must also factor in the distance that mass is from the axis of rotation.

See the section earlier on Newton's 1st Law of motion that describes rotational inertia and the conservation of angular momentum in greater detail. Briefly though, the further the mass of a rotating body is from the axis of rotation (point at which it rotates around), the harder it is to start rotating. This is because the rotational inertia or resistance to change has increased.

One of the benefits of junior players using smaller cricket bats, is that it reduces the rotational inertia and makes it easier to swing.

A full-sized bat is more massive and longer, so the mass would be further from the child's hands (axis of rotation). The greater rotational inertia would mean the child would find it much harder to start swinging the full-sized bat.

Figure 1.3.34: Smaller bats make batting easier for children, as they have lower rotational inertia.

Extension activity

Securely tape a small mass to both ends of a 1m ruler. Square juice containers (pop-tops) work well, as they have a flat side to place on the ruler. You can also change the mass by adding or subtracting water from the bottle.

Hold the ruler in the exact middle and begin to turn the ruler back and forth. Then repeat the procedure with the mass closer to the axis of rotation (your hand)

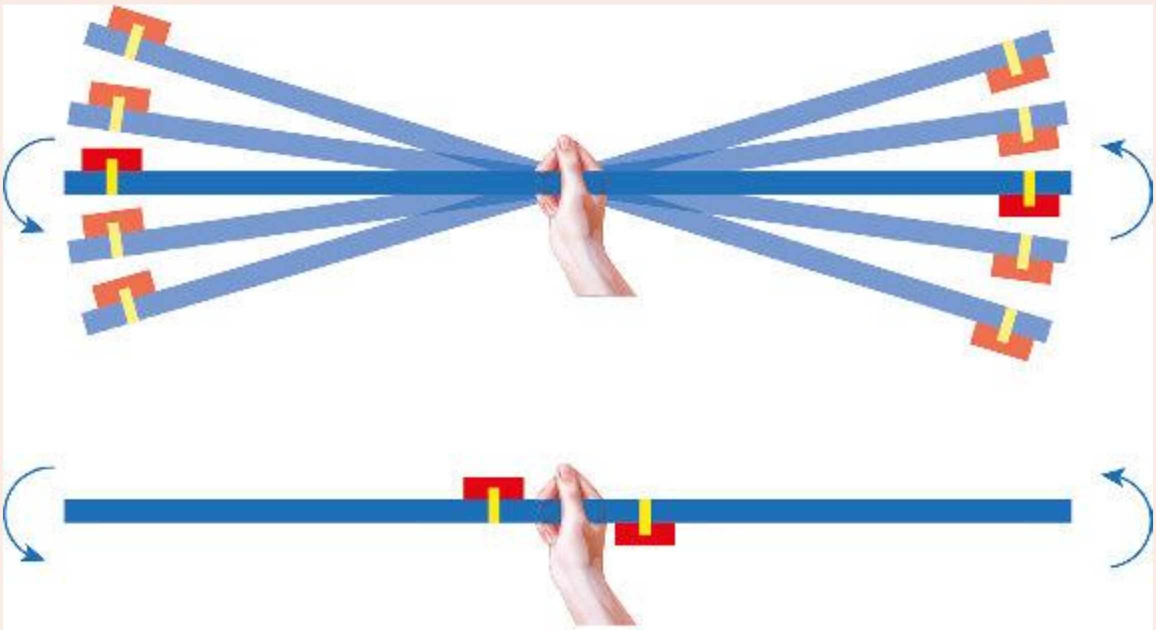


Figure 1.3.35: Rotational inertia demonstration.

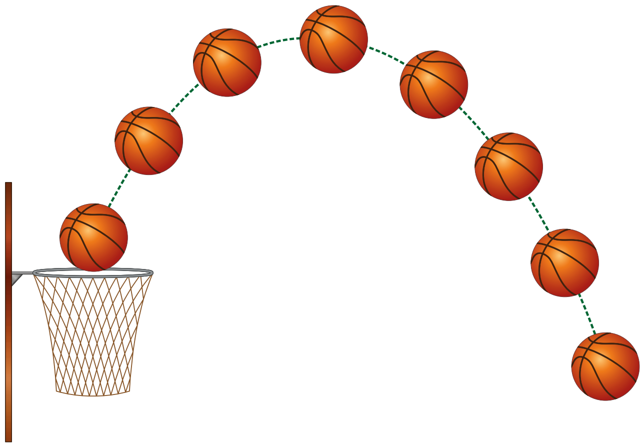
Describe what you felt in relation to which example was harder to start rotating. Then explain your findings with reference to rotational inertia.

Achieving Distance

This section will look at how to achieve more distance through leverage, angle of release, speed of release and height of release.

Any object that moves through the air after being released can be considered a projectile. This can be an object hit or thrown by humans or even people themselves becoming projectiles as they jump or dive, etc.

Once released, the projectile follows a predetermined parabolic path affected only by gravity and air resistance.



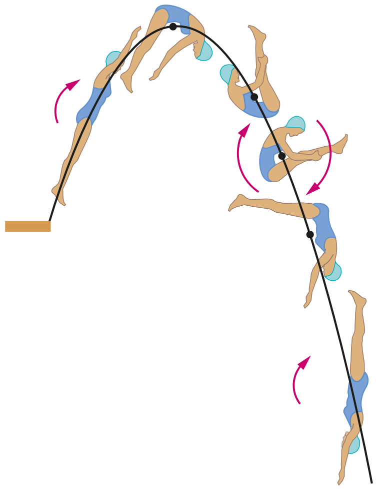


Figure 1.3.36 and 1.3.37: Projectiles follow a predetermined parabolic path.

Gravity

Gravity is a **FORCE** of attraction between two masses or objects. The greater the mass, the greater the attraction. For the purposes of this book, gravity is a force that pulls objects down towards the earth. So, for a projectile following a parabolic path, the force of gravity impacts on its acceleration. On the upward phase of the parabolic path the force of gravity is slowing (deceleration) an object until it reaches it's peak. Then as the object begins to fall its motion accelerates.

Ski jumpers appear to fly as they leave the ramp, often travelling in excess of 100m through the air. Yet, as soon as they leave the ramp, they become a projectile and the force of gravity acts to bring them down to the earth's surface

Figure 1.3.38: Ski jumper competing in the World Cup in Romania, 2019.

Air Resistance

When a projectile moves through the air, it does so by the front (leading) edge of the projectile 'pushing' its way through air molecules. This creates a form of friction as the air and projectile rub against each other. The DRAG FORCE is opposite to the velocity direction of the projectile, so it slows a projectile's velocity. The amount of air resistance a projectile encounters depends on a few factors:

- The speed of the projectile. The faster the projectile travels, the greater the air resistance will be.
- Mass of the projectile. The more massive the mass, the less impact air resistance has on the projectile.
- The cross-sectional area exposed to the air (or trying to push through the air). A more aerodynamic shaped projectile has less surface area trying to 'push' through the air.

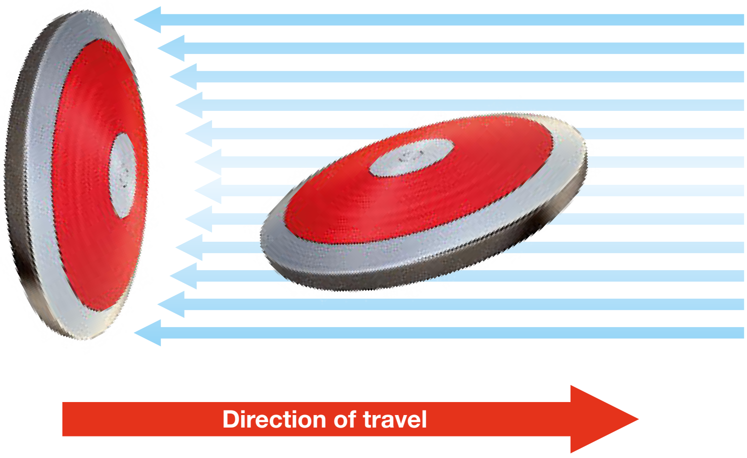


Figure 1.3.39: The cross-sectional area exposed to the oncoming air impacts on the amount of air resistance. The discus on the left has a greater surface area exposed to the air it's moving through, so is impacted by greater air resistance.

- Type of surface area. The rough surface layer of a tennis ball increases the air resistance compared to the smooth surface of a sofcrosse ball.

Lift

The distance a discus travels can also be influenced by lift forces during a throw. The shape of the discus enables air to move faster over the top of the discus than underneath it (provided the angle through the air is correct). Faster moving air has less pressure than slower moving air. Objects move from areas of high pressure to areas of low pressure. Therefore, this results in a 'lift' force, more time in the air and so more distance.

Faster moving air over the top creates ***'Low pressure'***.

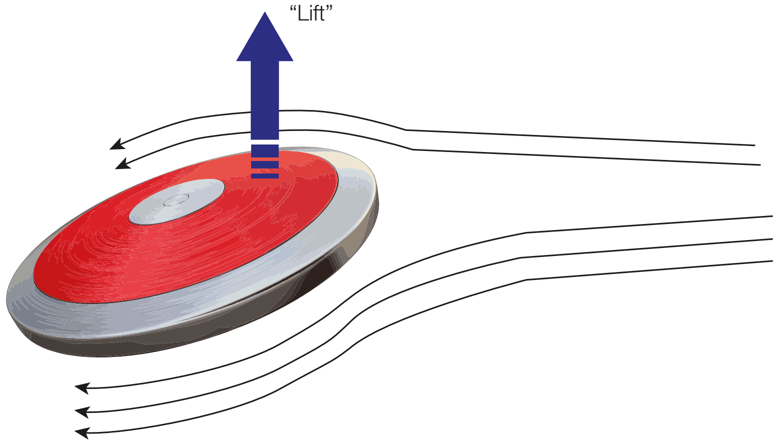


Figure 1.3.40: The discus 'lifts' as it moves from an area of high to low pressure.

Slower moving air flowing underneath creates ***'High pressure'***.

Spin on the projectile

A spinning ball actually has the air directly around it spinning also. This spinning air around the ball creates different air pressures levels. For example, in Table Tennis, if top spin is imparted on the ball, the pressure on the top of the ball will be higher than around the rest of the ball. This is because the top of the ball spins forward into the oncoming air, so the velocity of the air is slowed. At the bottom of the ball there is a higher velocity as the air is moving with the direction of travel. The higher velocity means lower air pressure. This means a lower pressure at the bottom compared to the top. Objects move from areas of high pressure to low pressure, so the net force is downward. A top spinning ball will therefore drop quicker and with a greater angle than a ball without spin. **Distance travelled is therefore less**.

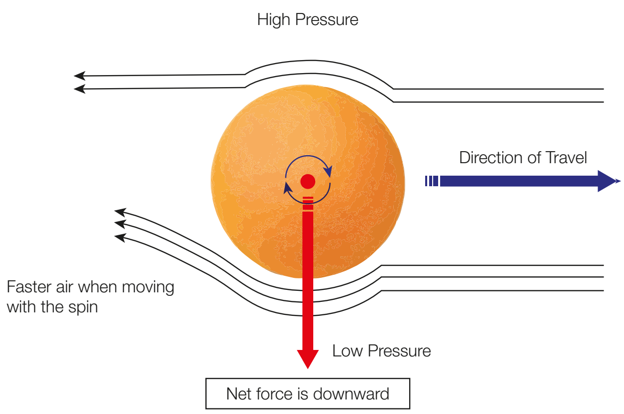


Figure 1.3.41 Top Spin

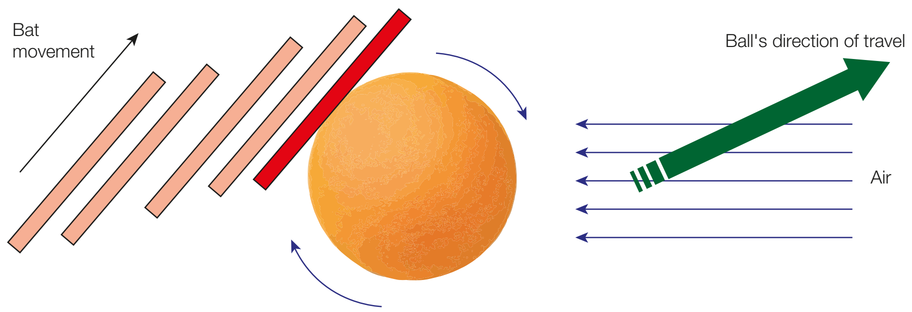


Figure 1.3.42: Simplistic view of the spin imparted on a ball with a topspin forehand in table tennis.

Figure 1.2.43: The player is setting up for a forehand topspin, where the paddle will brush up and over the top of the ball.

With **backspin** on the ball, the top of the ball is an area of lower pressure, so the ball lifts. The result is that it falls at a shallower angle than with topspin.

For more information about spin on a projectile and how it deviates the flight path, research the **MAGNUS EFFECT** or **FORCE**.

Helpful online resources

A video clip on the Magnus effect can be viewed here:

https://www.youtube.com/watch?v=23f1jvGUWJs

One of the best ways to increase the distance achieved by a projectile is to increase the force applied to the projectile at release. Newton's 2nd law states

FORCE = Mass × Acceleration

So, either increase the mass of the striking implement (i.e. baseball bat), increase the velocity of the striking implement or both to generate more force at the release of the projectile. These suggestions though are based on everything else remaining 'constant' in the scenario. Of these options, increasing the acceleration of the striking implement or throwing arm etc is probably the most likely to change. One method of doing this is by increasing the length of the lever (hitting implement, arm etc).

Leverage

Levers are 'simple machines' that make work possible or easier in most cases. Levers either increase speed or the force generated in a movement, depending on the length of the effort arm in relation to the resistance arm (see Figure 1.3.45). The human body's skeletal system creates numerous levers. The majority are 3rd class levers, where the effort arm is less than the resistance or load arm. Hence the human body is designed for increasing speed rather than force.

A lever consists of three basic components:

- Effort – some degree of effort needs to be applied to ensure movement. In the human body this effort comes from the contracting muscles attached to the skeletal frame via tendons.
- Load – load is the resistance that the effort attempts to overcome.
- Fulcrum – somewhere in the lever system there needs to be a pivot point about which the effort and load arm rotate. For example, the elbow or knee joints are pivot points in the human body.

Table 1.3.2: Alternative names for lever components.

Component	Alternative names
Effort	Force
Load	Resistance, Weight
Fulcrum	Axis, Pivot

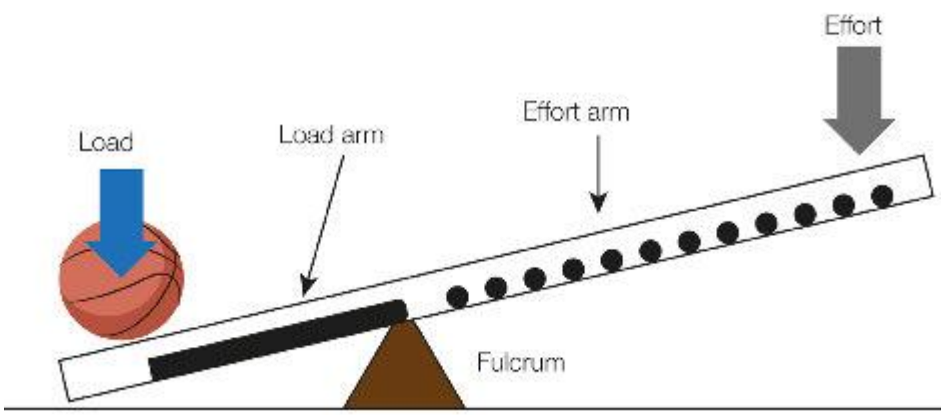


Figure 1.3.44: Simplistic view of a lever system.

The bicep's insertion point is on the upper end of the radius bone. This is where the contraction force of the bicep acts. Therefore, the lever responsible for the bicep curl would be a 3rd class lever, as the point of effort is in the middle of the lever (see Figure 1.3.45).

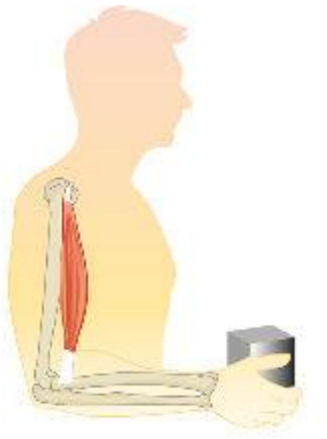


Figure 1.3.45: Example of a 3rd class lever in the arm (bicep curl).

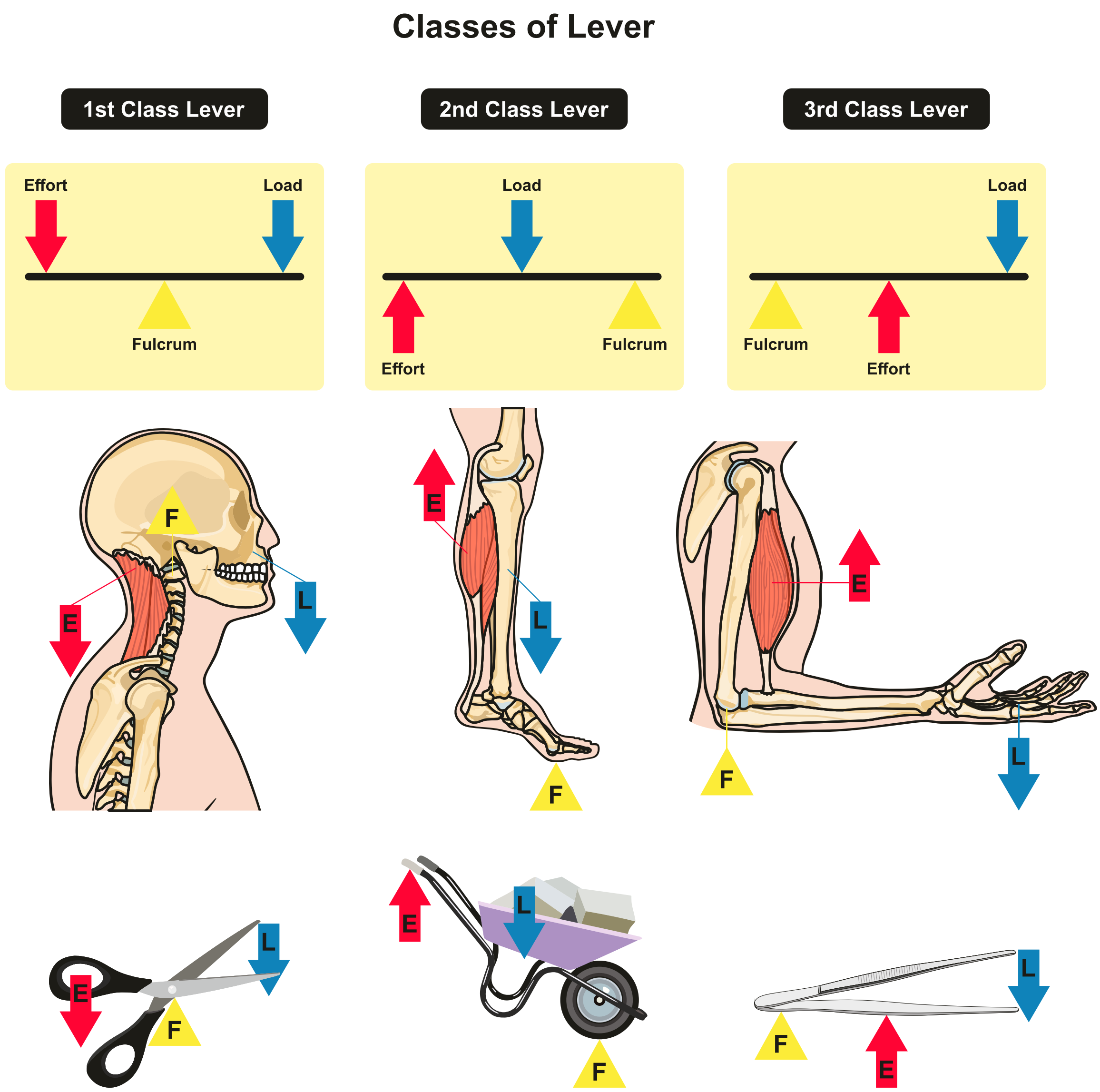


Figure 1.3.46: Examples of the three classes of levers operating in the human body and everyday life.

Third class levers are SPEED MULTIPLIERS which means greater speed can be generated. This is important in relation to the distance a projectile travels. Greater acceleration (if all else remains constant) means a greater force can be applied to the projectile on release.

Increased speed can be generated with a longer lever. In Figure 1.3.47, an increased lever length means more speed is generated at the point of impact, hence increasing the distance the ball travels. The speed comes from the greater distance the end of the lever must travel in the same time frame.

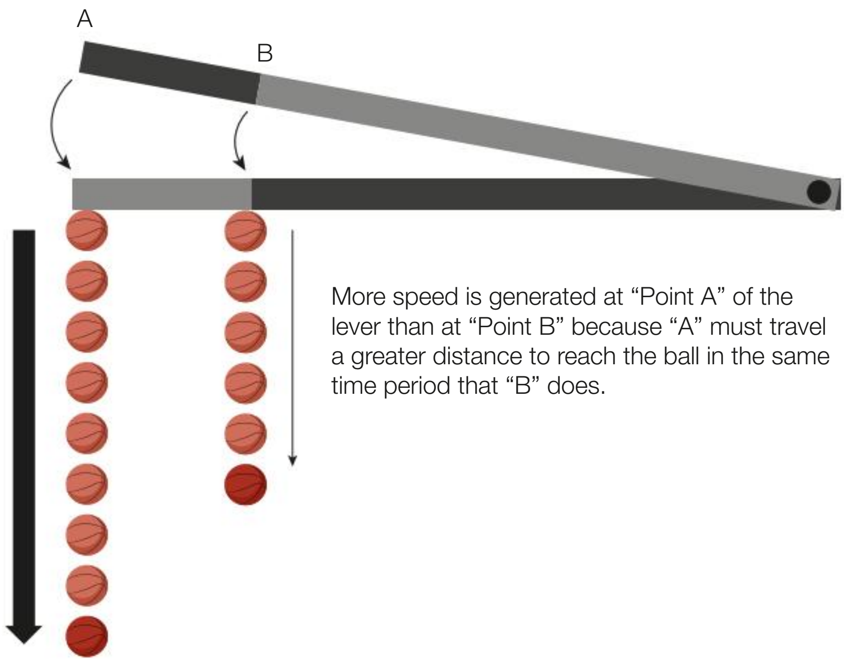


Figure 1.3.47: A longer lever generates more force.

Increasing the length of the lever to achieve greater racquet head speed at contact can be seen in Figure 1.3.48. The shuttle is contacted with a straight arm, maximising the length of the lever. The racquet head now travels a greater distance in the same amount of time compared to a shorter lever (bend arm or shorter racquet).

Figure 1.3.48 Badminton overhead clear.

Although in theory, a longer lever generates more speed at the end of the lever (more force on impact), in practice though hitting an object at the end of the lever often causes excess vibration and jarring. A ball striking the end of a bat or racquet will cause the implement to rotate backwards at the impact site and forwards at the end held by the hands. This can cause issues with the accuracy of the hit. The ideal spot to strike the ball or shuttle etc. is often referred to as the 'sweet spot'. This is the spot on the hitting implement that causes minimal backwards or forwards motion and is usually located slightly away from the end of the hitting implement.

Figure 1.3.49: The 'Sweet Spot' on a baseball bat is up from the base of the bat.
Source: Cross R 1998 The sweet spot of a baseball bat. American Journal of Physics, 66(9), 772-779.

On a wooden baseball bat, the 'sweet spot' represents an impact zone of approximately 3cm in size (Cross 1998) and is situated away from the tip (or end) of the bat.

Any increased length in a lever must be manageable and should not result in a loss of speed. Regulations within sports sometimes remove this option, as specific measurements are given for implements like bats and golf clubs.

Figure 1.3.50

Figure 1.3.51

The bat used in Figure 1.3.51 would in theory provide for a faster speed at impact, hence more force being applied to the ball and a longer distance achieved (if all else remains constant). The problem is the huge increase in mass would mean the batter would find it very difficult to actually swing the bat in time or fast enough to make contact. The rotational inertia would increase on a bat this long. So just starting the swing on this longer bat would be harder. Given a baseball batter only has approximately 0.4 seconds for a pitched ball (150km/h) to reach them (plus factoring in 0.2 seconds to respond), this is not likely to be a successful strategy.

One way around this is to maintain the hitting implement's current size but increase the mass slightly. More force can be applied to the ball through the greater mass of the implement. Again, speed should never be sacrificed to achieve this. Alternatively, a longer bat made of lighter material could be used, although the larger surface area combined with smaller mass, could have issues with increased air resistance.

Angle of Release

Changing the golf club used in a game of golf can increase the distance you hit the ball, as clubs are of different lengths. The two iron for example, is much longer than the nine iron, so if everything else remains the same, the two iron should hit a ball a greater distance.

However, along with a change in club length, also comes with a change in 'loft' or the angle on the club face. This then affects the **ANGLE OF RELEASE** on the golf ball. In Figure 1.3.52, the nine iron is on the far left, while the two iron is on the far right. The difference in the 'loft' or angle is evident.

Figure 1.3.52: The various angles of golf clubs.

The nine iron club is a much shorter club than the number two iron, so it has less club head speed at the point of contact with the ball. This means less force applied to the golf ball and so a reduced horizontal distance will occur. In addition, the greater loft (angle) the nine iron has on the club face means less horizontal distance, in favour of greater vertical distance than a two iron.

If all else remains constant, a change in the **ANGLE OF RELEASE** will affect the horizontal distance a projectile achieves. The optimum angle of release for an object starting and finishing at the same level is usually 45°. Assuming everything else has remained constant in Figure 1.3.53, the angle of 45° has resulted in the greatest horizontal distance. Increases or decreases of the same value either side of 45° result in the same horizontal distance.

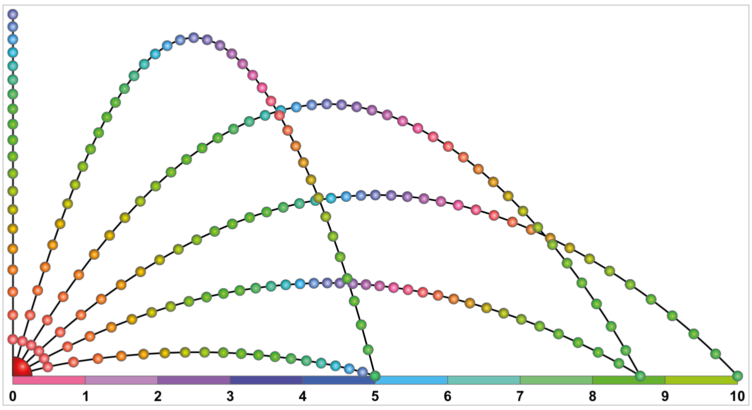


Figure 1.3.53: A projectiles angle of release and horizontal distance achieved.

In many sports though, the level at which the projectile starts, and finishes is often different. Basketball is an example where the finish location (basket) is above the height at which the ball is initially released. Therefore, the optimum angle is greater than 45°.

Figure 1.3.54: The optimum angle of release for basketball is greater than 45°.

Long jump starts and finishes at the same height, yet the optimum angle of release for a jumper off the board is not 45°. To achieve a 'take off' angle of 45° would mean the athlete needs to check or reduce their speed slightly when on the board. **SPEED OF RELEASE** though is another factor that influences the distance a projectile travels. A speed reduction at take-off would result in less distance. The optimum angle of release for an elite long jumper is in the 20's rather than the 45°.

Figure 1.3.55: Luis Felipe Méliz of Spain competing in the Long jump at the Spanish Indoor Championships.

Speed of Release

The faster an object is released, the further the projectile will travel (provided everything else remains constant). So, with the long jump example (Figure 1.3.55), the greater acceleration down the run way the greater his take-off force. Remember, force = mass x acceleration (Newton's 2nd law), so assuming no change in mass, an increase in acceleration will result in more force, and therefore greater distance.

Throwing events like Discus or Hammer all increase the speed of the projectile before it's released. The spinning of the throwers as they move across the circle, increases the velocity of the object (discus or hammer) from zero.

Height of Release

The taller or higher the point of release, the further the projectile will travel (again assuming everything else remains constant). For example, a taller shot putter if doing the same as a smaller thrower will achieve a greater distance simply because their shot will stay in the air for longer.

This can be seen in Figure 1.3.56, where everything is assumed to be the same, (angle and speed of release etc), yet the taller thrower achieves a greater distance.

Centre of Gravity

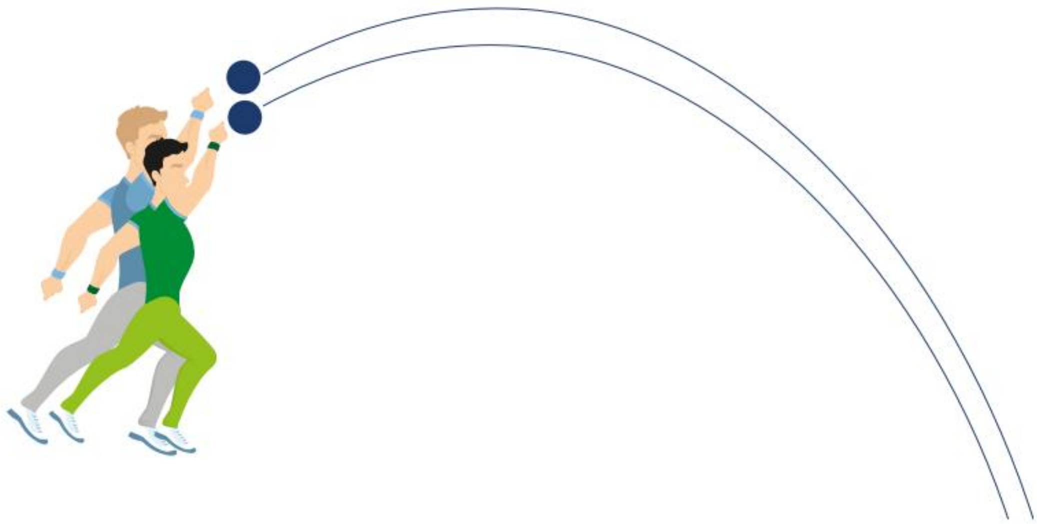


Figure 1.3.56: Height of release.

Achieving and maintaining equilibrium – Static and Dynamic

If forces acting on an object are unbalanced, then the object will experience linear or rotational motion, depending on where the unbalanced force was applied to the object in relation to its centre of gravity.

If the forces acting on the object are balanced, however, then the object is at **REST** or in a state of **EQUILBRIUM**.

Static Equilibrium

Static equilibrium occurs when the body is static or stationary. Held positions in gymnastics or sprint starts are examples of static equilibrium.

Figure 1.3.57: Balancing a handstand.

Figure 1.3.58: Holding the 'SET' position in the 100m.

Dynamic Equilibrium

Dynamic equilibrium occurs during movement. The body is not stable, but the different movements or types of motion occurring cancel each other out, so the body doesn't fall over. Running is an example of dynamic equilibrium, as the process of running involves alternating balancing and unbalancing the body.

Figure 1.3.59: Running is an example of dynamic equilibrium.

Centre of Mass – Balance and Stability

Centre of Gravity (Centre of mass)

Centre of gravity or mass is a 'theoretical' point through which gravity acts on the object.

An object is balanced when the centre of gravity is located within the objects base of support. The three shapes below are all stable as the centre of gravity sits within the base of support (area touching the ground). The Centre of gravity (or mass), is a point around which the mass (or matter) of the object is evenly distributed in all directions.

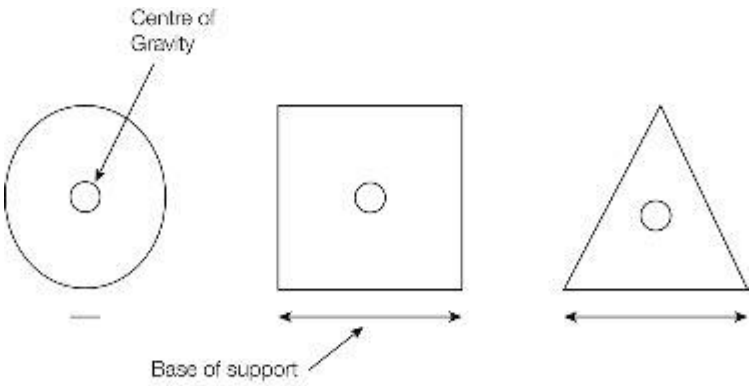


Figure 1.3.60: Balanced objects due to the Centre of gravity being within the base of support.

These are nice, one dimensional shapes though with even sides etc. Human bodies (especially when they move) are not regular shapes. In Figure 1.3.61 for example, the centre of gravity isn't even inside the body! The lady is balanced and stable because she isn't moving or falling over, even though parts of her body exists outside the base of support (outlined in red). Her legs have mass, so they counteract the torso's mass that is outside the base of support.

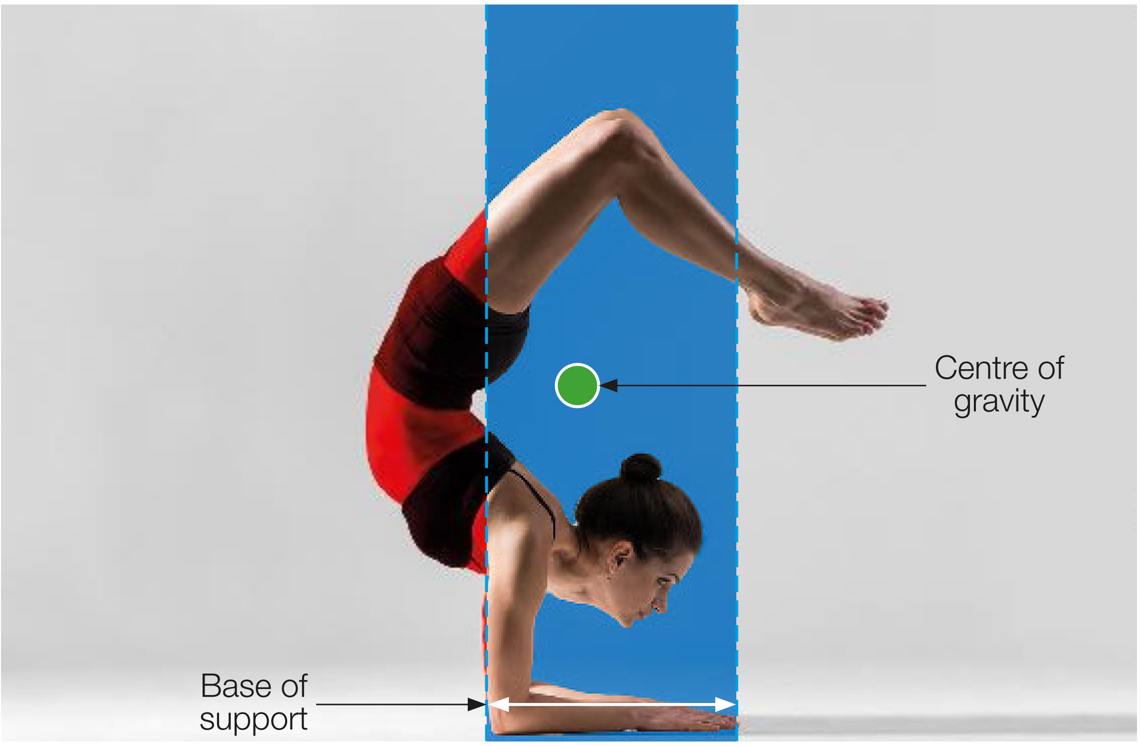


Figure 1.3.61: The Centre of Mass (gravity) can exist outside the body, as it's a theoretical point through which gravity acts.

Focus Questions

10. Shade in the area on the balance beam that represents the base of support. Then estimate where the gymnasts centre of gravity would be. Remember the gymnast is balanced (not moving).

Factors that affect equilibrium

1. Position of the centre of gravity in relation to the base of support.

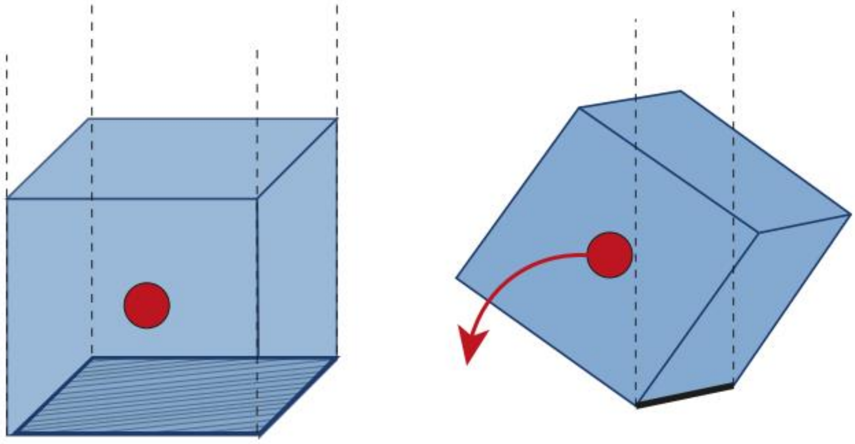


Figure 1.3.62: Balance requires the centre of gravity to be within the base of support.

When the centre of gravity (centre of mass) resides within the base of support, then it's easier to maintain balance.

2. The larger the base of support can be made the easier it is to maintain balance.

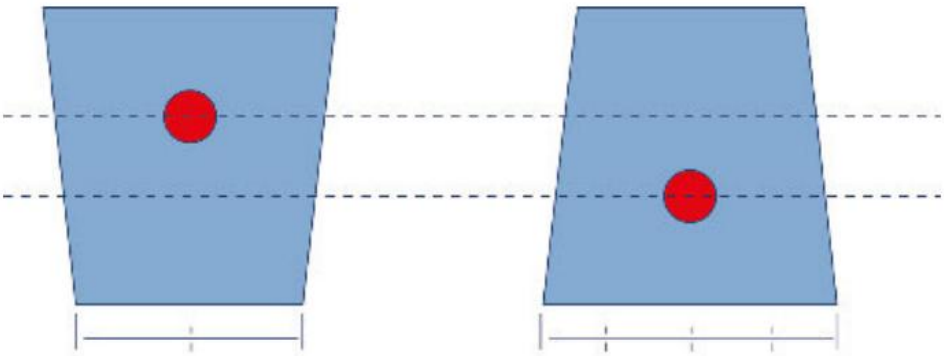


Figure 1.3.63: Larger base of support improves your chances to remain balanced.

3. Raising the centre of gravity in relation to the base of support results in a less stable position and less chance of maintaining balance.

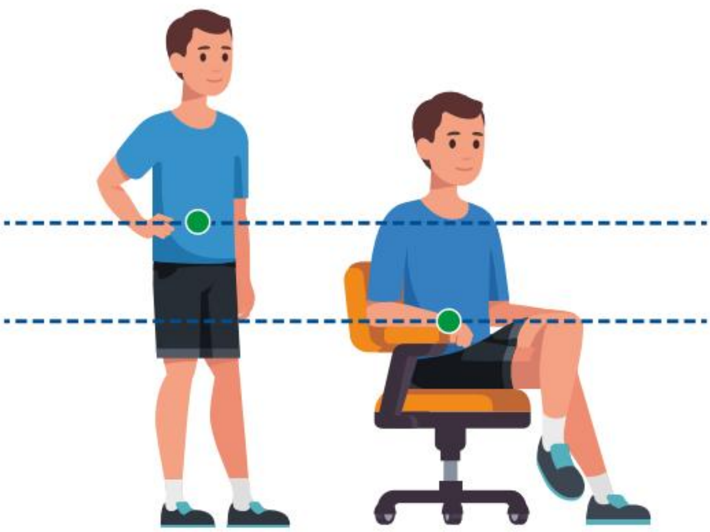


Figure 1.3.64: Changing the position of the centre of gravity.

4. When any limb is moved away from the body it drags the centre of gravity towards the direction of limb movement. This makes a person less stable unless another limb is moved, or the upper torso shifts to counteract the shift in the centre of gravity.

Figure 1.3.65: One leg counteracts the movement of the other away from the body.

Extension activity

Try moving one leg out away from the body as per the example in Figure 1.3.66. Can you explain the result of your actions.

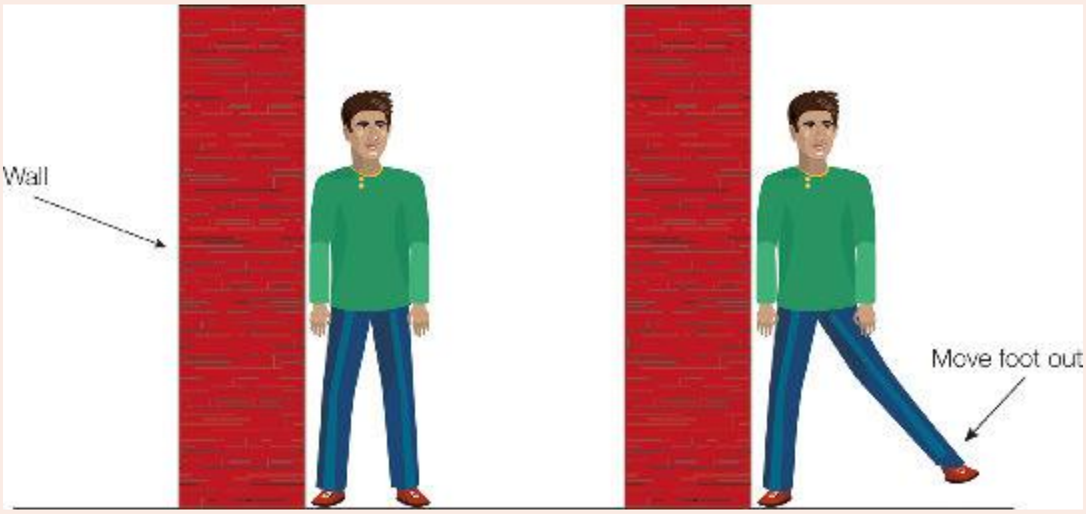


Figure 1.3.66: Balance experiment

Source: Adapted from Ash J.M., Jess T.J., Wilson B.G., Heffernan D.A. and Learmonth M.S. (1993).

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Balance and stability can be advantageous for sport performance in two ways:

- Balanced and stable: keeping your centre of gravity inside your base of support when being tackled in rugby allows you to stay on your feet and potentially break through the tackle (Figure 1.3.67)
- Unbalanced and unstable: Moving the base of support (hands) so that the centre of gravity is outside the base of support in the 100m sprint start means you start to fall forward. This is advantageous to your performance, as you are falling in the desired direction of travel and it helps with the movement out of the blocks (Figure 1.3.68).

Figure 1.3.67: Rugby tackle.

Figure 1.3.68: Sprint start.

Assessment Task 5

Reference material:

How does biomechanics affect physical activity and movement

A common approach to assessment tasks requiring knowledge and understanding from Focus Area 1.3 is an observational analysis of a particular skill or movement performed by the student. There is usually a comparison component to the question, whereby comparison is made between the student's movement pattern and that of a peer's or an elite performer. This is usually through video analysis, real-time observation, specialised video analysis software or a combination of some or all of these methods.

Application of Knowledge

Compare and analyse your performance in the Badminton clear to that of an elite performer.

Using biomechanical principles, analyse your technique compared to an elite performer and explain how differences in this technique may impact the outcome of the performance.

Suggested Response

The more common considerations would be:

Concept / Principle	Observation or comparisons to observe	Practical implication
Length of the lever The end point of a longer lever will travel further in the same time as a shorter lever. Therefore, in badminton the end of a longer lever (straight arm + racket) will travel faster. A faster lever means greater velocity of the racket head which then equals more force on contact with the shuttle.	The straighter the racket arm at contact, the longer the arm – racket lever will be. Are you reaching up high to make contact, or is the elbow bent and contact is lower?	The racket length should be the same as a professional, so lever length is reduced only if you are changing your arm length. If you have a bent elbow at contact, your overall lever length will be reduced. This means less racket velocity (head speed) at shuttle contact. Less racket head speed means less force imparted onto the shuttle. As a projectile, this means the shuttle will travel with less speed and/or with less distance as its release velocity will be less. Less speed means the shuttle may not clear the opponent, so they are not forced to move back in the court to play the shot. They then get to remain in a more attacking position on the court.
Angle of release (projectile motion) The angle at which the shuttle is struck above the head will impact flight trajectory. Trajectory in a clear should travel up and forward to avoid opponents in the midcourt.	Elite players will strike the shuttle slightly behind their head for an Overhead Clear to ensure the shuttle is traveling forwards as well as slightly upwards to clear the opponent's racket	Striking the shuttle directly above or in front of the body means there is limited upwards trajectory on the shuttle. If the shuttle doesn't clear the opponent standing in midcourt, it doesn't force them back and allows them to play from the more dominant midcourt position. Striking the shuttle too far behind the head results in too much vertical height and not enough horizontal movement, so the shuttle fails to reach the back of the court.
Summation of forces Force summation is where forces generated by previous muscle groups are added to the next. The force you generate in a clear shot can be maximised if the contraction of muscles and the movement of body parts is in sequential order. Sequential acceleration of body parts begins with the larger, stronger muscles of the legs and torso moving first, followed by the smaller and weaker, but faster muscle groups in the extremities contracting last.	Sequential summation of forces is best achieved with a side-on stance, allowing for the transfer of momentum from the legs, through the hips to the upper body. A front on stance reduces the ability to rotate the hips properly. This means the movement is being generated predominantly from the upper body only. Front on stance with bent elbow reduces much of the upper body movement to just the forearm/wrist.	Reducing the muscle groups sequentially contributing to the movement, limits the summation of forces. Less overall force summation means at the extremities (i.e. wrist) the acceleration of the racket at contact is reduced. This means less force is being generated at contact with the shuttle. Less force means less shuttle speed. Less speed means the shuttle doesn't fly as far or fast, increasing the risk the shuttle will be intercepted by the mid court opponent, opening the possibility of a smashed return.

Focus Area 1: In Movement

1.4 Practical Application of Learning Theories

- Coaching methodologies - linear and nonlinear
- Sociocultural considerations around constraints of games
- Ethical strategies to promote integrity and fair participation
- Game-based approaches and pedagogies (e.g. Game Sense, TGfU) and how they can be explored and manipulated to enhance inclusivity and equity
- Sports education model

Practical Application of Learning Theories

A coaching methodology refers to the method or set of strategies that a coach will use to teach their players the required sport specific skills. Before discussing the application of coaching methodologies however, it is important to first take a closer look at the very thing players will be hoping to learn from the coaching strategies - and they are the skills themselves. There are important relationships to consider between the type of skills to be learned, skilled performance and the learning theories behind coaching methodologies.

What is skill?

There are generally three different types of skills to consider:

- Cognitive skills - the ability to solve problems by thinking
- Perceptual skills - the ability to sense things from the environment and process them
- Motor skills - the ability to produce voluntary and precise muscle movements to perform a specific output.

It is easy to see that the skills required for an athlete or a student in Year 12 Physical Education will therefore incorporate all elements of these definitions. For example, cognitive skills are used when applying tactics to beat an opponent by deciding 'what to do' and 'where to do it'; perceptual skills are utilised when determining and perceiving the game environment such as player movements to discern 'when' to pass the ball; motor skills are utilised in the actual execution of the movement or skill within the game context. All three of these elements are critical to almost every motor skill performed in a game. For the remainder of this chapter, the term **movement skills** will be used to describe the actions used to participate in a variety of physical activities, games and sports utilising all of the motor, cognitive and perceptual elements of a skill.

Fundamental movement skills such as running, jumping, catching, throwing and balance are acquired during childhood and they form a foundation for lifelong participation in sport and physical activity, which is essential for long-term health and fitness benefits. In addition, from a performance point of view, it is believed that the acquisition of fundamental movement skills are essential to our enjoyment of a game and the attainment of more Specialised Movement Skills often required in elite sports.

Specialised movement skills can be learnt quicker if performers have experienced and developed a range of fundamental movement patterns as a child. Furthermore, a large repertoire of basic movement patterns will enable a performer greater capability to respond appropriately in unpredictable game environments. For example, an AFL player may be able to adapt their technique to kick accurately to a team player even whilst being tackled and pulled to the ground.

Table 1.4.1: Movement skills.

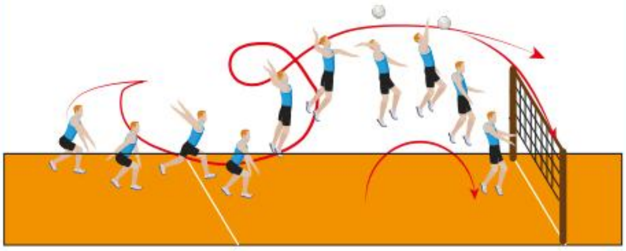
Fundamental Movement Skills involve different body parts such as the legs, arms, trunk and head, and include such skills as running, hopping, catching, throwing, striking, balancing and swimming. They are the basic movement patterns that form the building blocks for more specialised and complex patterns used in play, physical activity, games and sports.	 *Figure 1.4.1: The Fundamental Movement Skills - Jumping ('Lily Pad Jumping').*
Specialised Movement Skills are complex skills specific to a particular physical activity or sport. They are formed from a sequencing of the fundamental movement skills. For example, a volleyball spike involves the fundamental movement skills of running, stopping, jumping, twisting, striking and landing.	 *Figure 1.4.2: The Specialised Movement Skills - Jumping (the 'Spike' in volleyball).*

Figure 1.4.3: Adapting 'technique' to get a kick away even when being tackled.

Skill transfer refers to the ability of learning and performance in one movement or skill transferring to the learning of another. The transfer of movement skills from one sport or activity to another may be positive or negative.

Positive skill transfer:

When proficiency in one skill is improved by previous learning:

- Well-developed fundamental movement skills can be quickly refined and positively transferred to similar sport specific skills
- Sport specific skills with a similar motor plan can be learnt quicker and easier e.g. overhead smash (badminton), shooting at goal (handball) and a spike (volleyball) will provide a positive transfer (Figure 1.4.4).

Badminton smash / volleyball spike / handball throw are all similar movement skills

Figure 1.4.4: Positive skill transfer – All these skills have similar movement patterns.

Negative skill transfer:

When proficiency in one skill is decreased by previous learning:

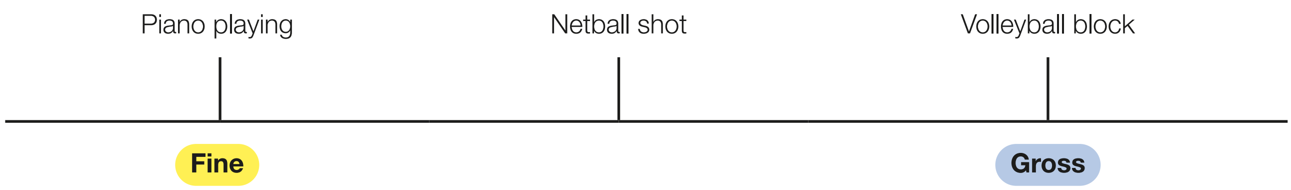
- Sport specific skills with a similar but different motor plan can make learning slower and more difficult e.g. tennis ground shot (full arm swing and follow through) may provide a negative skill transfer to a squash hit (wrist action).

Skill Classification

There are several skill classifications that are used to describe the nature of any skill required for a movement. The nature and classification of a movement skill will vary depending on its muscular involvement, environmental requirements, complexity and organisation.

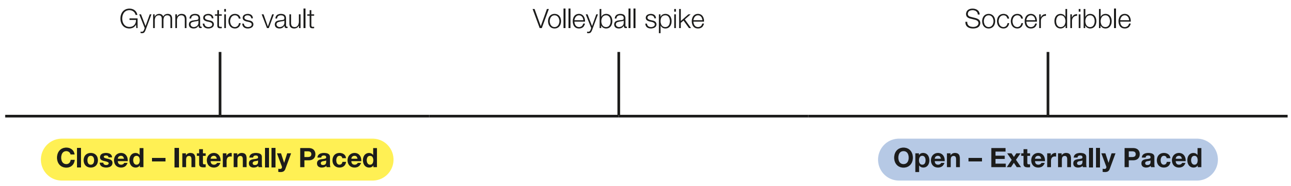
Each element of classification must be considered a continuum, where at each end of the line are opposites with the characteristic featuring either very strongly or not at all. A skill may also be placed anywhere along the line if it contains some elements of the particular characteristic.

Muscular involvement - this is based on the degree of musculature involved in the movement skill: Fine or Gross motor skills.



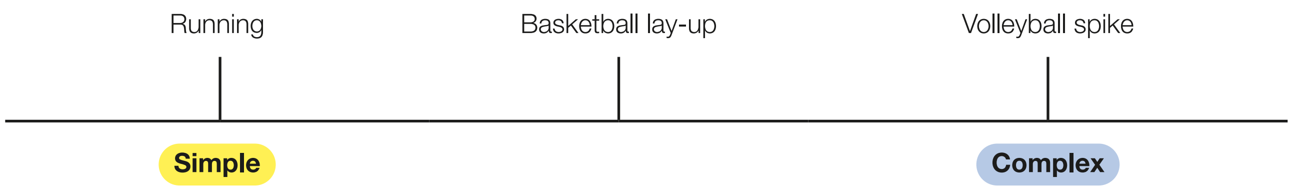
- **Fine motor skills** involve the movement of small muscle groups, often with considerable perceptual demands and fine control.
- **Gross motor skills** involve the movement of large muscle groups, often the whole body.

Environmental requirements - this is based on the perceptual demands of the skill and the time restraints that often determine the execution of the skill: Closed/Internally paced or Open/Externally paced motor skills.



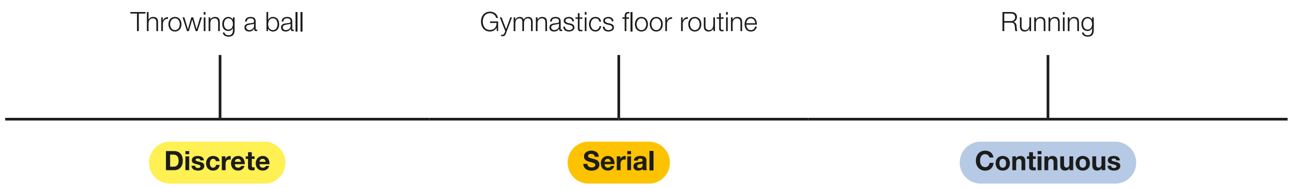
- **Closed skills** are performed in environments that are stable and 'predictable', so the same technique can be applied over and over with little variation or reference to the environment e.g. a gymnastics vault. In this regard, closed skills are also classified as being **internally paced**, because it is the performer's decision on when they choose to execute the skill.
- **Open skills** are performed in environments that are 'unpredictable' because they are constantly changing. The movement skills and techniques used here often need to be modified and adjusted to suit the changing conditions e.g. a 'contested' mark between two opposing AFL players in a game. In this regard, open skills are also classified as being **externally paced**, because it is the changing environmental conditions that determine when the performer must execute the required skills e.g. a tennis player has to respond to their opponent's shot immediately, and adjust their technique accordingly to return a shot before the point is lost.

Complexity of skill - this is based on the difficulty of the skill to perform: Simple or Complex motor skills.



- **Simple skills** are easy to perform and require little 'thinking' or conscious control to execute - they are not complicated movements to learn or perform
- **Complex skills** are difficult to perform in reference to the amount of information to be processed, number of decisions to make, speed of information processing or the extent of coordinated actions involved.

Organisation - this is based on the extent to which the movement is ongoing, as opposed to a very short and clearly defined movement: discrete, serial or continuous motor skills.



- **Discrete skills** have a clearly defined 'beginning' and 'end' point - often they have a very short duration of movement e.g. kicking a soccer ball. There are many different discrete skills used in a great variety of sporting settings.
- **Serial skills** are a collection of discrete skills placed together as a group to make a larger sequence or a new more complicated skilled action e.g. a gymnastics floor routine. The placement order of each discrete skill is very important and generally critical for the correct gameplay application e.g a soccer 'dribble step-over shoot' combination to 'fake' a defender wouldn't be successful if the discrete components of the movement were placed together in a randomly selected order.
- **Continuous skills** have no particular 'beginning' or 'end' point because the movement simply 'flows' continuously for a longer duration (sometimes many minutes) e.g. swimming, running and cycling.

Focus Questions

1. Identify and explain where you would place the following movement skills on the continuum: **Tennis serve, Gymnastics Routine** and a **Kayaking 1000m race**.

Discrete — Serial — Continuous

2. Identify and explain where you would place the following movement skills within a basketball game on the continuum: **Jump Shot, Tip off** and a **Foul shot**.

Closed – Internally Paced — Open – Externally Paced

3. Explain what is meant by the statement "a foul-shot in basketball is a closed skill in an open sport".

1

Focus Questions

4. Complete the following table, by classifying the following skills (place a tick next to each relevant category).

   There is room also to choose two categories of your own or from your teacher. All skills are to be considered in a competitive game situation.

	Fine	Gross	Open	Closed	Internally Paced	Externally Paced	Continuous	Discrete	Serial
Tennis serve									
Receiving a volleyball serve									
A basketball 'drive' to the basket for a 'lay-up' score									

The characteristics of a skilled performer

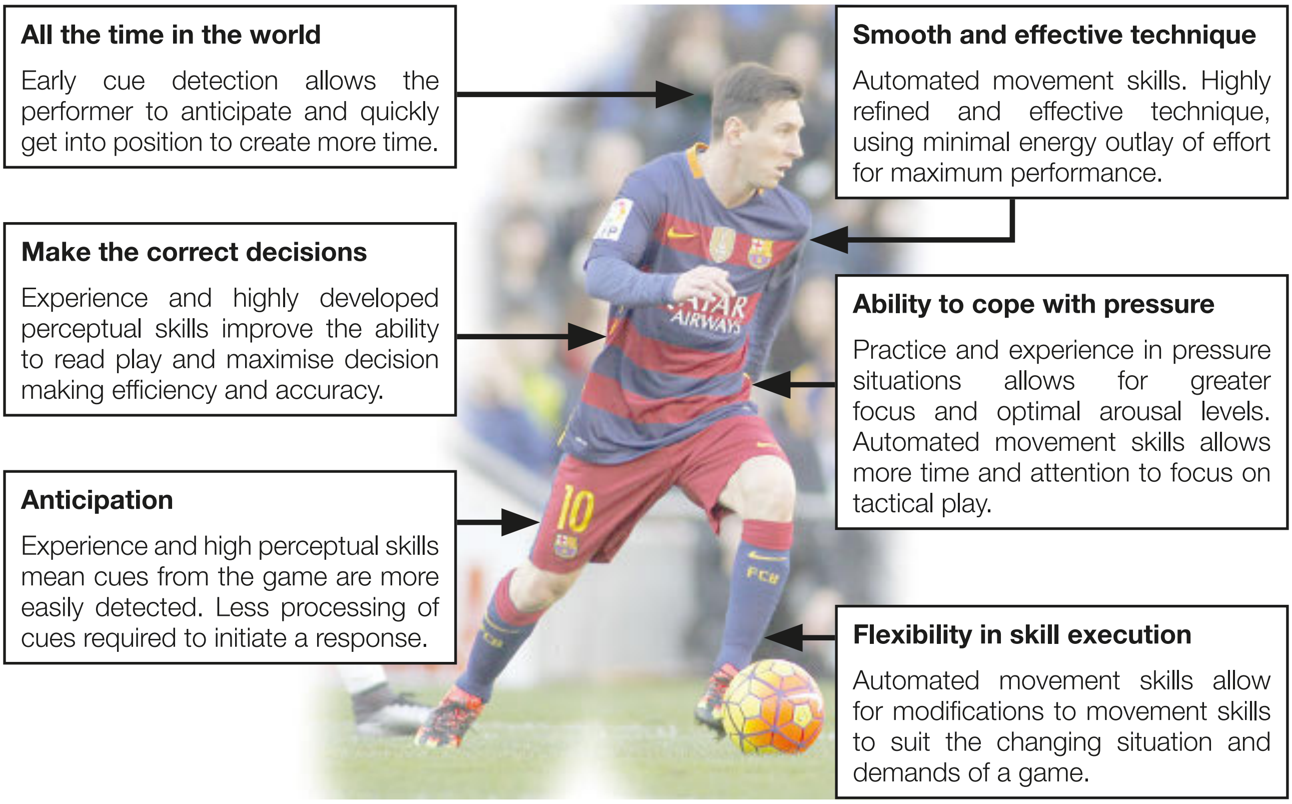


Figure 1.4.5: The characteristics of a skilled performer.

Movement skills can be learned and improved, but they require practice and are developed from experience.

The characteristics of a skilled performer are as follows:

- All the time in the world
- Make the correct decisions
- Anticipation
- Smooth and effective technique
- Ability to cope with pressure
- Flexibility in skill execution.

All the Time in the World - Skilled performers often appear to have a lot of 'time' to execute a movement skill.

- Skilled players are able to recognise relevant cues from the environment quickly and efficiently with improved **signal detection** (being able to detect small and relevant cues from the game sooner) and also by improved **selective attention** (being able to filter out irrelevant 'noise' and only process the information relevant to performance). These abilities enable elite players to spend less time processing cues from the environment and have more 'time' available to set or prepare themselves for the execution phase of the skill.
- In a team sport, being able to recognise relevant cues quickly allows a player to 'read the play' so they are able to determine where the ball or opponents are likely to go, so they can get the ball or themselves into an open (free) area of the playing field. Space = time, allowing the player more time in which to perform the skill; thus, they don't appear rushed, but instead calm and in control when executing the skill.

Make the Correct Decisions - Skilled performers often make appropriate choices in a game whilst demonstrating decision-making efficiency and accuracy.

- Skilled performers have developed excellent perceptual skills which enable them to make an accurate analysis of the demands of a game and make correct decisions in accordance with this information. A skilled performer knows when to pass, when to hold onto the ball, evade, shoot etc.
- Detecting relevant cues early also allows more time for the skilled performer to process the information and apply an effective output.

Anticipation - Skilled performers are able to predict (anticipate) what is about to happen next in the game, given only partial cues. Anticipation is a well-educated guess, based on previous experience.

- Anticipating and timing a move to intercept the ball, etc. comes from the quick recognition of relevant cues and ignoring irrelevant cues. Recognising the relevant cues early enough allows the skilled performer to move earlier and get into position faster (because they don't need to wait to detect all the cues before making a decision).

The tennis player (receiving the serve) detects relevant 'cues' quickly from the environment allowing them to **anticipate** the likely service ball placement and quickly move into position. This allows more time for the receiver to exhibit correct **decision making** and select the correct return shot. As they set up for the return stroke earlier, they are not 'rushed' (**all the time in the world**), so the technique looks **smooth and effortless**, with greater control over the placement, thus increasing the chance of a **successful and effective** shot.

Figure 1.4.6: Characteristics of a skilled tennis shot.

Smooth and Effective Technique - A skilled performer is able to execute movement skills in an economically smooth, effective and efficient manner.

- Through extensive practice the movement skills of a skilled performer are usually based on an effective technique that has been refined to maximise results and minimise energy outlay, and so the technique appears smooth and effortless.
- The recruitment of different body parts flow in a coordinated sequence of movements.

Ability to Cope with Pressure - A skilled performer is able to remain optimally aroused to efficiently execute their movement skills appropriately in 'pressure' situations. They seldom experience the phenomenon of 'choking' or performing more poorly than expected in any situation.

- Practice in game-situations has exposed skilled performers to 'pressure' situations (open and unpredictable game environments) allowing them to be aware of the factors associated with a tight game or contest. The fact that the skill level of an elite performer is automatic also allows them to concentrate on the changing environment and tactics whilst not overly concentrating on the execution of basic skills.
- In addition, skilled performers have the ability of 'selective attention' to concentrate on the essential stimuli (ball, etc.) and exclude other irrelevant details (i.e. crowd noise). A less skilled performer could struggle to process all game information appropriately, and experience 'information overload'. As a result, they may execute an incorrect response (i.e. a 'poor option') or perhaps not even execute a response at all. Either option would give the impression the player has 'crumbled under the pressure of the situation'.

Flexibility in Skill Execution - A skilled performer is able to vary their execution of a movement skill, by speeding up or slowing down their movements or selecting a different skill so that their response meets the demands of the game.

- Once a working model of a skill is developed, it can be modified to suit the playing environment at the time. For example, once learned, the basic throwing action of a pass can be modified slightly in a game of netball if the target (the intended pass) is moving; a skilled performer doesn't need to concentrate on how to throw, rather concentrate on the small adjustment(s) needed to hit the moving target (a teammate).

Focus Questions

5. Explain the importance of anticipation when receiving a serve in a game of professional tennis when the average processing time is 0.2 seconds, and they serve the ball at around 200 km/h.

6. In a sport of your choice, explain a cue or stimulus that would allow an opponent to accurately anticipate the likely outcome of a skill or movement.

Individual differences when learning movement skills

Every individual is unique with many different characteristics that may affect their rate of learning with an interplay between a learner's capacities and constraints. Some of the individual differences that may impact learning movement skills are discussed below:

Table 1.4.2: Individual differences when learning a movement skill.

Age/Maturation	Ability	Learning Style
How the brain develops influences maturity, and therefore a performer's readiness to learn: • Physical - development and growth of the body • Cognitive - how we 'think' and process knowledge • Social - how a person relates & works in a group.	The way a learner is able to process and apply new skills. These may include: • Intelligence • Perception • Coordination • Fitness factors.	The way a performer learns best can influence their motivation & ability to learn a movement skill: • Verbal? • Visual? • Kinaesthetic?
Social background These include cultural and economic circumstances: • Socio-economic status may influence learning with restricted access to skill learning due to inequalities, lifestyle or a lack of prior opportunities. • Socio-cultural status may influence learning with certain characteristics - including gender, race or ethnicity - affecting factors such as temperament, learning style, social norms and motivation to learn movement skills.	 *Figure 1.4.7: Learning to juggle.*	
Prior Experiences These can include recreational activities, games or sports that a learner may have already experienced. Is it a totally new experience? Is there a transfer of learning from a previous activity e.g. Basketball player to Netball? Was their previous experience positive/negative?	**Genetic Composition** Certain body characteristics are inherited and may affect the way an individual learns. In elite levels of performance, heredity characteristics may determine a person's ultimate success in a skill, and can include: body shape (somatotype), height, muscle fibre type etc.	**Motivation** This is linked to the positive learning attributes required to learn a skill and includes observable traits such as reliability, consistency and enthusiasm. Confidence, self efficacy and a willingness to take risks and learn with a **growth mindset**.

Coaching methodologies - linear and nonlinear

Learning a movement skill is a complex process that involves a multitude of factors. A key challenge for coaches and teachers is to cater for individual characteristics during practice to maximise learning. Over the years there have been different coaching methodologies (methods) presented when it comes to teaching and learning movement skills. Essentially, these can be referred to as either a linear or nonlinear approach to teaching.

A **Linear coaching methodology** has traditionally been used by coaches for skill teaching. It is sometimes referred to as the "skill and drill" or "direct" method of coaching because it involves explicit teaching where:

- A game is broken down into the sport specific movement skills required
- These skills are then taught:
  - Sequentially (from the basic to the complex)
  - Repetitively (with many drill activities to 'clock-up' hours to gradually master a skill)
  - In isolation (often in closed and 'predictable' environments)
  - With perfect technique (using a textbook 'reference' coaching model).

The traditional linear coaching model is ultimately based on the underlying assumption that skill learning is a gradual and linear process, with regular, distinct and definite stages of learning - therefore skills must also be taught using a linear progression (from basic skills through to the more advanced).

Table 1.4.3: The linear coaching method.

<table>
<tr><th colspan="2">Linear Coaching Methodologies (Traditional)</th></tr>
<tr><td rowspan="2">A linear coaching methodology is based on:
• An ideal movement pattern (technique) for every movement skill - it is the coach's role to assist learners to recreate that pattern to maximise performance
• Deliberate practice - repetitive practice or 'drills' used to reinforce the 'perfect' motor pattern
• Short games at the end of a session often used as a 'reward'
• Coaching expertise - all sessions are designed and implemented by the coach
• Players listening to the 'expert' on how to perform skills and apply tactics
• Drills beginning in a closed environment and slowly but deliberately moved towards an 'open' environment as the learner develops.</td><td>
Figure 1.4.8: Drill activities.</td></tr>
<tr><td>
Figure 1.4.9: Coaching knowledge and 'expertise' is important in linear teaching methodologies.</td></tr>
</table>

The 'traditional' approach to teaching movement skills is designed to:

- Facilitate early-stage skill learning with 'direct' coaching input
- Provide a predictable/closed environment to reduce the perceptual requirements of beginners
- Keep learners 'on task' with structured activities
- Quickly provide for skill performance improvements in a linear progression
- Deliver learners with an immediate set of rules/scenarios to guide decision making (tactics).

However, more recent evidence from **dynamic learning theories** have challenged the traditional linear approach to skill acquisition, stating many limitations including:

- Drill based practice can be monotonous and boring - raising motivational problems for players and coaches
- Players are dependent upon coaches for tactical decisions and therefore unable to adapt skills in a changing (open) game environment
- Complex and sport specific language to deliver 'technical expertise' can confuse and turn-off a learner
- Extrinsic motivations - potentially lowers the level of player independence when they only practice in the presence of a coach, instead of intrinsic (motivations within the player) to improve and drive their own learning and experience.

There is a growing body of research suggesting that skill acquisition is more effective using a **nonlinear coaching methodology.** This teaching approach is based on the assumption that the learning process does not follow a continuous or steady linear progression of regular, distinct and predictable stages of learning. Instead, skill learning is a stop-start, dynamic process with nonlinear skill progression as a performer develops capacity for self-organisation (independence) and begins to solve sporting problems in their own way.

From a practical standpoint, a nonlinear teaching methodology uses a student-centred approach to teaching where learners are challenged to solve problems using their own strengths and capabilities during game-like contexts.

Table 1.4.4: Nonlinear Coaching Methodologies

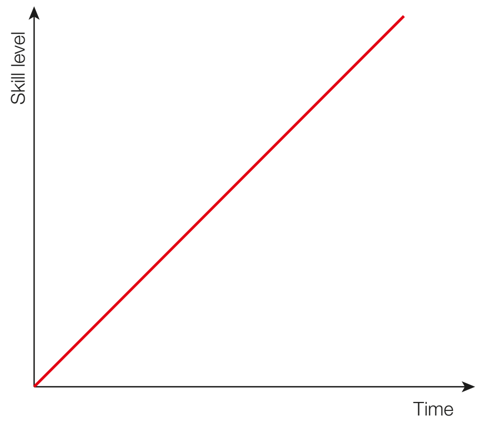
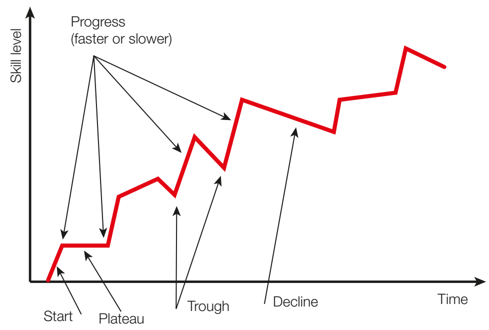
Nonlinear Coaching Methodologies	
A nonlinear coaching methodology is based on: • Movement outcomes rather than movement skill techniques • Implicit learning - no expert coach to instruct how a skill should 'look' or be produced • Learner's being challenged to creatively adapt their own movement skills to find solutions to specific game environments based on their own strengths and abilities • Movement skills learnt are transferable across similar structured sports	 *Figure 1.4.10: Game-based learning is a feature of nonlinear coaching methodologies.*

Nonlinear learning systems

> "Learners should be conceived as nonlinear dynamical systems, comprising numerous component parts that interact and self-organize to form stable patterns. The emergence of self-organized functional movement solutions is facilitated through the interaction of performer, task and environment constraints which act as boundaries to shape goal-directed behaviours".
>
> ***Jia yi Chow et al, 2014***

The underlying assumptions of **Linear** and **Nonlinear** learning are represented in the graphs below.

Table 1.4.5: Skill learning progressions.

Consider how your own past skill development progressed throughout your practice.	
Linear Learning • Were improvements directly proportional to the time you spent practicing? • Did practice result in regular & predictable improvements? • Did you move through sequential stages of skill learning?	 *Figure 1.4.11: Linear learning.*
Nonlinear Learning • Were improvements unpredictable? • Were there sudden gains? • Were there sometimes regressions where performance went backwards?	 *Figure 1.4.12: Nonlinear learning.*

Constraints-led teaching

One implementation of the nonlinear coaching methodology has been through the **constraint-led** approach to teaching**.** Coaches, PE teachers and experts in skill acquisition often refer to Newell's model of movement constraints (Table 1.4.6) in order to structure a learning environment that maximise the learning of movement skills and decision-making in their players.

Constraints are factors that can limit, contain, or shape the development of movement skills. In a constraints-based teaching model, the coach deliberately manipulates the interaction of **individual**, **environmental** & **task** constraints to create specific problems in a game to be solved by the players adapting their skills and tactical thinking.

Individual constraints

These constraints are located inside the performer. These are structural and functional aspects to consider with the individual:

Structural: These can include body shape (e.g. height, muscle mass and arm length) and fitness levels etc which can result in the movement solutions for different individuals being very different.

Functional: These include behavioural functions such as attention, motivation and emotions.

Environmental constraints

These constraints are located outside the body and can include physical and cultural factors:

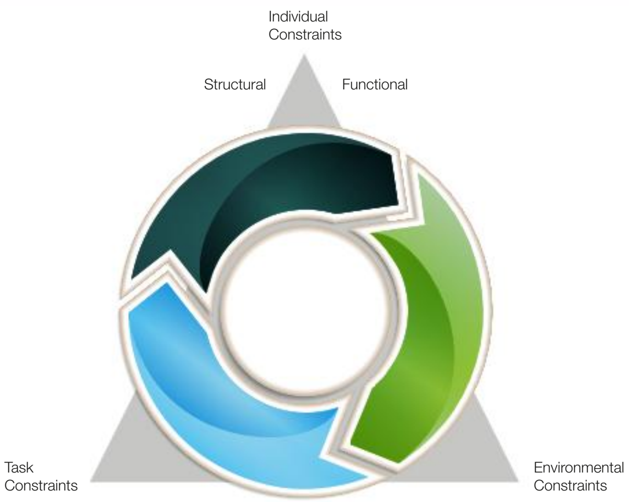
Physical: These include weather conditions, practice facilities, playing surfaces, noise or even the access and exposure to play areas when growing up.

Cultural: These include gender roles, family support and networks, school culture (e.g. sport versus academic achievement) or even media representation within a specific sport (e.g. AFLW's recent growth and exposure within the community).

Task constraints

Task constraints can include the rules, equipment, field dimensions, goals, number of players or even the different role players may have within a game. Manipulating task constraints will allow performers to develop optimal movement patterns that take into account their own variations in individual constraints as well as how they interact with the environment.

Table 1.4.6: Newell's model of movement constraints.

Newell's model of movement constraints	
 *Figure 1.4.13: Model of movement constraints.*	1. **Individual Constraints**: • Body size & shape • Motivation • Attention 2. **Environmental constraints**: • Size and shape of playing surface • Weather conditions • Society expectations/cultural norms 3. **Task Constraints**: • Rules • Equipment • Number of players

It is obvious that some constraints may be very difficult to alter in the short term. For example, the individual constraints of a performer's body height and limb length cannot (easily) be altered! However, for a coach, it is generally the task constraints (rule changes etc.) that are particularly important as they can be most easily manipulated to develop specific movement skills and decision-making behaviours quickly and efficiently.

Movement outcome versus movement technique

A constraints-led teaching approach emphasizes the manipulation of constraints for learners to explore and discover their own effective movement solutions. This obviously means there will be multiple ways for students to achieve a task goal. However, coaches should not worry if their learners are not performing a 'technically correct' movement pattern. Research suggests that movement variability is an essential process in acquiring a new skill. The strength of a nonlinear approach to teaching is that it prepares the individual learner with a variety of movement solutions to cope with a dynamic sporting environment i.e. an 'open' game.

Table 1.4.7: Examples of constraints that can be manipulated to maximise learning.

Constraint		Outcome on Learning & Performance
Net Games i.e. Badminton	**Task Constraint**: Court changed to enable the athletes to work on specific aspects of their game e.g. Playing with a higher net	Higher Net = Slower game • More time to respond to shots leading to changes in perceptual decision-making skills • More tactical shot placements required to shift opponent & create space & hit where opponent is not
Invasion Games i.e Handball	**Environmental Constraint**: Adapt the practice environment to force athletes to develop specific technical skills or tactical decisions. e.g. Beach handball	Playing Handball on sand = slower running / no dribble opportunities • Forces the players to develop a range of different skills and tactical decisions to overcome the soft-sand surface ○ Slower running = more passing ○ No dribble = more passing ○ Soft sand = more diving shots?

Helpful online resources

What this video which compares **constraints learning** versus **isolated practice**:

https://drowningintheshallow.wordpress.com/2016/03/14/what-is-a-constraints-led-approach/

Constraints - practical considerations

A constraints-led approach to teaching relies on the use of problem solving within practice games to establish a **perception–action coupling**. This can be explained as the relationship that exists between what information the performer takes in from the game environment (perception) and the subsequent action(s) they decide to take to solve the problem as a response. In this way, a performer's perception of the game will influence their game response, and in turn, their game response will influence their perception of the problem next time.

Affordances are opportunities for action in the environment (i.e. a game). They describe the environment in terms of behaviours that are possible at a given moment. Affordances will shape an athlete's decision making and provide for the **perception–action coupling**. Because of the dynamic nature of sport, affordances can come and go in an instance i.e. a 'gap' between opposing players can open to '*afford*' a passing opportunity at one moment, but then collapse into an impenetrable barrier in the next moment. **Attunements** describe the athlete's ability to 'read the dynamics of the game' and recognise the affordances available at any one moment.

Beware! Simply adding constraints into games without considering the expected and/or unexpected outcome(s) can be a problem for novice coaches and teachers using poorly considered constraints.

However, here are some ideas to consider when adapting task constraints for players:

- Altered court/field dimensions to work on specific aspects of their game?
- Small-sided games?
- Multiple scoring options?
- More or less players? Player zones?
- Incorporating player roles/responsibilities into rules:
    - one player must receive the ball every 3rd pass
- Adapt the practice environment to force athletes to make different tactical decisions
    - Place obstacles/cones to force tactical decisions to solve problems

Table 1.4.8: Because of the fast pace of many sporting activities, opportunities for 'action' on the playing field often come and go in an instant.

Figure 1.4.14 Game practice provides 'opportunities for action' to strengthen a player's perception–action coupling.

Affordances - the opportunities for 'action' in a game.

E.g. a space between two Hockey defenders 'opens-up'

- Can I pass through the gap?
- Can I dribble through the gap?

The player's ability will determine which affordance is executed.

Attunements describe the athlete's ability to recognise the affordances available at any one moment.

Focus Questions

7. Using a task constraint-led approach to coaching, identify and explain a possible practice session to target the following criteria of your learner(s). Explain the constraint manipulated and how this has structured the learning outcome desired in your athlete.

    (a) A volleyball player has struggled to hit forcefully down (spiking) in a game - instead they hit the ball into the net every time. You have identified two relevant factors:

    - Insufficient height in jump
    - Inconsistent sets from team

    (b) A soccer team are consistently turning the ball over to their opposition by players who dribble the ball too much and lose possession.

    (c) A badminton player has great force and power on their overhead shots (smash and clear), but they often lose points in the front court.

Focus Questions

8. Consider the linear and nonlinear teaching methodologies and identify when each would be an appropriate form of movement skill practice.

Sociocultural considerations around constraints of games

Implementing a constraints-led approach requires an understanding of the sport and skill learning, the individual learner and also the environment. The environmental considerations include the learner's socio-cultural background.

All learners have individual socio-cultural backgrounds, characteristics, interests and needs that may affect and influence how they choose to participate and learn movement skills (refer to Table 1.4.2). Some of the characteristics to consider when establishing a constraints-led teaching approach may include:

- gender
- sexuality
- ethnicity
- disability
- religion
- cultural beliefs/traditions
- economic status
- family and friends.

As an example, some socio-cultural characteristics surrounding gender (women's participation in sport), for a coach to consider when establishing a constraints-led approach to teaching may include:

Socio-cultural issue	Barrier or Enabler?
Sport choices in PE and school sport have been limited	
Dislike taking part in 'traditional' sports for men	
Women's sport usually has had lower status/less media coverage	
Women's AFL has recently seen great growth in popularity in the community	
Boys have monopolised possession and play aggressively in PE lessons	
Introduction of gender split PE classes in school	
Body image and PE uniform cause embarrassment	
Women 'Matilda's' have received equal pay deals when representing Australia in soccer	
Girls have lacked positive role models – locally and nationally	

Which of the sociocultural constraints (above) would be considered a **Barrier** or **Enabler**?

Although it is important not to develop stereotypes or make assumptions about a person's socio-cultural influences, being aware of any possible impact these characteristics may have on a learner's participation and uptake of movement skills is important to maximise participation and learning. This helps create empathy, tackles inequality and promotes inclusion.

Ethical strategies to promote integrity and fair participation

Ethics refers to a system of moral behaviour that ensues a level of integrity or good character is maintained - it helps us differentiate right from wrong and good from bad in sports.

In recent times, it seems that almost any discussion around elite sport competition can very quickly lead to ethical, integrity and fairness discussions, where the focus is shifted from sporting performance in its own right, to various moral problems and dilemmas that challenge the integrity of the sport itself. In high performance sport, integrity issues often refer to concerns around the use of performance enhancing substances or match-fixing.

However, integrity issues are not restricted to high performance sport. Even traditionally high-performance issues such as supplements, doping and match-fixing are increasingly being seen to impact at a grassroots level of sport. This is on top of a myriad of issues that impact on how fair and safe sport is. When learning, teaching or coaching a sport, for the lesson/practice to remain safe, fair and inclusive, people (players and coaches) need to have integrity.

An ethical approach to sports is often viewed as 'sportsmanship', where these attitudes for 'fair play' provide for healthy competition and contribute to a community of respect and trust between competitors and in society. The goal in sportsmanship is not simply to win, but to pursue victory with honour by giving one's best effort.

Gamesmanship on the other hand, is where 'winning is everything'. Athletes and coaches looking to bend the rules to gain a competitive advantage over an opponent, with less consideration for the safety and welfare of other athletes and/or the competition. For example:

- Deliberate fouls / cheating
- Getting a 'head start' in a race / cutting the corner in a mountain bike race
- Tampering with equipment, for advantage
- Intimidating an opponent
- Win at all costs attitude.

Ethics in sport requires four key virtues: fairness, responsibility, respect and integrity.

Table 1.4.9: Can the pressure to succeed overwhelm ethics?

<table>
<tr><th colspan="2">Play by the Rules</th></tr>
<tr><td rowspan="3">
Figure 1.4.15: Referees must apply rules equally without bias.</td><td>Fairness
• Follow established rules and guidelines
• No one is discriminated against or excluded from participating
• Referees apply the rules equally without bias or personal interest in the outcome</td></tr>
<tr><td>Responsibility
• Responsibility for performance/action on and off the field (including emotions)
• Don't lay-blame for performances on opposition, teammates, coaches or officials
• Know the rules and regulations</td></tr>
<tr><td>Respect
• Respect for teammates, opponents, coaches, and officials</td></tr>
<tr><td colspan="2">Integrity
• Play the game as it is 'intended' to be played. This is similar to fairness, in that any athlete who seeks to gain an advantage over an opponent by means of a skill that the game itself was not designed to test i.e. deliberately diving or 'faking' as a way of intentionally deceiving an official into making a bad call.</td></tr>
</table>

In a Physical Education lesson or sport at a community grassroots level, integrity and ethics concerns are likely to surround issues such as disengagement, poor teamwork, disrespect, poor sportsmanship, win at-all-costs or aggressive and unsafe play.

Think about your own values, principles and morals in sport - the things that matter the most to you and inspire you.

- Why are they important to you?
- Where did you learn them?
- Have they evolved over time?
- Have you exhibited these values under pressure?
- Do they match up with how other people describe you and your behaviour?
- Do they represent how you live today?

Figure 1.4.16: Striving for personal excellence but respecting opponents is an aspect of good sportsmanship.

Why is fair play important for:

- Enjoyment?
- Engagement?
- Confidence?

One strategy to optimise positive engagement and build the capacity and capability of sport to provide a safe, ethical and inclusive sporting environment is to establish a code of conduct document. Enacting a code of conduct will provide a guideline for expected behaviour and a course of action that will contribute to a positive experience for all students in the lesson.

Given that many of the coaching and teaching experiences in the Year 12 Physical Education course will involve students playing in games (constraints-led) and tournaments (sport education models) a **Sporting Code of Conduct** to promote fair play and optimise integrity, can be specifically written to incorporate all student roles and responsibilities including player, coach (technical, tactical, fitness and motivational) and official. A code of conduct provides a clear mandate for the desired outcomes for all members of the class. A great place to begin looking for ideas to establish a class code of conduct is the **Play by the Rules website:** https://www.playbytherules.net.au.

Table 1.4.10: Code of conduct - a guide of behavioural dos and don'ts (modified from Play by The Rules).

Player's Code of Conduct	Coach's Code of Conduct
• Strive for personal excellence • Play by the rules • Cooperate with team and game officials • Respect opponents • Learn to value honest effort, skilled performance and improvement	• Encourage and create opportunities to develop individual skills • Teach a wide range of team skills • Give all students a chance to participate equally in training and games • Encourage and recognise sportsmanship at every opportunity

A class code of conduct should:

- address appropriate behaviour
- include guidance on ethical behaviour and unacceptable behaviour
- be constructed by many members of your community to encourage a sense of ownership
- be accessible and communicated to all relevant people.

Game-based approaches and pedagogies (e.g. Game Sense, TGfU)

As the name suggests, the **Game-based** approaches to teaching refer to a general principle of learners understanding a game by playing it, and skill learning will then be added 'along the way' when the players are ready to learn them.

Teaching Games for Understanding (TGfU) is one game-based teaching approach that was originally developed by Bunker and Thorpe (1986), but it has since been adapted and used under other names including **Game Sense** (Thorpe, 1996) and **Play Practice** (Launder, 2001).

Game-based pedagogies are essentially a nonlinear constraints-led approach to teaching where students play modified games and learn through problem-solving during the game itself. The coach will then focus a player's understanding of the game with open ended questioning to guide players in a 'self-discovery' approach to learning (refer to Focus Area 1.5: Psychology of sporting performance).

For example, a key focus in the TGfU model is that learners will play the game to firstly learn about **WHAT** they need to do, before they learn **HOW** to perform the actual skills required. In this approach, it is believed that learners will become motivated to practice the necessary skills or way of playing to improve their game performance once they realize what abilities are required.

Table 1.4.11 TGfU uses a six-stage model of teaching with a constraints-led approach.

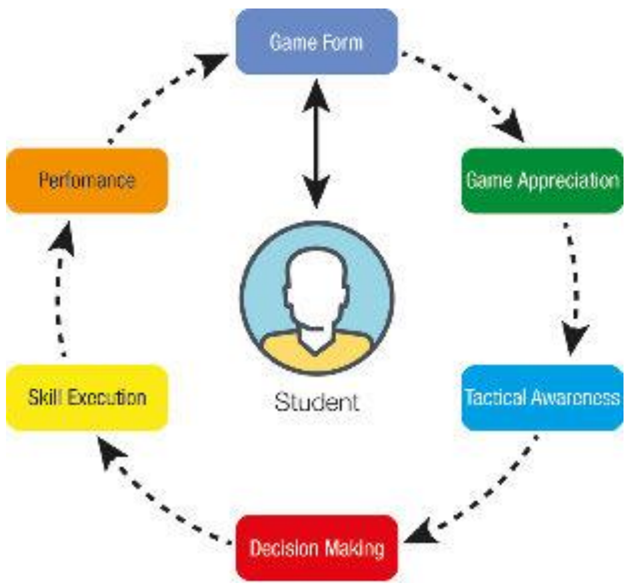


Figure 1.4.17: The TGfU process is a cyclical one with participants continuing to adapt and change as needed for the best playing experience.

- **Game Form** – Learners play a modified version of the adult game where the rules are designed for the physical, social and mental development of learners.
- **Game Appreciation** – Playing the modified game develops an appreciation of the rules that shape the game.
- **Tactical Awareness** – Game appreciation leads to an awareness of the game tactics needed for success.
- **Decision-Making** – Tactical awareness enables the learners to recognize and practise making decisions of "what to do?" and "when to do it?"
- **Skill Execution** – Decision making ability enables the learners to understand, identify and practise the technical skills or tactical applications needed to play within the context of the game and a students' ability limitations.
- **Performance** – Putting it all together! Applying the skills, decision-making and tactics in game situations.

Recent adaptations to TGfU have advocated a thematic approach to teaching games instead of teaching a single sport-specific unit (e.g. volleyball, basketball or softball). Instead, the learners will apply skills and knowledge to different sports by playing a variety of games that are 'themed' together because they have similar game characteristics e.g fundamental movement skills, primary rules, structures and game tactics.

For example:

- **Target Games** where an object is thrown or hit at a target - archery, golf etc.
- **Court and Net/Wall Games** where the participant propels an object into space trying to make it difficult for an opponent to return it - volleyball, squash, badminton etc.
- **Striking/Fielding Games** where the participant strikes an object, so it is placed away from defenders in the field - softball, cricket etc.
- **Invasion Games** where participants invade an opponent's territory to score - soccer, netball, AFL etc.

In the **Game sense** teaching approach, there is a strong focus on open ended questioning to stimulate players to think about the game instead of a coach directly telling the player what they should do. It is hoped that learners will be more motivated in discovery-based instruction because they take ownership of the learning process.

Figure 1.4.18: A Game sense modified game where learning occurs through problem solving and open-ended questioning.

Game Sense - Modified Soccer (3v2)

Open ended questions revolve around 4 concepts:

Time: When should you … *keep possession of the ball?*

Space: Where is the best 'space' to … *move to once you have passed the ball?*

Risk: Which option … *creates more space to pass the ball?*

Execution: How should you … *kick the ball to keep possession?*

In the 'Game-based' approaches to teaching, the coach is still interested in identifying a player's poor technique and they will try to fix any problems. However, the incorporation of isolated technique work and direct feedback is kept to a minimum. Instead, coaches will manipulate constraints to emphasise a particular learning goal (skill or tactical awareness) and their feedback is limited to 'teachable moments' that arise during the game.

The main benefits of the game-based teaching approaches include:

- The development of 'thinking players' because the performers are provided with opportunities to think and reflect for themselves
- Players are well prepared for 'open' competitive games that are unpredictable environments because of greater variability in practice
- Problem solving and 'self-discovery' promotes independent learners with a 'growth mindset'
- Children, coaches and parents all acknowledge that games and game-like situations are more fun than technical 'skill drills'.

Some of the disadvantages of game-based teaching approaches include:

- Novice coaches may just 'play-a-game' and not utilise a constraints-led approach or open-ended questioning to allow for player development
- Movement skills may not improve in a short timeframe; problem solving through self-discovery takes a longer time to achieve
- Game-based teaching may not keep all learners 'on task' when coaching large groups of students and there is only one coach for open-ended questioning.

Sports education model

Sports education model

The Sport Education model for teaching was first introduced by the Australian Sports Commission in 1995 and was called the **Sports Education in Physical Education Program** (SEPEP). It has been a popular and successful program ever since, particularly in middle school PDHPE programs with its focus on student centred learning and potential cross curricular links with other subject areas.

Essentially, a SEPEP curriculum involves a 'sports tournament' that is completely organised and directed by the students as a collaborative group, with teachers taking on a facilitating role instead of any direct or 'explicit' teaching. The educational philosophy surrounding a SEPEP program is that if students are presented with responsibility to run their own sporting tournament (with structured teams, roles and matches) they will take ownership of it, developing knowledge, skills, values and behaviours contributing to their overall physical literacy.

Helpful online resources

Take a look at this video link for a quick introduction to the Sports Education model:

https://www.youtube.com/watch?v=Xs9qiYpo6KE

The Sport Education teaching model is reported to be the most implemented and researched teaching approach worldwide, with considerable evidence that this teaching approach can benefit the development of students' social goals, healthy sport behaviours as well as Game Performance and Game Involvement.

As with the game-based teaching methodologies (TGfU and Game Sense), SEPEP is a student-centred model where the teacher's role is to oversee the whole process within a 'game sense' approach. This enables students to "make appropriate decisions during game play" (Hastie et al., 2009) and also "execute motor skills according to the circumstances of the game" (Farias et al., 2015).

Table 1.4.12: Descriptive statistics showing improvements for Game Performance and Game Involvement measures using a Sports Education Model (Farias et al, 2017).

Category	Context	Pre-test	Post-test
Game Performance	Basketball	*57.3*	*66.3**
	Handball	81.2	90.8
	Soccer	79.9	87.8
Game Involvement	Basketball	*60.3*	*67.3**
	Handball	98.7	116.0
	Soccer	105.7	112.8

* Not statistically different

Adapted from **Sport Education as a Curriculum Approach to Student Learning of Invasion Games: Effects on Game Performance and Game Involvement,** *Cláudio Farias, Carla Valério and Isabel Mesquita, J Sports Science & Medicine 2018 March, 17(1): 56-65, Published online 2018 Mar 1.*

Students are required to fully engage in the SEPEP as a player, but they must also take on added responsibility and roles associated with running the sports competition. An example of some of the key roles may include:

Team roles

- Coach – Technical, tactical, motivational and fitness coaches to conduct warmups, skills, tactics, fitness sessions, group dynamics etc.
- Captain – Team motivation, player positions, conduct warm up, role model sportsmanship etc.
- Manager – Team meetings, communications, uniforms/posters/banners etc.

Competition roles

- Sports Board – Manage the competition with initial team selections, game rules, tribunal, competition draw etc.
- Record keeper – Scores and premiership table, statistician(s) for relevant awards etc.
- Publicity officer – Weekly article reviews for game reports etc.
- Team duty roles – Referee, scorer, equipment officer etc.

The roles performed by students are often undertaken on a rotational basis within a middle school PDHPE setting. However, in a senior school setting such as a Year 12 Physical Education 'Group Dynamics' assessment task, roles will become more specialized and extended in nature to allow a full exploration of a student's ability to implement ***a plan for improving performance and/or participation of other team member(s)*** *and then to* make ***reflections on collected data and feedback, to inform the actions taken to improve participation and/or performance of their team*** (SACE subject outline, 2020).

Features of Sport Education

The SEPEP program is characterised by the following elements:

SEASON

- An extended 'Season' of trainings and fixtures - it's not a unit of sport
- Seasons typically last between 10-20 lessons - a longer season promotes in-depth understanding of the material
- The season includes formal fixtures and trainings - typically, competitions are interspersed with team practices and/or meetings.

MODIFIED SPORT

- Selected sport/activity can be teacher directed or with a student vote
- Rules must be modified to cater for modified games, fewer numbers, individual and sociocultural constraints of players etc. to promote participation and inclusivity
- You do not need to play the 'full' sport using all rules and regulations e.g. 5 v 5 handball / 3 v 3 mini-volleyball / 4 v 4 ultimate / 5-a-side soccer etc.

TEAMS

- Establish a team name! Students will quickly become 'affiliated' members of their team – encourage this
- Teams should be evenly selected for competition - numbers & abilities/strengths
- Team-lists for the season stay the same
- Teams take turns to be 'duty managers' who set up the field and provide referees/scorers etc.

CULMINATING EVENT

- A competitive event (finals etc) highlight the season and provide goals for players to work towards
- Festivity - the 'atmosphere' created during the competition and finals adds an important element for participants.

RECORDS

- Premiership points for the championship are totalled
- Records are kept and publicised to provide feedback, define standards, and establish goals for players and teams - can be used for data to help shape assessments
    - Points can be awarded for anything:
        - Motor skill performance of team members (peer assessments)
        - Competition performance (wins v losses)
        - Sportsmanship
        - Attendance / correct uniform
        - Proper warm-up etc.

Benefits of the SEPEP teaching approach

SEPEP can cater for all ability levels and extends learning beyond that of a traditional Physical Education program.

- Students work collaboratively to be a part of a team
- Team roles develop leadership skills and experience of being a coach
- Inclusive learning environment (everyone participates, not just highly skilled)
- Student centred and game-based
- Opportunity to monitor and promote personal growth among all players
- Students develop the capacity to problem solve and make informed and rational decisions about sporting issues
- Students develop and apply their knowledge about umpiring, refereeing and training
- Teachers and students enjoy this model!!

Example of a SEPEP Timeline

Lesson	Lesson Content	Responsibility
1	**Introduction** of the SEPEP concept, explain leadership roles etc. • Activity selection	Teacher-led
2-3	**Modified game play** • Selection of Sports Board - begin notes for team selections	Teacher-led Sports Board
4-5	**Skill development** (game-based - TGfU etc) • **Modified game play** - final notes from Sports Board to select even teams	Teacher-led Sports Board
6	**Announcement** festivities! • Competition structure announced • Team roster is announced • Captains announced (Sports Board and/or Teacher?) • Players move into teams and establish team name, team-roles etc	Teacher Sports Board - led Players
7-9	**Teams** publish their roster, mascot etc. • Team roles established and planning begins • Team trainings - separately run by respective coaches (teacher checks off criteria when satisfactorily completed) • Who leads practice? – teacher can offer 'assistance' by rotating to help each team's practice, but gradually it is taken over by student coaches • Written assessment of rules, etiquette, and strategies?	Teacher Sports Board Team Players - led
10-12	**Preseason** games (are the teams even?) • Teacher mini workshop? Guest coach? Any last minute advice/tactics with a skills session? • Duty group rostered team to 'plan' for competition start in next lesson • Training for rules for referees, field/court set-up for managers, score keeping for statisticians etc.	Teacher Sports Board - led Team Players - led
13-18	**Competition** begins! • Rounds per lesson (1 × game or more?) depends on local context - sport, tournament structure, team numbers etc • Duty group roster to run tournament • Competition usually interspersed with 1-2 training sessions/meetings - led by student captain & coaches etc.	Teacher Sports Board - led Team Players - led Duty Group - led
19-20	**Culminating events** • Final Play-offs - Preliminary finals? Grand final? • Should be festive and fun - announce championship games via publicists (school bulletin? PE board?), Sports Board/teacher distributes awards (most improved, 'play' of the tournament, fairest player… etc.) • May be linked in with player reflections, assessment tasks etc	Teacher Sports Board Team Players Duty Group

Focus Area 1: In Movement

1.5 Psychology of sporting performance

- The role of feedback and its effect on learning and performance
- Giving and receiving feedback

The role of feedback and its effect on learning and performance

If an athlete were to repeatedly practice a skill over and over, they will reinforce this movement pattern into their motor program, and it will become permanent. With this understanding, it is believed that "practice makes permanent". In the same way, if an athlete were to incorrectly practice a skill over and over, they will make that error permanent. An incorrectly learned motor program (skill) may be ineffective, could lead to injury and may be difficult to "unlearn" or alter in the future. Therefore, accurate feedback for a performer is essential because only "**Perfect Practice Makes Perfect"**.

Feedback is defined as information given to an athlete about the extent to which their performance corresponds to expectations (Carpentier and Mageau 2013). Feedback, therefore, either confirms and reinforces a performance, or it can indicate inadequacies in the performance and highlight modifications needed to improve the performance.

Accurate feedback is an essential component of the **Information Processing Model** (refer to Figure 3.6.1), allowing athletes to receive information about their 'output' to refine or modify their skill execution to maximise performance on subsequent attempts.

Figure 1.5.1: Volleyballers.

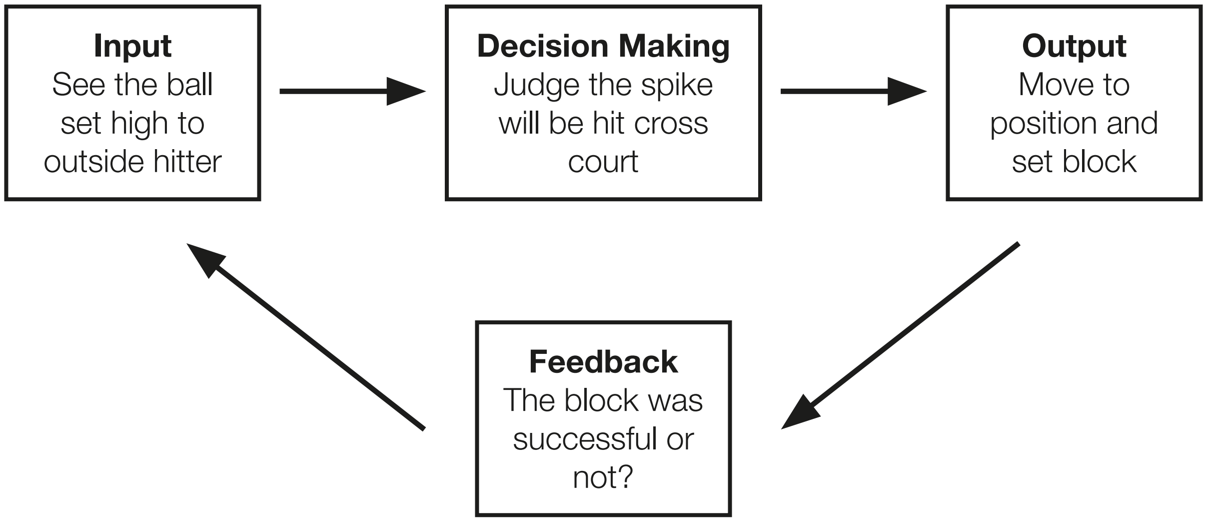


Figure 1.5.2: The Information Processing Model applied to a volleyball 'block'.

In sport, feedback can come from a variety of sources including the coach or even from the performers themselves.

There are two main classifications of feedback used in developing and maintaining motor skills: internal feedback and external feedback.

Internal feedback–This information is received during the execution of a skill and comes from within the performer. This feedback is provided via our proprioceptive sensors and is used to assist an athlete to make adjustments during the execution of a skill. This sensory input is used to establish a **kinaesthetic sense** (described as the 'feel' of a movement) and allows an athlete to differentiate between effective skill execution and error. Sometimes internal feedback is called **intrinsic** feedback.

An elite tennis player like Roger Federer (below) is able to use his proprioceptors to 'feel' the smooth and efficient technique (body position, joint angle, muscle length, muscle force etc) to deliver perfect timing, power and efficiency of effort during a tennis shot.

Table 1.5.1: Internal feedback from our proprioceptors contribute to the kinaesthetic feel of an elite performer such as Roger Federer.

<table>
<tr><th colspan="3">Tennis "Volley"</th></tr>
<tr><td colspan="3">Proprioceptors are muscle 'sense' organs located within muscles, tendons and joints to provide information on muscle tension, joint angle, body motion and balance.
The two main muscle 'sense' organs to provide kinaesthetic feedback are the muscle spindles and Golgi tendon organs.</td></tr>
<tr><td rowspan="2"></td><td>Muscle Spindles</td><td>These are 'coils' surrounding muscle fibres that provide feedback on muscle stretch and motor unit recruitment to produce 'smooth' and coordinated contractions.</td></tr>
<tr><td>Golgi Tendons</td><td>These are located in the tendons and are also sensitive to stretch and strength of muscle contraction to again, deliver efficient and effective movement.</td></tr>
</table>

Figure 1.5.3: Elite divers have good kinaesthetic "feel" to determine their body position during the dive.

Elite athletes who have mastered the execution of complex skills are able to make good use of intrinsic feedback, as they are acutely aware of how a movement pattern should "feel".

These elite platform divers use all of their senses to establish where their body is in space and exactly when and how to move their body to exit their rotation and enter the water the correctly.

Initially, a **cognitive** (beginner) learner will not know how a skilled performance should 'feel' and they will make many errors. Once they start to understand the movement patterns involved, they will increasingly be able to provide their own internal feedback and begin to move into the **associative** stage of skill learning where they start to 'feel' the movement and begin to self-correct their own performances.

External feedback–This information is provided by external sources, during or after a performance. It can come from teachers, coaches or team-mates and also includes things that the performer can hear or see in the game environment such as the sound of a hit ball, applause from the crowd or watching the successful (or unsuccessful) execution of a skill. Sometimes external feedback is termed **extrinsic** or **augmented** feedback.

There are two types of external feedback:

- **Knowledge of Results** is feedback on the outcome of the performance – was it successful or not? For example, the performer's score, time or position at the end of the activity will show the result of their efforts.
- **Knowledge of Performance** is feedback on the athlete's quality and pattern of the movement (technique) whilst completing the skill. This information can then reinforce technique or provide opportunities to modify motor plans if required.

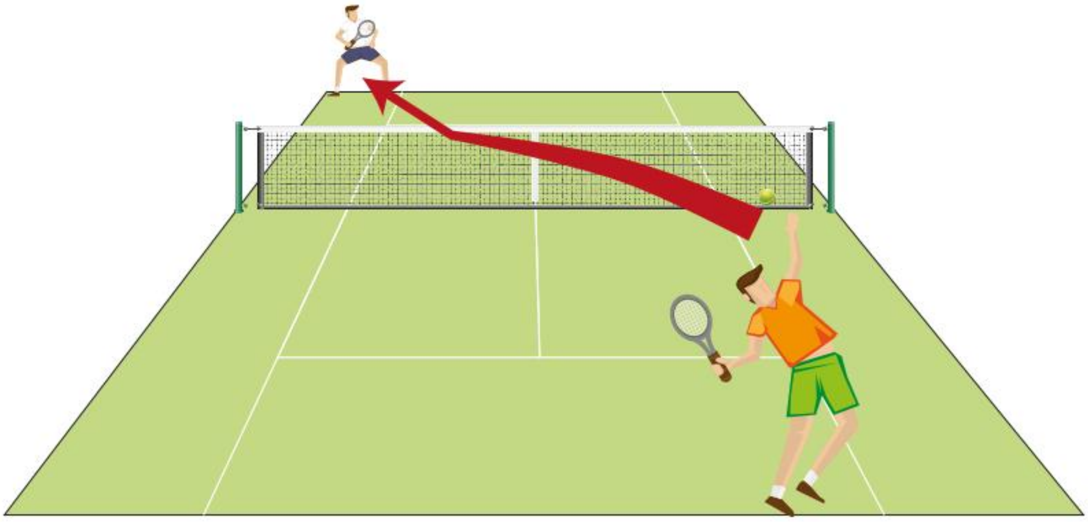
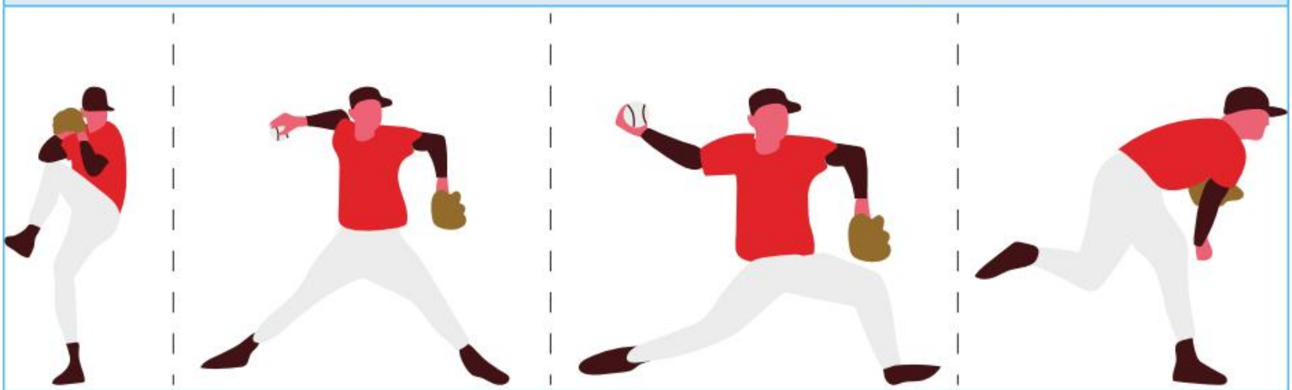


Figure 1.5.4: This player receives external feedback (knowledge of results) as they see the successful outcome of their serve as it lands 'in' the opponent's service court.

In most real-world applications, it is not very effective for a coach to improve the performances of non-elite learners by verbalising knowledge of results. For example, a coach telling a basketball player that they have just missed a foul shot is usually feedback that the performer has already received from the environment anyway (i.e. they have seen the shot miss the ring), so it is simply duplicated feedback and potentially detrimental to a player's motivation.

Table 1.5.2: Examples of internal and external feedback received by the baseball pitcher.

Baseball Pitcher–Types of feedback received



Internal Feedback	External Feedback	
Kinaesthetic Feedback	**Knowledge of Performance**	**Knowledge of Results**
The baseball pitcher 'feels' a smooth coordinated action with the sequential summation of muscle groups whilst pitching the ball with efficient outlay of energy.	The coach provides feedback on the pitcher's technique–"snap the elbow to full extension".	Pitcher watches the ball hitting the catcher's glove for a "strike" call.
'Feel'	**'Technique'**	**'Outcome'**

In addition to internal and external feedback, there are further classifications of feedback including:

- **Continuous (Concurrent) Feedback** is received during the skill or performance
- **Terminal Feedback** is received after the completion of the skill or performance
- **Positive Feedback** is provided when the player receives 'technique-confirming' feedback from a successful outcome
- **Negative Feedback** is provided when the player receives 'change-orientated' feedback to alter technique because the movement was unsuccessful.

At this point, it should be noted that no particular type of feedback is received by an athlete in isolation as there are many interactions between the different classifications of feedback. For example:

- If a coach were to provide 'constructive criticism' on an athlete's technique after the game, it could be classified as external, negative, terminal and knowledge of performance feedback.
- The feedback an athlete receives from the 'feel' (kinaesthetic) as they execute a soccer kick could be classified as internal, continuous and knowledge of performance feedback.

Focus Questions

1. What type of feedback is each of these examples? Circle the type of feedback received.

(a) A skier feels that they don't have good control of the skis when making a turn and they feel off-balance:

- Intrinsic feedback
- Continuous feedback
- Terminal feedback
- Negative feedback

(b) A golfer sees their final position on the scoreboard at the end of the competition:

- Extrinsic feedback
- Knowledge of performance
- Continuous feedback
- Knowledge of results

(c) A netball shooter watches her shot go into the hoop and hears the crowd cheer as they celebrate the score:

- Terminal feedback
- Extrinsic feedback
- Knowledge of results
- Knowledge of performance

2. Explain how proprioceptive feedback will aid this elite diver in performing the dive successfully.

3. Beginner divers will make major errors when attempting to complete rotations or twists through the air before entering the water. Explain how a coach could apply effective knowledge of performance feedback to a beginner to eliminate errors.

Giving and receiving feedback

Most performers will benefit from a variety of different types of feedback. The type of feedback delivered to a performer at any one time will be determined by a range of factors including the performer's stage of learning, playing ability, level of competition, cognitive/emotional development, motivation and individual learning style.

Below are some ideas to consider when providing feedback to performers that have been sourced from a variety of different feedback models.

Feedback for the different 'levels of learner'

Generally, cognitive, associative and autonomous performers (refer to Focus Area 3.7) will seek different types of feedback at different times.

Cognitive learners are only beginning to understand the basics of what needs to be done to complete a skill. Therefore, they cannot self-assess what they are doing correctly (or incorrectly) so they often rely on external feedback (knowledge of performance)from a coach to correct regular and large errors. Coaches will typically use basic descriptions, cues and visual demonstrations to highlight the important subroutines of a skill. However, any feedback given to a cognitive learner should be kept simple and very short to avoid confusion and information overload. It should be noted that in addition to feedback, cognitive learners will benefit from large amounts of time playing the game (or more appropriately, modified versions of the game) to actually use the skills and begin to develop their own kinaesthetic 'feel' for the movement patterns relevant to the sport.

Feedback considerations for cognitive learners include:

- Feedback should be simple and short
- If a learner can't detect their own errors, then provide feedback
- Positive feedback can maintain motivation i.e. "Bend your arm" is better than a negative statement i.e. "no, your arm is still straight"
- Feedback should be specific i.e. "That was good because…" is better than a 'feel good' statement like "great job"
- Feedback should focus on the fundamental movement patterns (knowledge of performance) before giving outcome feedback knowledge of results
- Develop keywords or phrases to 'chunk' information and feedback to avoid long explanations
- Decide which movement pattern features are most critical to performance and give feedback to these first
- Use the concept of faded feedback—frequent feedback in early practice, then gradually less feedback as the learner becomes more proficient
- Feedback is most effective when the movement it describes is not separated by other interfering activities such as a conversation with a friend, attempting a different task etc
- The feedback delay interval should not be too short or too long—usually 5-10-seconds is sufficient time for a learner to process what they have done, yet allow time to consider their skill execution.

Associative learners have learnt the fundamental skills of the sport, and their performance becomes more consistent with the number and size of errors less. Movements will become more coordinated as their 'kinaesthetic feel' develops. In the associative stage, it is important for the coach to provide more sport skill specific feedback through demonstrations, verbal descriptions and video analysis to refine technique.

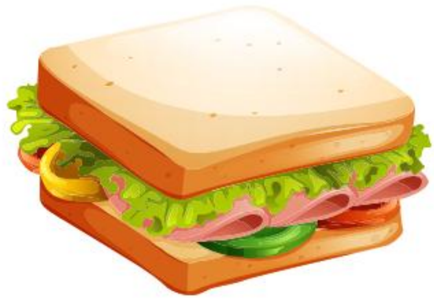
Feedback considerations for associative learners include:

- Use both knowledge of performance (KP) and knowledge of results (KR) feedback
- Do not give constant feedback on every trial—the motivational effect will be reduced, which can produce learner dependency
- Mix encouragement (positive reinforcement) with information about errors to maintain interest and motivation
- A coach/PE teacher can use other athletes (peers) to provide feedback on simple aspects of a skill or game
- Giving feedback instantaneously following a movement can interfere with a learner's self-processing
- of knowledge of performance (KP)—allow a short feedback delay interval for the performer to process how the movement felt, looked and sounded etc
- When providing practice for several tasks in the same session, provide all feedback for a given task before switching practice to the next activity.

Autonomous learners have mastered many of the skills and movements in the sport and can perform these 'automatically' without thinking because the movement patterns have been embedded into their long-term memory for instant recall and lower order thinking. This allows for more selective attention to higher-order cognitive processes, such as game strategy and tactics. Although autonomous performers rely more on their own intrinsic feedback (kinaesthetic 'feel') to maintain or further refine skills, at times they may also need extrinsic feedback (knowledge of performance) from a coach to overcome inconsistencies or to fine-tune complex skills. This feedback can come in a variety of forms including verbal, video, data or biomechanical analysis.

The Feedback Sandwich

Imagine a sandwich with two pieces of bread and some filling in the middle. Like a sandwich, some coaches advocate a 'feedback sandwich' for their athletes where a positive comment is delivered, then a constructive criticism, followed by a final positive comment — as a way to make the delivery of negative feedback more palatable.

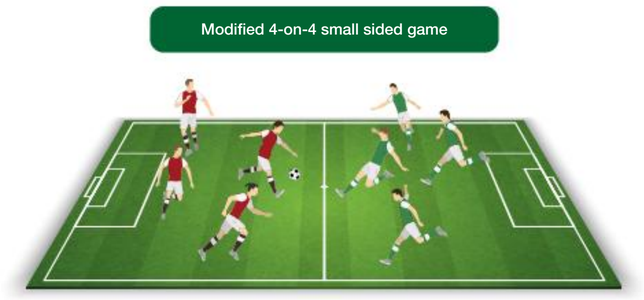


1. **Positive opening statement:**
   "Well done, you made no unforced errors that game."
2. **Constructive criticism:**
   "Next time, look for deeper placement on your shots."
3. **Concluding positive statement:**
   "Your court coverage has been excellent."

Figure 1.5.5: The feedback sandwich.

Questioning Feedback – Game Sense (Teaching Games for Understanding)

Many coaches and teachers advocate a questioning feedback model. In this approach, a coach will ask the performer questions on what they think should happen, what they did well and how they can improve next time, instead of simply providing this information (feedback) directly to the performer. This feedback model has developed from a coaching pedagogy called "Game Sense" which can be described as a 'discovery' approach to teaching, where sporting techniques are taught within the context of a modified game (refer to Focus Area 1.4: Game-based approaches and pedagogies). A player's understanding of the game and their skills are then guided into 'self-discovery' through a coach's questioning strategies about the game.



Feedback is turned into questions that revolve around 4 concepts:

Time: When should you …?

Space: Where is the best 'space' to …?

Risk: Which option does ...?

Execution: How should you ...?

Use open-ended questions

Figure 1.5.6: The use of modified games and questioning is central to the instructional and feedback emphasis of a Game Sense approach.

The key benefits to this type of feedback is that it promotes the development of 'thinking players' because the performers are provided with opportunities to think and reflect for themselves. The feedback provided by the coach is in the form of questions or challenges as a substitute for 'telling' the performer how to execute a skill or play the game. In a 'Game Sense' approach to teaching, the incorporation of isolated technique work and direct feedback is kept to a minimum and limited to 'teachable moments' that may arise during a game.

External Focus feedback

During traditional linear practice and coaching methods (refer to Focus Area 1.4: Coaching methodologies - linear and non-linear). feedback is often provided by a coach in regard to a performer's technical execution of a skill (i.e. their technique). For example, a tennis coach informing their player on all technical aspects of the 'volley' shot provides external knowledge of performance feedback. However, as can be seen in the example on the following page, this type of feedback has the potential to be very confusing to a beginner.

Figure 1.5.7: Complicated technical feedback has the potential to be very confusing to a learner.

There is growing research demonstrating that feedback and instruction is most efficient when it is directed at telling a learner what to do (using an **external feedback** focus), rather than a 'traditional' how-to-do-it approach (using an internal feedback focus).

External focus feedback is designed to reduce conscious control of a movement and make a skill more automatic. Too much conscious thinking of how body parts must move to perform a skill can consume a large share of a learner's working memory capacity and interfere with their natural learning process. If the processing demands of feedback and instruction exceed the capacity of an athlete's working memory, performance will deteriorate as a result of information overload.

External focus feedback emphasises **movement outcomes** which encourage learners to solve their own problems and establish their own individual techniques, allowing skilled movement to become more automatic. Instead of being too descriptive, a coach will help guide and direct a performer's thinking with questioning and provide feedback only after the performer has experienced and fully explored the learning environment (game) developed by the coach.

Table 1.5.3: External Feedback versus Internal Feedback Focus

	'Traditional' Internal focus	'Non-Linear' External focus
What is it?	An individual's attention is drawn to the actual body movements required for the skill (technique).	An individual's attention is directed towards the outcome of a movement.
Example?	A golf coach may explain: "Shift 60% of your body weight onto the forward foot during the shot".	A golf coach may explain: "Hit the ball high like a rainbow"
Outcome?	Information overload and error?	Reduction of conscious control during the movement making the skill more automatic.

The more complex or challenging the task, the greater the advantages of adopting external focus feedback with research demonstrating improvements in all aspects of skill performance across a wide range of skill levels and ages.

Assessment Task 6

Reference material:

Psychology of sporting performance

A common approach to assessment tasks requiring knowledge and understanding from Focus Area 1.5 is addressing the different forms of feedback and their impact on learners. This usually involves coaching or teaching a sport of their choice to peers or primary classes by the student. Reflection on the type of feedback given and the impact or effectiveness of the feedback is then evaluated. There can also be a comparison component to the question, whereby a comparison is made between the student's feedback delivery and that of the PE teacher. Data collection is usually done through audio analysis, real-time observation, or a combination of both of these methods.

Application of Knowledge

Role of Feedback

You are tasked with teaching a Year 4 class a lesson on a sport of your choice to investigate the role of feedback in learning. You are to plan and implement your own lesson. Using evidence, analyse and evaluate the types of feedback and the suitability of the feedback you gave the students.

An additional or alternative question might include:

Observe a teacher taking a PE lesson. Compare the feedback given by the teacher to your own experience teaching primary students. As part of your analysis, compare the type of feedback given and discuss the suitability and impact of the feedback for this learning group regarding the potential impact on learning.

Suggested Response

Possible considerations for a range of sports may include:

Points to consider	Observed examples	Suitability / impact
Positive feedback 'Technique confirming' feedback (information) from a successful outcome.	'Good' 'Well done'	• Essential for beginners to maintain motivation to keep persevering with learning the skill. • In isolation though, there is little benefit to the actual skill acquisition part of learning a skill. It's ability to help modify a technique is limited.
Negative feedback 'Change orientated' feedback (information) to alter the technique as the movement was unsuccessful.	'No' 'That's wrong'	In isolation, not appropriate to most beginners as it risks damaging their self-efficacy, confidence and/or motivation to continue to strive to learn or improve the skill.
Terminal feedback Information received after the completion of the skill or performance.	Can be positive or negative. Results based or Performance based.	The suitability or impact of terminal feedback depends on the type of feedback given (refer to comments on positive vs negative feedback, Knowledge of results vs performance-based feedback).
Continuous (concurrent) feedback Information received during the execution of the skill.	Often 'kinaesthetic feeling' during movement (A platform diver feels whether they are balanced or not with a handstand before completing the rest of the dive).	Depends on the skill. Doesn't lend itself to quick movements as not enough time to process the feedback. Continuous feedback is often received as kinaesthetic feedback, so not effective for beginners, as they don't understand yet what 'feeling' they should be trying to obtain.
Internal feedback Information received during the execution of the skill and comes from within the performer.	The 'feeling' you get when you shoot the ball. With experience, Basketballer's can 'feel' whether a shot will be too short or long.	Refer to Kinaesthetic feedback for more detail.

Points to consider	Observed examples	Suitability / impact
External feedback Information provided by external sources, during or after a performance.	Feedback from: Coach, video, scoreboard, crowd response etc Possible examples are similar to Terminal feedback.	Technique based feedback (knowledge of performance) is more beneficial to a beginner learner initially, as they often know they have made a mistake already. They just aren't sure why they made the mistake. Beginners especially need information on how to correct or modify a technique.
Knowledge of results Feedback on the **outcome** of the performance only.	'Yes' 'That was a goal' 'Correct' 'You scored'	• Verbalising knowledge about the result is usually feedback that the learner has already received from the environment via their senses (sight etc). • Often it is just duplicated feedback, which at the beginner learner stage could be detrimental to motivation if technique is wrong. • No information given on how to implement a change to the faulty technique.
Knowledge of performance Feedback on the quality of the athlete's movement pattern (**technique**).	'Finish with your bat at head height' (Table Tennis – top spin)	• Information on the quality and implementation of a movement pattern (technique). • Excellent for learners as it provides information to reinforce a technique or provide opportunities to modify a movement pattern (technique).
Kinaesthetic feedback Internally generated feedback from proprioceptors in the body. Sensory input is used to get a feel for the movement (kinaesthetic sense). Allows the athlete to differentiate between effective skill execution and error.	• Batter in cricket can feel whether they hit the ball correctly or not to judge whether the ball will run to boundary. • Divers knowing when to open out of a tuck position.	Kinaesthetic feedback is going to have limited value for beginners purely because they have little idea of what a good movement should 'feel' like. Visual and auditory feedback should be the focus initially to get the learner to a point where they can start to appreciate what a good movement feels like.
Questioning feedback Information provided in the form of questions or challenges as a substitute for 'telling' the performer how to execute a skill or movement.	'What do you think should happen?' 'What did you do well?' 'How could you improve next time?	It's suggested this approach: • Allows learners to better solve problems presented by the game • Allows learner to develop more autonomy and understanding about how to play the game more effectively. • Promotes individualised movements, rather than replicating an idealistic movement pattern
External focus feedback Information directing the learning 'what to do', rather than 'how to do'. Encouraging learners to solve their own problems and develop their own technique.	'Concentrate on looping the ball into the net' (shooting in netball) 'Throw the ball to resemble a rainbow shape' (fielder throwing the ball in softball)	• Fosters a child's desire for autonomy, allowing them to solve their own problems. This can lead to greater motivation or desire to continue participating. • Allows for creation of functional movement solutions, or variation in techniques, rather than an idealistic model or movement pattern that everyone tries to replicate. This can have particular benefit to low skilled individuals, as focus is on the outcome (finding a technique that works), rather than replicating an idealistic movement pattern or technique that often proves difficult and only serves to highlight their lack of physical ability. So, positive social and mental well-being benefits can come from focusing on outcomes.

Focus Questions

4. Explain why some research suggests that knowledge of performance feedback is more powerful than knowledge of results feedback for a beginner learner.

5. Explain why some coaches advocate a 'feedback sandwich' as a way to make the delivery of negative feedback more palatable.

6. For each stage of learning, identify one form of feedback that would be most effective to improve performance and explain why.

   (a) Cognitive:

   (b) Associative:

   (c) Autonomous:

7. The use of questioning is central to the feedback emphasis of a 'Game Sense' approach.

   Using specific examples from the sport of your choice, construct four open ended questions to help a learner think and reflect for themselves (you may wish to consider the four concepts of Time, Space, Risk & Execution).

   Sport:

   (a) Time:

   (b) Space:

   (c) Risk:

   (d) Execution:

Extension activity

External feedback provided by coaches can provide a performer with additional information to improve their performances.

Use the table below to record the type and frequency of feedback provided to a performer during a game in your PE lesson or sport training session. In addition, take notes to describe how the feedback was given and any noticeable outcome(s) on performance from that feedback. For example, were there any changes in motivation, engagement or performance of the player?

External Feedback			
Feedback Type	Frequency	How was the feedback provided?	Outcome? Response from performer?
Knowledge of Results (KR)	e.g. I	"That was a goal"	Player smiled and appeared happy–pumped fists!
Knowledge of Performance (KP)			
Continuous Feedback			
Terminal Feedback			
Positive Feedback			
Negative Feedback			
Questioning Feedback			
External Focus Feedback			

During a physical education lesson, this activity can be completed in a group of three with allocated roles as follows:

Player: Play the chosen game (or modified game) and listen to feedback from your allocated coach. Listen and act upon the feedback from your coach during the game as required.

Coach: Watch your allocated player in the game and provide specific feedback to try to improve their performance.

Recorder: Using the table, record the type, frequency and description of the feedback provided by the coach. In addition, record any notable outcomes on performance from the player after they receive the feedback.

Now rotate roles!

At the completion of this activity, discuss the different types of feedback that were provided and the impact these had on the performer's learning during the game. You may wish to consider the following questions:

(i) What classifications of feedback did the coach use the most?

(ii) Was there any classification of feedback not used by the coach? Why?

(iii) Which feedback was most helpful to the player? Why?

(iv) Which feedback was least helpful to the player? Why?

Focus Area 1: In Movement

1.6 Analysis of movement concepts and strategies

- Collecting valid and reliable data
- Making sense of movement concepts and strategies to improve participation and/or performance
- Application of concepts and strategies in unfamiliar contexts

Collecting valid and reliable data

In the world of elite sport and also in the context of the Year 12 Physical Education course, data collection is a valuable and necessary tool to assist players to improve and maximize the performance and participation of themselves and/or others.

Collecting data is useful because it can:

- Establish baseline data for 'pre' and 'post' test measurements, which are critical to monitor progress in games or training programmes
- Identify or confirm if there are weaknesses or strengths in aspects of performance and/or participation
- Contribute to motivation when training
- Allow athletes to reflect, alter their training programs and set short/long term goals.

There are four different types of data that can be collected:

- **Primary data** - this is data that you collect directly from the source (i.e. a person) and may be in the form of questionnaires, interviews or observations to investigate your research e.g. a one-to-one interview with an 'expert' coach.
- **Secondary data** - this is previously published data found in books, websites, journals, government publications/agencies, research, and other forms of media. Secondary data is commonly used to form rationales for your research e.g a review of research data from a journal of sports science.
- **Quantitative data** - this is data that can be quantified as a number or value - it is factual and objective e.g. In the 20m shuttle run test (beep-test) they reached Level 10, Shuttle 5.
- **Qualitative data** - this is data that is non-numerical in nature - it is based on opinion, feelings, perceptions, and concerns. It is subjective data e.g. survey results reporting an athlete felt 'worried' about the 20m shuttle run test (beep-test), believing they were 'highly unlikely' to enjoy running it.

A number of methods can be used to collect data, and various methods will be discussed later in this chapter. However, no matter what data collection method is used, to assist a performer or coach improve participation and/or performance, it must be valid and reliable:

- **Reliability** - A data collection method is considered **reliable** if the same result can be repeated when using the same method on repeated occasions e.g. the athlete's mass was consistently measured at 74.5kg, even after several repeated measures. Reliability is essential to make sure that any differences between a 'pre' and 'post' test are the result of the program (a training effect) and not measurement error or variability.
- **Validity -** A data collection method is considered **valid** if it measures what it actually intends to measure e.g. the standing vertical jump test is a valid measure of power in the legs. It would not be valid to say that the 30m sprint test is a measure of power - despite power being an important aspect of a 30m sprint performance.

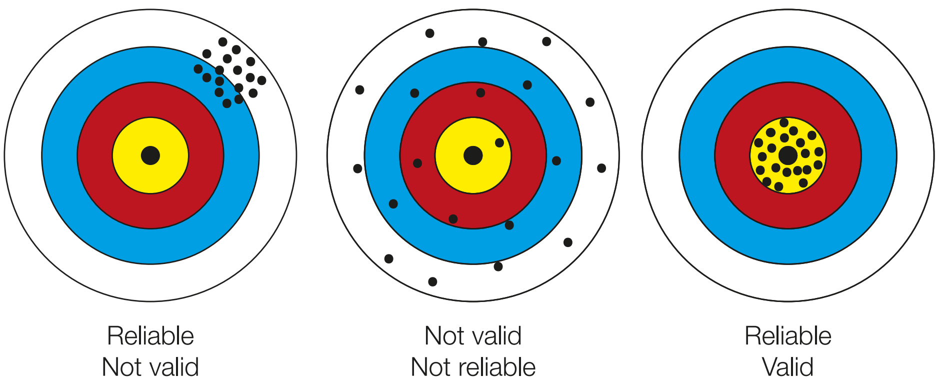


Figure 1.6.1: A data collection method must be valid and reliable for accurate 'data analysis'.

Validity

Will your data actually measure what you think it is measuring? For example, a student decides to collect data for an analysis of a team member's 'decision-making' by observing the number of effective passes they make during an activity. However, if the activity used for this data collection is a closed drill, then the data will only provide feedback in the form of knowledge of results (the number of successful passes made). A closed drill has little to no tactical decision-making elements in the activity - so the data collected is not valid. In this instance, a game-based model of teaching, where tactical and strategic problems are posed in a modified game environment would be a better option to allow a player to make tactical decisions based on the **affordances** in the game - so the data is valid.

Figure 1.6.2: A 'drill' based activity.

Drill based activity - performed in a rehearsed, closed environment with minimal decision-making opportunities. Not a valid measure for evaluating the decision-making abilities of a player.

Figure 1.6.3: A Game-based activity.

Game based activity - performed in an open and unpredictable environment where a player must respond to the opportunities for action (**affordances**) presented in the game. This would be a valid measure for the decision-making abilities of a player.

Making sense of movement concepts and strategies to improve participation and/or performance

Before data can begin to be collected, a coach or performer must also consider carefully the measures (movement concepts and strategies) they are wanting to measure, in order to establish what they want to find out. In the Year 12 Physical Education course, the following movement concepts and strategies are looked at as ways for a player(s) or coach improve participation and/or performance:

Movement concepts are needed in all sports

Movement Concepts

- Body Awareness
- Movement Quality
- Spatial Awareness
- Relationships

Movement Strategies

- Executing movement
- Creating space
- Interactions
- Making decisions

Figure 1.6.4: Movement concepts are needed in all sports.

The **Movement Concepts** are elements of movement that provide a framework for enhancing movement performance.

Table 1.6.1: Movement Concepts.

Movement Concepts	
Body Awareness	Refers to ***what the body can do*** (what movements can be performed?): • Balance • Flight • Stability • Transfer of body weight. Criteria to consider may include - body shape (stretched, curled, twisted, symmetrical, asymmetrical etc.), body parts used (arms, legs, head, torso etc.) and the body action involved (flexion, extension, rotation, stability, swing, pouch and pull etc).
Movement Quality	Refers to ***how the body can move*** (effective execution of movements): • Speed • Accuracy • Force • Flow. Criteria to consider may include - the continuity and outcome of movements i.e. Fast or slow? On-target or off target? High force or low force? Free flowing or bound and restricted? Effort (high motivation or low motivation?)
Spatial Awareness	Refers to ***where the body can move*** (awareness of space for the body to move): • Use of space • Direction of movement • Planes of movement • Movement pathways. Criteria to consider may include - personal and general space; curved, straight or zig-zag pathways; sagittal, horizontal or frontal planes; forward, backwards, sideways, up or down; heights (high, middle or low).
Relationships	Refers to ***human and environment*** (connections with objects): • People • Positions • Equipment. Criteria to consider may include - position on courts or field; people (alone, opposition, officials and team), equipment (bats, balls, uniform etc).

The **Movement Strategies** refer to a variety of approaches that will help a player or team to successfully achieve a movement outcome or goal. These broadly include the ‘tactics’ that are required in a game to solve a problem and include: executing movement, creating space, interactions, making decisions.

Although different games will have different rules and regulations, many sports require similar activities or goals and will therefore use similar movement strategies to achieve success.

Table 1.6.2: Movement Strategies.

Movement Strategies	
Executing Movement	Refers to relationship to/with objects, people and space: • Application of individual movements to collective game strategy: ○ Patterns of play (attacking/defence systems of play) ○ Use of space (concepts of width and depth) ○ Situational plays ○ Identifying strengths and weaknesses (game strategy/tactics and counter tactics) ○ Fitness factors - strengths and other constraints.
Creating space	Refers to movement within and around the playing area: • Create space while invading your opponent's territory (attack) ○ Create space for teammates ○ Create space for yourself ○ On-ball and off-ball running ○ Width v depth v balance • Contain space while the opposition is invading your territory (defending) ○ Zone v player-player, width v depth v balance • Hitting a ball into space (away from opponents) to make it difficult to retrieve or return the ball.
Interactions	Refers to interactions with opponents and other players: • Communication (verbal and non-verbal) • Tactical discussions • Change interactions/relationship - movement, space and time • Team approaches (warm up, training, reflections, goal setting) • Fair play (opposition, officials, spectators) etc.
Making Decisions	Decision making in the context of the changing game environment: • Gain/maintain possession • Avoid defensive players • Attack/defend the goal • Offense/defence positioning • Predicting opponent's movement • Utilising team strategy.

Curriculum link

To meet the SACE assessment criteria, it would be highly recommended for students to collect data for reflection and goal setting (to improve the participation and/or performance of themselves or other players) in reference to the SACE movement concepts and strategies.

Application of concepts and strategies in unfamiliar contexts

There are a number of methods that can be used to gather data on all eight of the Movement Concepts and Strategies listed above. However, because a student's overall assessment in a unit of work will be determined by the students' own learning and what has taken place, as well as, their ability to reflect on what they and/or others have learned, the most accurate data collection method(s) will be unique to each student's needs. However, the information presented below should provide a starting point for a general idea of how to collect data to provide information on strengths and areas where they or their team might want to improve.

Standardised fitness tests - These are primarily the fitness tests that are discussed in Focus Area 1.2: Application of the effects of training on physical performance. Standardised fitness tests have strict protocols to follow to ensure reliability of the data collected, to ensure any variations in measurements between 'pre' and 'post' test measures are the result of training improvements and not measurement error. There are a wide variety of different tests that can be used to gather data on the specific fitness factors relevant to performance. Most standardised fitness tests also have ‘norms’ (normative data) for athletes to compare themselves to.

Sometimes, a fitness testing battery relevant to the sport or activity is useful to establish baseline data with a fitness profile and use this to monitor performance improvements that may occur after a training program.

Table 1.6.3: A standardised fitness testing battery used for data collection for Australian Football.

Fitness Test	Fitness Factor	Specificity to AFL
30m Sprint Test	Speed	Short sprints to win a 50:50 contest
Standing Vertical Jump	Power	Maximal jump (100%) to win a marking contest
20 Shuttle Run (Beep Test)	Cardiovascular endurance	Players cover 15km+ with lots of submaximal periods of recovery after high intensity efforts.

Heart rate monitors

Monitoring a player’s heart rate can provide valuable data in a number of different contexts:

- Are players exercising in the correct HR zone (and therefore the correct intensity)
- Are players adapting to training (submaximal HR decreasing with same workloads etc)
- Causes of fatigue (a high HR indicates high exercise intensity above OBLA and therefore lactate accumulation - implications for game strategy etc)?

Figure 1.6.5 and 1.6.6: Heart rate monitors and associated apps provide data for a focus on the body’s response to physical activity.

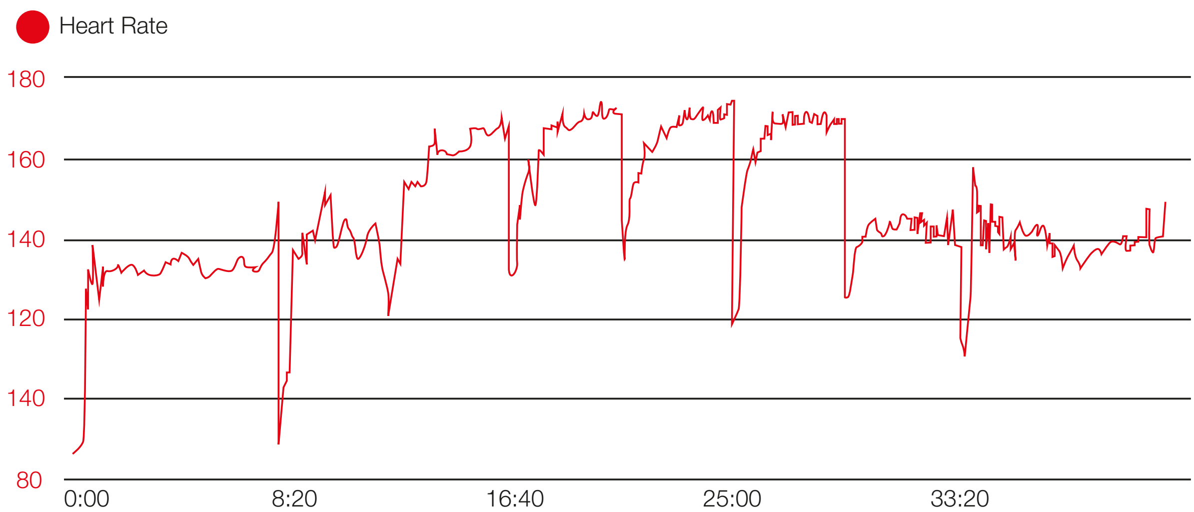


Figure 1.6.7: Heart rate data during a training session - with 4 × 1km efforts (tempo).

Standardised Skills Assessment

Specific skills criteria assessments can be used by teachers and coaches during competition or game situations to inform their judgments against specific performance standards.

Table 1.6.4: Skills criteria assessment for volleyball – blocking.

Specific features	Specific skills	Grade Level
Blocking	Ability to consistently: • Use effective technique incorporating timing and execution • Move effectively in response to the position of the set • Position block appropriate to where the ball will cross the net • Move effectively to establish double block when appropriate	**B**

Standardised Skill Tests

There are countless examples of Standardised Skill tests (as opposed to fitness tests) that students can research and perform to establish base-line data. Although these tests are by nature performed in a very 'closed' environment without elements of decision making, they can still be useful to try to assist with the evaluation of changes in technique when looking at key ideas such as Focus Area 1.3 : How does biomechanics affect physical activity and movement.

Table 1.6.5: Skills Test - backhand flick serve.

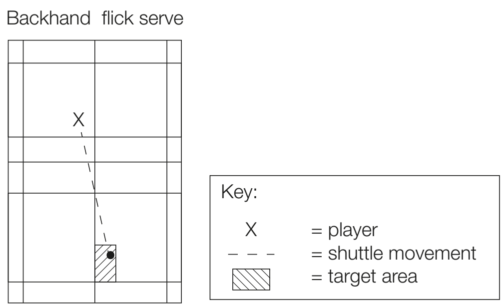
<table>
<tr>
<td>


Figure 1.6.8
</td>
<td>
The player stands in position (as shown on diagram) and serves using a 'backhand flick' over the net into the target area.
Scores are recorded.
Generally, a basic test scoring system would involve the number of correct attempts out of a predetermined number of attempts.
More elaborate scoring systems can be developed with criteria in place i.e.
• 'Minimum height' for shuttle to be hit
• Graded scoring - a 3, 2,1 or 0 point scale based on where the shuttle lands on the court.
</td>
</tr>
</table>

Adapted from the Government of WA School Curriculum and Standards Authority https://senior-secondary.scsa.wa.edu.au/syllabus-and-support-materials/health-and-physical-education/physical-education-studies

Game Performance Assessment Instrument (GPAI)

One recognised method of collecting data to measure game performance when using a game-based model of teaching is the Game Performance Assessment Instrument (GPAI). This method of collecting data allows for the assessment of a player's decision-making ability and their skill execution, so it provides a more holistic assessment of a player's ability within a game context.

Table 1.6.6: GPAI collection method.

<table>
<tr><td colspan="2">The GPAI is a collection method based around seven different game components that include both 'on-the-ball' and 'off-the-ball' movements during a game. Game components can be re-written to become sport specific. If any components do not apply to that activity, they are simply omitted.</td></tr>
<tr><td>Base</td><td>Player returns to a 'base' or 'home' position on the court following each skill execution</td></tr>
<tr><td>Adjust</td><td>Player's court/field movement (offense and defence) during the game</td></tr>
<tr><td>Decision Making</td><td>Player's decision-making during the game</td></tr>
<tr><td>Skill Execution</td><td>Player's efficient performance of skills during the game</td></tr>
<tr><td>Support</td><td>Player's off-the-ball movement</td></tr>
<tr><td>Guard/Mark</td><td>Player's defensive role marking opponents (with or without the ball)</td></tr>
<tr><td>Cover</td><td>Defensive support for the player on-the-ball</td></tr>
</table>

Table 1.6.7: A Game Performance Assessment Instrument (GPAI) for volleyball.

<table>
<tr><th colspan="6">A Game Performance Assessment Instrument (GPAI)</th></tr>
<tr><td colspan="6">1. Focus on an on-the-ball or an off-the-ball movement skill.
2. Record "✓" or an appropriate response or "✗" for an inappropriate response for each movement skill as the point is played.
3. After 3 or 4 points give feedback to your player based on your observations.
4. Return to game focusing on new movement skill or repeat movement skill if improvement needed</td></tr>
<tr><td>Skill</td><td colspan="5">Hitting the ball efficiently into the appropriate target area/striking the ball in the hitting zone</td></tr>
<tr><td>Base</td><td colspan="5">Recover to a position to defend expected target area/transition to attack opponent's target area</td></tr>
<tr><td>Decision Making</td><td colspan="5">Read game with anticipatory movement/set up and moving-in to attack/attack options</td></tr>
<tr><td>Cover</td><td colspan="5">Respond with quick split-step preparation/move to cover where ball sent</td></tr>
<tr><td>Adjust</td><td colspan="5">React to ball with small push-off movements to set-up to execute shot in the hitting zone.</td></tr>
<tr><th>Player</th><th>Skill</th><th>Base</th><th>Decision Making</th><th>Cover</th><th>Adjust</th></tr>
<tr><td rowspan="2">Lockie</td><td>✓✓</td><td>✗✓✓</td><td></td><td></td><td>✓✓✓✓✗</td></tr>
<tr><td>Well timed Backsets</td><td>Good defence coverage position 6</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Ashleigh</td><td>✓✓✓</td><td></td><td>✓✓✓</td><td>✓✓✓✓</td><td>✗✓✗</td></tr>
<tr><td></td><td></td><td>Good attacking shot selection</td><td></td><td>Jump off two feet to avoid net touch</td></tr>
</table>

General Observation Schedules look at all the basic aspects of a performance. They allow strengths and areas of development to be identified during a game performance.

Table 1.6.8: Observation Schedule: Soccer.

Record each time the behaviour is seen in the game					
Criteria	**First Half**	**1st**	**Second Half**	**2nd**	**Totals**
Dribble left foot	✓✓✓✗	3	✗✓✗	1	4
Shot – right foot	✗✓✗	1	✗	0	1
Shot – left foot	✗	0	✓✓	2	2

Table 1.6.9: Observation Schedule: Badminton.

General Observation Schedule				
Criteria	**Never**	**Occasionally**	**Regularly**	**Always**
Varied shot selection		✓		
Use of deception		✓ predictable drop shots		
Recover to base			✓	

Touch Football – Game Fitness Analysis

Table 1.6.10: Observation Schedule: Touch.

Athlete:	Charlie D	Date: 13 / 03 / 19 Game Play Period: 9 mins	Recorder: EM
Movement		**Frequency**	**Totals**
Standing	Standing	II	2
Shuffle	Right	III	3
	Left		3
Walking (50-60%)	Walk 1-10m	F 𝍸	5
		B III	3
	Walk 11-20m	F	
		B	
	Walk 20m+	F	
		B	
Jogging (60-75%)	Jog 1-10m	F 𝍸	5
		B IIII	4
	Jog 11-20m	F	
		B II	2
	Jog 21-30m	F	
		B	
	Jog 30m+	F	
		B	
Running (75-90%)	Run 1-10m	F IIII	4
		B III	3
	Run11-20m	F I	1
		B I	1
	Run 21-30m	F	
		B	
	Run 30m+	F	
		B	
Sprinting (90-100%)	Sprint 1-10m	F II	2
	Sprint 11-20m	F II	2
	Sprint 21-30m	F I	1
	Sprint 30m+	F	
Other	Dive (Score / Tag)	I	1
	Lunge (Score / RollBall / Scoop etc)	II	2

This observation schedule (Table 1.6.10) was actually developed by a group of students in a lesson (plus homework) prior to a Touch game.

Step 1: A recording of an elite game of Touch was viewed and annotated by the students. Through observation of the recording, the dominant movement patterns were noted and documented during the game (fitness factors, type of movements, speed of movements, direction of movements) etc.

Step 2: Game notes and annotations were discussed and through discussions and collaboration, transcribed to become the General Observation Template (Table 1.6.10).

Step 3: Three teams were established to play in a game of Touch - teams A, B and C. Through a rotated schedule, all teams played each other in a round-robin tournament. Each team were allocated an 'observation duty' when they weren't playing, and they recorded the movement data for one allocated player, on the template.

Scatter diagram

This is similar to a heat map, but it involves simply documenting a 'map' of the playing area - in this instance a soccer pitch. An observer can then plot on the 'map' where a performer has had touches of the ball. Using an identification system (i.e. blue = successful or red = unsuccessful), students can analyse movement around the pitch in a very easy to read way.

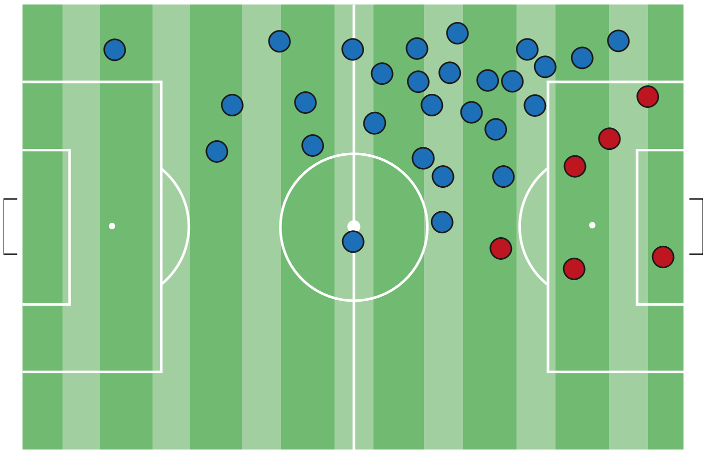


Figure 1.6.9: The plots of ball contacts (successful or unsuccessful) provide a quick movement reference which can be compared to elite performers.

This is an easy way to construct a version of a 'heat map'.

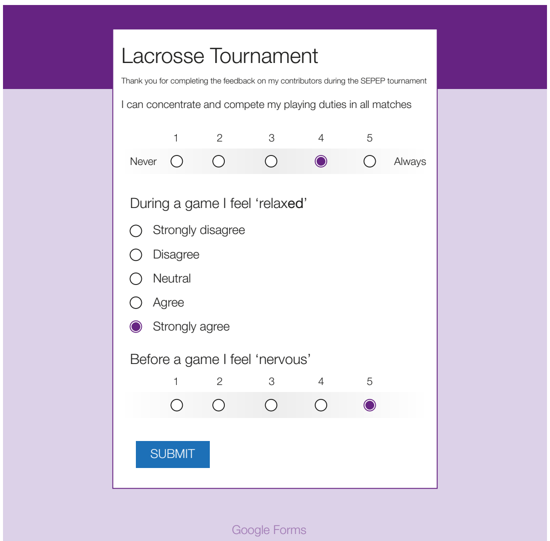


Figure 1.6.10: Survey form to reflect on the Psychological and Sociological knowledge base.

Qualitative data collection

This is data based on opinion, feelings, perceptions, and concerns. The main methods of data collection are likely to be as follows:

- **Player interviews** can be structured or unstructured and individual or focus group based.
- **Questionnaires** can be used to find out about a variety of sociocultural or psychological factors that impact on performance. The result is written down in hard copy or electronically recorded in a survey platform (Survey Monkey/Google Forms etc) and the findings produced can give an idea of both how well you do something and how often you do something.
- **Reflection diaries** record an individual's feelings and thoughts about their training, progress or performance. Reactions to situations such as happiness, anger, and surprise can affect the performance. This can provide information about a performer's strengths, worries/concerns and areas for development and data for the psychological and sociological knowledge base.
- **Self-appraisal/questionnaires** can record data on an individual, team or group's ability to work cooperatively and display team spirit etc. Refer to Figure 1.6.10.
- **Junior athlete-friendly** forms to collect qualitative data may be an important consideration if you or your group are working with primary school students and need to collect valid data.

Figure 1.6.11: Junior athlete friendly.

Player tracking - video analysis

Many elite sporting teams make heavy use of player tracking devices with heart rate monitoring and global positioning systems (GPS) to track player movements for data reflecting a player's intensity of effort, speed of movements and distance covered. These setups provide insightful information but can be cost prohibitive in a school environment. Alternatively, students and/or coaches can videotape student performances in a game setting (video camcorder, SLR or phone) with accessible technology, and then watch and translate data to construct their own personalised 'player tracking' data. The worked example shows tracking for 3 minutes in netball game.

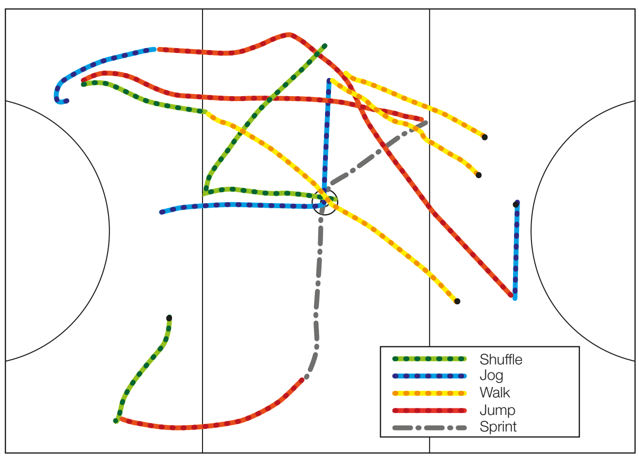


Figure 1.6.12: Video analysis of a netball player (centre) from video analysis - movement specific.

Focus Area 2: Through Movement

2.1 Social Psychology

- Group dynamics
- Team-building strategies; communication, leadership, norms, rules
- Personal well-being; growth mindset, character strengths

Group dynamics

A study of **group dynamics** looks at the interplay of behaviours, actions and the psychological processes of a group. These processes can occur within or between groups. A group is defined in this context as being two or more individuals who are connected by and within social relationships (Forsyth 2014).

Stages of Group Development

Groups go through stages as they develop. This is due to various individuals, each with their own experiences and opinions attempting to merge into one cohesive unit. Group formation progresses through stages, but exactly how many stages depends entirely on the theory of group development one decides to adopt. Tuckman and Jensen (1965) were some of the early pioneers in this area suggesting five distinct group formative stages. In comparison, much later work by theorists Kottler (2001) or Yalom (1995) proposed either three or four stages. Despite these differences, the theoretical underpinning of all these frameworks are very similar.

Groups start with uncertainty, with individuals coming together to **form** a group. Norms or rules for the group haven't been established or adopted yet, trust needs developing, and members are initially more compliant or conforming to any initial leadership structure. However, in the next stage, individuals become more confident and assertive, so less conforming and **conflicts** begin to arise over different opinions. This may lead to new leadership, and the roles of all group members becoming clearer.

With conflicts resolved, members interact more openly with each other in the third stage as the trust begins to grow. **Norms** begin to be established that help with the governing of the group. There is now also a greater recognition of the group roles, with members taking more personal responsibility of these roles. The fourth stage is the '**performing'** stage, where essentially the work of the group gets done. The group strives to achieve their goals.

The last stage covers the **dissolution** of the group once the task is completed.

Forming (Orientation) → **Storming** (Conflict) → **Norming** (Structure) → **Performing** (Performance) → **Adjourning** (Dissolution)

Figure 2.1.1: Tuckerman and Jensen's (1965) original theory on the 5 stages in group formation.

The actual formation a group or groups will vary depending on the environment in which they form. For example, groupings in business are generally based on experience, skill levels etc. While in a school setting, group formation is often randomly or semi-randomly assigned by teachers or a student led selection process. The method used to form groups can have implications for the overall work output. Researchers (Chapman et al 2006) looking at the influence of the group selection method, found students were less satisfied with their group if randomly assigned compared to self-selected. The desire to work and the pride in their work was self-reported to be higher in the self-selected groups.

Diversity

There are mixed results also reported on diversity in group composition (Van der Vegt & Bunderson 2005). One would think that a greater diversity in a group would allow for a greater range of opinions and ideas. Although diversity in group members would provide this, the group still needs to interact effectively to achieve outcomes. So, the time it takes for a diverse group to 'gel' and get to know each other etc, may compromise the outcome.

Figure 2.1.2: Diversity in groups can bring a wider range of ideas and opinions

Group Efficacy

Group efficacy (one's belief in the group's ability to achieve) has also been reported as a factor influencing the dynamics and performance of a team (Potosky and Duck 2007). The more members of a group that believe in the group's ability to achieve the task at hand, the more likely they are to behave in a manner conducive for the group to succeed.

Group Size

The number of members in a group can influence its nature. For example, a group of three is more likely to be directly connected to each other compared to a much larger group. By not having members directly connected to each other a larger group is more likely to split into subgroups. The number of ties or relationships needed to connect all members of a group increases exponentially as the number of group members increase (Forsyth 2014).

Ultimately it is important to use a group selection method that allows group members to work together or have the potential to work together to complete tasks effectively.

Social Loafing

This is a concept which refers to the idea that people will work less or exert less effort on a task if in a group situation compared to working alone. This concept goes against the idea that pooling resources and working in a team will be more productive and generate a more efficient product. The basis for this concept is that individuals may experience less personal accountability with more people doing the task. They may assume that someone else is doing it.

Group size also impacts on this concept. In smaller groups individuals are more likely to believe that their contribution is worthwhile, important and valued. The '**Ringelmann effect**' states that individuals become less efficient as the size of the group increases. This concept was discovered by a Frenchman by the name of Maximilian Ringelmann. He was able to prove in an experiment, that when you have more people pulling on a rope (tug of war for example), the group becomes less efficient, as individuals didn't exert themselves as much. A sporting example would be:

- Rowers in a coxed 8: An individual might perform very well individually on the rowing ergometer, yet when in a team of eight their output is less.

Focus Questions

1. Using the definition stated earlier for a group, would you classify a crowd at the football as a group? Explain your response.

2. Consider a group that you are in (sporting, social etc) and discuss the following points:
   (a) The group you are involved in.
   (b) The roles in the group, and what your role is.
   (c) The norms of the group vs the rules of the group.

Team building strategies

Norms

Norms are informal rules that govern the way a group interacts. These norms are often unspoken or unwritten rules. Norms aren't necessarily the same, they vary based on the group, the group personnel and what the aim of the group is. Norms guide individual members within the group on how to act in the group setting. In comparison, rules dictate behaviour/actions in a group.

Establishment of acceptable social standards and group behaviour will need to be developed in the initial stages of any group forming. Recognition of the developed 'group norms' is important for the effective functioning of the group.

Leadership

Leadership in any group setting will need to involve facilitating some degree of social or emotional support to be effective. Some ways this support can occur is through:

1. Encouraging: responding to contributions by group members in a positive way and respecting all group members. This fosters a positive and safe environment that members will feel comfortable contributing to in future.
2. Harmonizing or balancing views: differences in opinions and ideas will need to be reconciled in a positive and constructive manner. This helps reduce group tension.
3. Gate-keeping: Controlling access in the sense of who is contributing. A leader needs to ensure all members of the group can contribute. One member can't be allowed to dominate communication at the expense of the others who wish to contribute.
4. Maintaining norms/settings: reminding group members of expectations, roles, norms, rules etc, if they stray from these previously set standards.

Leadership doesn't need to be an assigned role in a group setting. All the strategies above can be instigated by any of the group members, it doesn't need to be the assigned chairperson, captain etc.

Figure 2.1.3: Leadership in a team doesn't always have to come from the Captain or person in charge.

Are leaders born or made?

Debate on whether leaders are born or made has been argued for centuries. Behavioural theorists believe leaders are made. Therefore, anyone has the potential to be a leader. Developing leadership occurs through life observations (**Social Learning Theory**), and teaching. The skills needed to be a great leader are taught through life experiences, practice, direct teaching etc. The Australian Defence Force is an obvious example in life of **Behavioural Theory** in action. They have a whole college dedicated to teaching recruits leadership.

Conversely, there are those that assign to '**Trait theory**'. This is probably the more popular theory that underpins the idea that leaders are born, **not** made. By looking at great leaders, key traits or attributes that aid leadership were established. Attributes like motivation, integrity, self-confidence, achievement, etc. were determined to be important. From this list of traits, leaders can be identified.

Leadership styles

One of the more common theories on leadership or coaching styles, is that there are three major coaching styles or models of coaching. These three styles have a variety of alternative names, yet the characteristics are constant:

Authoritarian

The authoritarian coach dominates the learning environment, setting all the tasks, making all the decisions and instructing rather than asking.

Democratic

The democratic coach is more open to suggestions about training and guides the team or individuals rather than directing. The coach is more interested in the players' impressions and what experience they can bring to the group. Generally, the democratic coach is far more supportive.

Casual

The coach's role is minimal with this style of coaching, with players running most of the training and decision-making. The coach takes on more of a supervisory role. How much involvement this type of coach has will depend on the independence of the players.

A good coach will inevitably have a degree of more than one style, dependent on the level of the learner in their care and the activities they teach or coach. For example; an authoritarian coach might be an appropriate form of coaching to beginners in dangerous activities i.e. head stands or somersaults in gymnastics to avoid injury. Yet, later when the same athletes have mastered these skills, an authoritarian approach may no longer be appropriate.

Communication

The level of communication that occurs within a group depends on various factors

- How well members know each other
- Personality type
- Opportunities given to voice opinion
- Safe environment in which to express opinion

Communication in a group dynamic setting is the 'sharing of ideas, opinions or information', preferably by everyone.

No communication by members doesn't mean that they agree with an idea, opinion or the direction the group is taking. So, it is important that all members communicate. Everyone has an opinion (or can contribute). An effective group weighs up all these opinions and makes a fully informed decision.

Figure 2.1.4: Regardless of the mode of communication, a good group will listen to everyone's opinion.

SEPEP

Team building for SEPEP (Sports Education in Physical Education Program)

In order for your team to perform to their maximum potential in a SEPEP unit, your team needs to make the best use of its individual group members. Team coaches (Tactics, Technical, Fitness and Motivational) can work collectively to achieve this by:

- Establishing clear group and individual roles of equal status
- Encouraging shared decision-making
- Setting group goals with time limits
- Encouraging group identity (name, uniform, tactics etc)
- Respecting group members.

Personal well-being

Well-being

The term ‘well-being’ is a construct, as it’s an idea or theory that is composed of various conceptual elements (ideas or notions that occur in the mind). Well-being is used in positive psychology rather than ‘happiness’, as happiness or what constitutes happiness is dependent on the individual. What constitutes the conceptual elements of personal well-being depends on the theory being followed. For example, the PERMA model of wellbeing proposed by Seligman (2011) reports five elements that contribute to well-being. By making more informed choices around these five elements, it is suggested that you can improve well-being.

- Positive emotion – joy, comfort, happiness
- Engagement
- Relationships
- Meaning and purpose
- Accomplishment

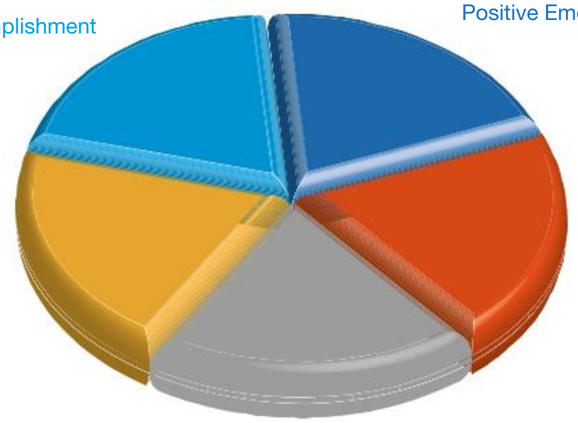


Figure 2.1.5: Five elements of the PERMA theory of well-being

In the PERMA theory on ‘well-being’, (Figure 2.1.5)) each of the 5 elements contribute to an individual’s well-being. However, it should be noted that an individual’s path to ‘well-being’ will vary and the contribution from each of these five elements won’t be consistent across groups of people.

Positive Emotion

This element is about increasing your positive emotion. This is about joy, comfort and happiness, or basically feeling good about life or oneself. In a sporting context, positive emotions are important. When you are enjoying or interested in the activities you are undertaking, then you are more likely to continue with that activity and strive to improve, even in the face of challenges. Positive emotion can also negate negative feelings if a shot, kick etc wasn’t successful in sport or an idea didn’t work in a group setting.

Engagement

Engagement is the level of commitment to a task. So, the more engaged an individual is to the task the more likely they will get satisfaction or gratification from the process. This means fully employing their skills and attention to the task at hand. The positive psychology term for this gratification or satisfaction you can achieve through doing this is ‘a state of flow will be reached’. This is a point where you are participating in the activity for the ‘love of it’, rather than because it leads to something or you get something out of doing it. In a group setting or sporting environment, engagement is likely to be developed if an individual’s skills and talents are identified and they are given the opportunity to use this skill or strength to the betterment of the group. This links in to Focus Area 1.4: Linear vs non-linear teaching methodologies. Linear teaching methodologies are based around skills and drills. So, motivation and direction are extrinsic. Non-linear teaching methodologies include game-based or constraints-based activities. Through manipulating certain constraints or factors within a game so different information or problems are presented, learners can take more ownership for their learning and movements. Motivation and direction are more intrinsically driven.

Relationships

A positive relationship with others is core to 'well-being' and happiness. Forming friendships or a relationship with a group or team members can also lead to more trust developing within a group and lead to greater sharing or contribution.

Figure 2.1.6: Positive relationships improve well-being.

Meaning

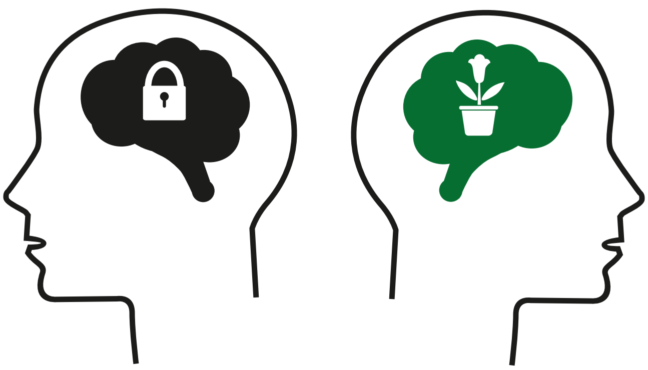
This looks at whether individuals believe they have a 'sense of meaning or purpose'. An individual that believes they have a 'purposeful existence' within the group is more likely to want to be there, be actively involved and find satisfaction in the task.

Accomplishments

This element relates in part to having goals and achieving these goals. Realising goals leads to a sense of accomplishment. There is a sense of pride, fulfillment or satisfaction from mastering a new skill, or having success in a sporting activity. These achievements can also link into self-esteem and self-efficacy. Feeling better about yourself because of your achievements increases the belief that you can achieve more (self-efficacy) and therefore a greater desire to engage with tasks.

Mindset Theory

The mindset individuals or members bring to the group can make a difference to personal achievement and group outcomes. The mindset individuals have plays a role in motivation and interpersonal interactions within the group. Carol Dweck (2006), a researcher at Stanford University developed a theory that there are two core mindsets. A **fixed mindset** and a **growth mindset** that essentially sit at opposite ends of a continuum. These beliefs or mindsets shape how individuals approach challenges, which in a group setting is important to understand.



Fixed Mindset vs Growth Mindset

Figure 2.1.7: Mindset theory – growth vs fixed mindset.

Helpful online resources

Watch the following YouTube clip for more information:

youtube.com/watch?v=KUWn_TJTrnU

Fixed mindset

The fixed mindset involves an individual believing that ability, talent and intelligence is fixed. Essentially, an individual believes they are born with a certain level of ability. With this mindset, individuals will tend to avoid challenges, give up more easily to obstacles and see effort as worthless. The reason being, that if your ability is already set 'why would you try to do better'? This mentality is also driven by a desire to look smart or intelligent (Dweck 2006), so failing at challenges, damages this image. Success of others around them may also challenges this image.

Growth mindset

A growth mindset however, embraces challenges and persists with obstacles as there is a genuine desire to learn. So, effort is seen to develop new skills and talents. For that reason, criticism and challenges are constructive and helps refine mastery of a skill, rather than being taken as negative. The success of others is perceived as inspiration to achieve.

In a group setting, individuals with a growth mindset will more often result in higher levels of achievement. This is due to their ability to embrace any challenges that the group faces. This coupled with a willingness to learn and not be afraid to make mistakes, gives a group more flexibility when faced with problems/challenges.

Figure 2.1.8

Focus Questions

3. Match the characteristics with the correct mindset.

Characteristic	Fixed	Growth
'Loves challenges'		
Mistakes are valuable learning tools		
A successful image is important		
The success of others is problematic		
Very persistent with tasks		
Criticism not appreciated		

Character Strengths

'Character strengths' are concepts developed by two psychologists in the field of positive psychology. Character strengths are the 'psychological ingredients – processes or mechanisms - that define virtues. (Peterson & Seligman, 2004).

Virtues are characteristics valued by society or individuals as they promote 'greatness', 'goodness' or high moral standards. Therefore 'character strengths' help individuals and/or groups achieve these virtues.

In 'positive psychology', there are 6 virtues (Peterson and Seligman 2004). Within these virtues lie the 'Character strengths' that define them.

- **Wisdom**
- **Courage**
- **Humanity**
- **Justice**
- **Temperance**
- **Transcendence**

This construct developed by Peterson and Seligman (2004) and the placing of the 24 'character strengths' within each virtue is theoretical, so care should be taken when interpreting any results generated from any survey. For example, two studies looking at how well the character strengths fit into the 6 virtues, both reported degrees of overlap. Meaning, an individual character strength could fit into more than one virtue. The results of one study, revealed that the character strengths fitted better into a one or four virtue models, not six (McDonald et al 2008). So, either having just one overarching factor, or four may be plausible. McDonald and colleagues suggested the 4 virtues (Interpersonal strengths, Fortitude, Vitality and Cautiousness) option better encompassed the 24 character strengths.

For the purpose of this workbook, Peterson and Seligman's (2004) model (six virtues) has been adopted. However, you can research and adopt your own model if it better suits your requirements.

In addition to the six '**virtues'** there are 24 '**character strengths**' that make up our personality:

Table 2.1.1

Wisdom	**Courage**	**Humanity**
Creativity	Bravery	Love
Curiosity	Perseverance	Kindness
Judgement	Honesty	Social Intelligence
Love of Learning	Zest	
Perspective		
Justice	**Temperance**	**Transcendence**
Teamwork	Forgiveness	Spirituality
Fairness	Humility	Gratitude
Leadership	Prudence	Hope
	Self-regulation	Humour
		Appreciation of Beauty & Excellence

It is proposed that everyone possess elements of these 24 character strengths, however, the 'strengths' exist on a continuum. Meaning, everyone has the characteristics, yet in different degrees. An individual's character profile or personality, therefore, is going to be unique.

Extension activity

You can find out your character strengths by taking the free survey at www.viacharacter.org and clicking on the 'take the free survey'. The free results will rank your character strengths from highest to lowest.

Focus Questions

4. (a) Identify your highest ranked character strength.

(b) Research the main characteristics of this character strength.

(c) Which of the character strengths ranked lower than you thought? Explain why?

(d) How does this character strength assist your group work?

Focus Area 2: Through Movement

2.2 Psychology of Sporting Performance

- Neurochemical balance
- Perception of Effort (PoE)
- Strategies to improve an athlete's relationship with Perception of Effort
- Goal Setting strategies; process, outcome and performance goals
- Mental rehearsal strategies; mental rehearsal of the entire performance, visualisation of one aspect of skill execution prior to performance, and internal and external perspectives of imagery.
- Positive self-talk strategies including using positive cue words and positive emotions to create self-belief.
- Self-confidence strategies; identifying how thoughts can affect self-confidence, e.g. Situation, thoughts, emotions and reactions, using affirmation to change personal reactions to situations.

Neurochemical balance

Neurochemicals are chemicals interacting with cells in the brain. Many are neurotransmitters, or chemical messengers, released from neurons which regulate neuronal function (Choudbury et al 2018). Neurochemicals can influence a person's ability to exercise through interactions in the peripheral and central nervous system (Meeusen and De Meirleir 1995).

'When you exercise there is a positive increase in mood related neurotransmitters and a decrease or a balancing of stress related hormones'(Basso and Suzuki 2017). Although this is a very simplistic view of the actual complex neurochemical changes that are occurring inside your brain, in general terms, acute exercise is reported to enhance a person's mood and emotional state.

The changes in neurochemical transmitters, though, is much more complex than the earlier statement would suggest. The intensity of the exercise, or even the level of fitness all impacts the changes in the neurochemicals being released (Ploughman 2008). Adding to this complexity is the fact that some of this 'understanding' on the role neurochemicals play during exercise is based on studies with animals (rodents), rather than humans. Theories or ideas about what is happening at a neurochemical level when we exercise, are also based on assumptions with the chemical's makeup and which areas of the brain it is found etc.

For a Year 12 PE course, physical activity stimulates the release of numerous neuro transmitters. These help with counteracting the pain of exercise and improve your mood. The more common chemicals to do this are;

- Endorphins
- Dopamine
- Serotonin

Endorphins or the 'feel good hormone' is commonly associated with the phenomenon of the 'runners' high'. The 'endorphin hypothesis' states that during exercise this compound activates the brain's opioid receptors (Saainjoki et al 2018). These are the receptors in the brain that control pain and reward. So, the release of endorphins can 'reduce' the pain of exercise and through triggering the release of dopamine also make the experience pleasurable. Although still a popular theory, some researchers are beginning to question it (Dietrich & McDaniel 2004), suggesting instead that **Endocannabinoids** are now more likely to be responsible for this 'high' exercise can produce for some people.

Dopamine plays a variety of roles within the body. The more common role is in the reward system of the brain, where it gives the athlete a sense of pleasure. This acts as a reinforcement for the action or activity i.e. because the brain has received a feeling of pleasure it will want to achieve it again and again. This means, even though exercise and training might be painful, the release of dopamine is 'rewarding the brain'. So, you are more likely to keep coming back to train or exercise.

Serotonin – 'boosts' your mood and overall sense of well-being during and after exercise. The positive effects of exercise on anxiety and stress are in part attributed to serotonin. A positive mood and attitude are advantageous in sport, as it potentially means a greater desire to train or continue training.

Figure 2.2.1: There are numerous neurochemicals that operate in the human brain.

Perception of Effort

Perception of effort is a conscious and subjective feeling or sense of how hard or strenuous a physical task is. It is also known as 'perceived effort or exertion' or 'sense of effort' (Pageaux 2016). Closely related to this concept is that of 'Potential Motivation'. This is the highest level of effort you are prepared to exert in order to complete or be successful in a task. Therefore, if the perceived effort to be successful in a task (i.e. running a 1500m race) is perceived to be higher or more than what you are prepared to exert (perceived motivation), people will likely disengage or stop participating.

Figure 2.2.2

Perception of effort increases as workload increases. Perception of effort increases linearly with a relative increase in intensity or workload. Meaning, two swimmers (one elite, one not) would both have a different perception of effort for swimming 100m at the same pace (or time) as each other. The elite athlete would find it easy if swimming at the same rate as the other swimmer. Yet, if both are instructed to swim at 90% of their VO_2 max, their perception of effort would now likely be similar.

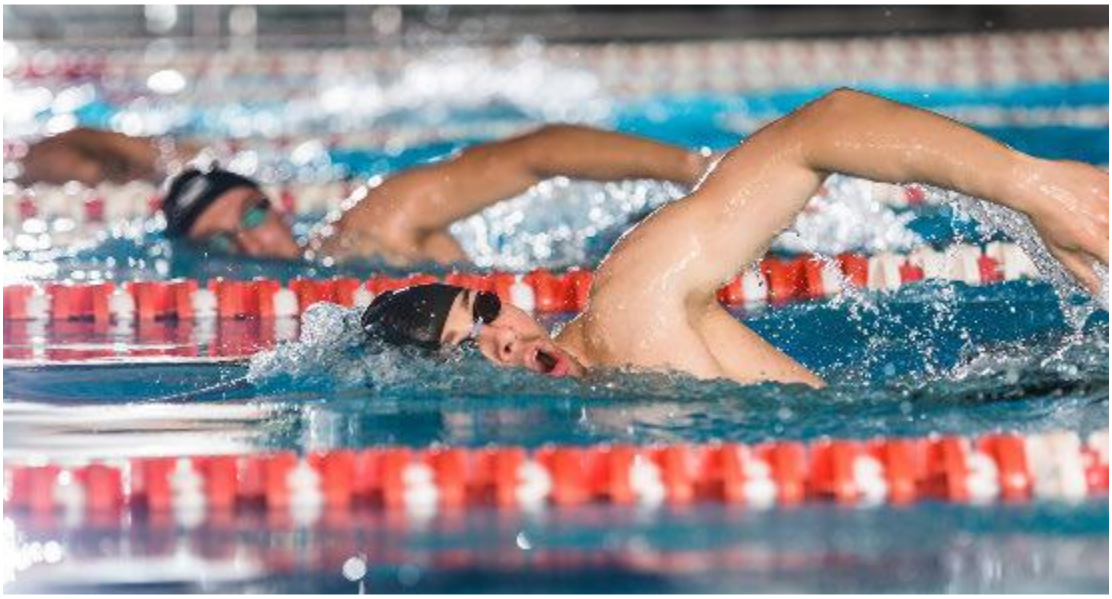


Figure 2.2.3: Swimming 100m

Strategies to improve an athlete's relationship with Perception of Effort

1. As the relative fitness of an athlete impacts on their perception of effort, physical training to improve fitness is a determinant of perceived effort (Marcora 2010). Training effectively and demonstrating fitness gains, aids in giving the athlete more confidence and self-efficacy in their ability to complete a physical challenge.
2. A review of studies into caffeine use before exercise revealed a 5.6% decrease in the rating of perceived exertion or effort (Doherty & Smith 2005).
3. Distraction can reduce a person's perceived exertion or effort rating for an activity, provided it's at low to moderate intensity. For example, listening to music is the most common distraction. The theory behind this strategy is that the capacity to continually process information like the perception of effort is limited. The stimuli of the music competes for this limited capacity in the brain, so distracts or 'takes your mind off the effort'. In turn this has the potential to lower perceived effort or exertion, which may result in a greater output (intensity, workload etc) by the athlete. (Chow & Etnier 2017).
4. Keeping cool during exercise. One study reported cooling the body during exercise reduced the perceived exertion or effort rating compared to non-cooled participants (Armada de siliva et al 2004).
5. Exercise duration. The perceived effort required increases as the duration of the activity prolongs at a fixed intensity or workload (Marcora 2010). This particular concept links in with why some people begin to 'fatigue' during prolonged events.
6. Psychological factors like personality, mood, self-efficacy all can affect a person's perception of effort. Therefore, addressing concerns or improving these psychological aspects can improve the perception of effort.

Figure 2.2.4: Caffeine can influence perception of effort

Focus Questions

1. Using the terms ‘Perception of effort’ and ‘Potential motivation’, explain why a cyclist might drop off the pace in the last one-kilometre sprint finish.

2. Explain how listening to music can improve perception of effort at lower exercise intensities.

3. Explain how wearing ‘ice vests’ at training may influence your perception of effort?

Goal Setting strategies; process, outcome and performance goals

Goal-setting in sport formalises an athlete's goals or personal expectations for the future. The importance of goal setting is two-fold: motivation to continue training and finally to ensure that the athlete remains on track (focused) throughout the training period. For this to be achieved, the goal-setting procedure should follow a few guidelines:

Table 2.2.1

	Example
SPECIFIC It is important that the goal set by the athlete is specific in nature and spells out exactly what they are endeavouring to achieve.	Runs City to Bay in 60 mins
MEASURABLE If the goal is quantifiable (able to be measured), then it is easier for the athlete or others to assess whether the goal was achieved.	60 mins for 12km = running at **5 min/km**
ATTAINABLE The goals need to be realistic. A goal that is too easily achieved could result in the athlete becoming complacent and underachieving. Too hard and the athlete might lose interest.	Currently training 3 × week for 12 weeks to ensure fitness gains.
RELEVANT The goal must be relevant to the athlete and the event or skill that the athlete will ultimately perform.	Does the goal relate to running? Does it relate to 10-12 kms of running?
TIMELY The goal has a deadline or a finish date, to keep the athlete motivated.	City to Bay 20th Sept 2020
EVALUATED Evaluate your goals at regular intervals to ensure they have the best chance to be achieved.	Was goal achieved? Regroup, set new goals if needed.
REVISITED/REWARD Once achieved, reward yourself and then revisit your goals and possibly aim higher next time.	The reward will be a new GPS watch, or fancy dinner etc. Revisit the goal and maybe aim now for a half marathon.

Figure 2.2.5: Goal setting.

In addition, other factors to consider are

Progressive improvement

Over time the goals set by an athlete should produce improvement in relation to the skill or movement. If there is no progressive overload in the expectations or workload, then it will be difficult for the athlete to continue to improve.

Accountability

If the 'contract' or goals you have set are recorded or are known by others (coach), then you become more accountable for your actions. If others know of your plans and what you want to achieve, they can bring it to your attention when it is apparent you have strayed from this goal.

Figure 2.2.6 What are your goals?

Focus Questions

4. Create your own goals for your assessment type two task – 'Improvement analysis' (or a sport of your choice) using the 'SMARTER' principles of goal setting.

Three major goal types that can be utilised by athletes are: Outcome, Performance or Process goals.

Outcome goal

The main goal you are working towards where your performance is compared to other athletes.

Generally, outcome goals are not controlled by you, as the performance of others will affect the result.

Examples:

1. Winning an event or competition i.e. win the 1500m at sports day
2. Finishing in the top 8, or making the finals

Figure 2.2.7: Training to achieve a goal

Performance goal

Performance standard you are attempting to achieve. By working on achieving your performance goal, you get closer to achieving your outcome goal.

You are more in control of these goals.

Example:

If your outcome goal is to win the 1500m run at your local sports day, then performance goals that work towards this might include:

- Run 1500m under 5 min 10 sec by the end of February. Once this performance goal has been achieved, you adjust the performance goal to
- Run 1500m under 5 mins etc.

If 4 mins 48 sec was the winning time last year, then setting performance goals that gradually work towards this time will help achieve your outcome goal.

Generally, performance goals in a sporting context are along the lines of:

- a set distance in a set time or
- number of goals/actions in a game etc.

Process goals

Process goals work towards you achieving your performance goal.

- small tasks that once achieved help you reach your performance goals
- you are in control of these goals ie. they are achievable

Example:

With your **Outcome** goal of winning the 1500m at sports day, you set **Performance** goals related to running times and speeds i.e. you would run 1500m in under 5 mins in 2 months. To help achieve this performance goal you will need to train at least 3-4 times per week. So, your **Process** goal may be ‘I'll train 4 times a week’. This is very achievable, as you are in direct control of whether this happens. By training 4 times per week you are more likely to start achieving fitness gains, meaning your performance goal (run under 5 mins) is more likely to occur.

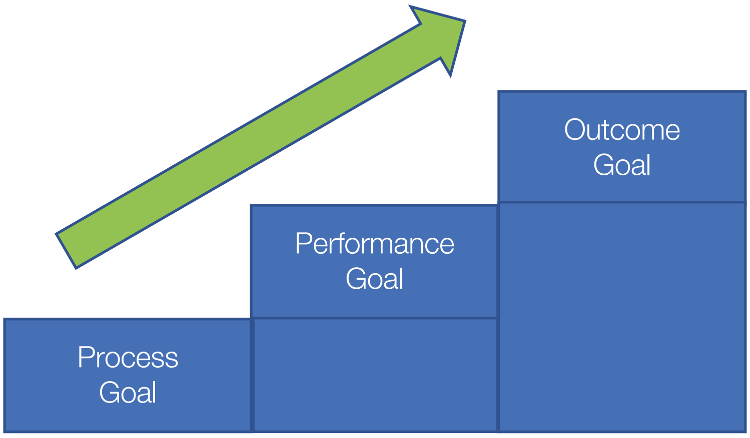


Figure 2.2.8: Process, performance and outcome goals.

Focus Questions

5. Create your own 'Outcome' goal for a sport of your choice (or your assessment type 2 task). Then identify the 'Process' and 'Performance' goals you'll need to hopefully achieve your outcome goal.

Mental rehearsal strategies

Mental rehearsal of the entire performance, visualisation of one aspect of skill execution prior to performance, and internal and external perspectives of imagery.

Mental rehearsal strategies

Mental rehearsal, visualisation, mental imagery, mental practice are all terms that often get used interchangeably in literature, particularly in the public domain. Regardless though of the terminology used, in this book we are classifying them all as a mental technique or procedure where an image, movement, feeling etc is imagined or visualised without performing it in the 'real world'.

Mental imagery is more commonly utilised in scientific literature. However, in physical education literature, you often find a distinction being made between imagery and rehearsal. **Mental rehearsal** is often used to describe the use of imagery for **entire performances**. For example, individuals picture themselves successfully executing skills and movements during a game environment. **Mental imagery** is described as the technique that is employed to enable rehearsal of skills or techniques. Individuals visualise or imagine themselves performing a technique 100% correctly in their mind.

Figure 2.2.9: German Dragon Boat rowing team mentally rehearsing the paddle to come in Singapore, 2008.

Ultimately, mental rehearsal strategies are a construct or theory. For mental imagery, the early work of Allan Paivio (1985) set the basis for a lot of the thinking today. His initial theory stated imagery could have either a cognitive or motivational function. Therefore, the process can be used for reducing anxiety, increasing concentration, and as a tool to develop a technique or movement within a particular skill. Mental rehearsal can reinforce cognitive and neural pathways. So, as it can be used as a learning tool, the rehearsing or visualising of the skill in the mind needs to be accurate (correct) and complete to maximise the benefits of the process.

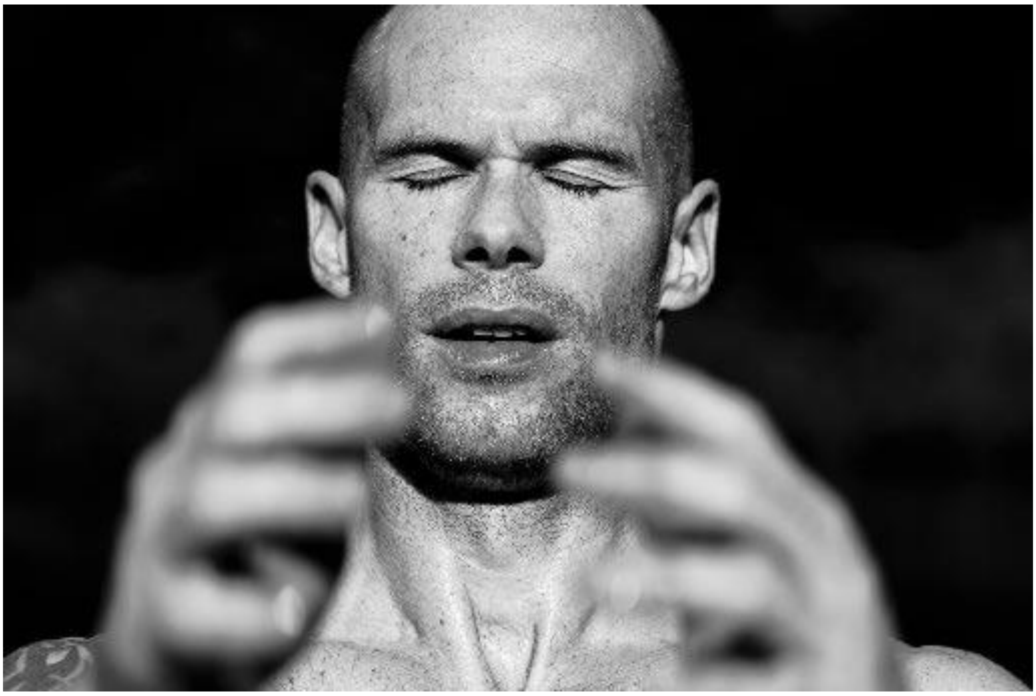


Figure 2.2.10: Divers use mental imagery prior to leaving the platform

There are also different types of imagery in relation to the perspective used. Imagery used to develop motor skills is usually divided into either **visual** imagery or **kinesthetic** imagery (Yu et al 2016). Yet the visual imagery can have an **internal** (1st person) or **external** (3rd person) perspective. The internal perspective incorporates you seeing the movement or play as if seen or filmed through your own eyes. The external perspective relates to you seeing a performance or movement from an external position, much like a spectator watching a game. Kinesthetic imagery is about the feelings and sensations associated with the movement being imagined.

As the external perspective is looking at others conducting the movements and the environment in which it is being played, then it tends to lend itself more to experienced learners in open skills/sports (Yu et al 2016). The internal perspective processes are less complex, so are suited to either open or closed skills, and more accessible to lower skilled learners.

Figure 2.2.11a: Internal perspective and 2.2.11b: External perspective.

The motivational aspect to imagery is about improving self-confidence and motivation through imagining a successful movement. This taps into anxiety and arousal and helps with moderating these levels. One model put forward (Martin et al 1999), suggests there are three types of motivational imagery, each focusing on a different area.

- Self-confidence, mental toughness etc (Motivational General Mastery)
- Anxiety and arousal (Motivational General Arousal)
- Goals and achievements (Motivational Specific)

Outcomes of imagery

Skill development

- One of the main cognitive functions of mental imagery is the development of skills and techniques. The second is strategies and routines used in the competitive environment or game being imaged or viewed in the mind before actually participating for real.

Confidence

- One of the two major motivational outcomes of imagery is a change in self-efficacy, self-confidence or mental 'toughness'. Visualising yourself successfully performing a skill, a component of a skill or achieving a goal is possible through mental imagery. This visualised success can lead to increased confidence and improved self-worth, or belief in your own capabilities.

Anxiety/Arousal

- The second motivational outcome is the regulation of anxiety and arousal levels during competition. Anxiety levels prior to a performance can increase if your level of self-efficacy is lower than the perceived demands of the activity. This in turn can lead to higher than required arousal levels. Imagery used correctly can lead to a reduction in anxiety and arousal through visualising success in techniques or skills, hence improving self-efficacy levels.

Arousal can be described as a readiness to participate. This readiness can vary from a very high level, to the athlete essentially being 'asleep' and showing no desire to participate.

One of the earliest models or theories to try and explain the impact of arousal on performance was the 'inverted U hypothesis' (Humara 1999). This hypothesis states that optimal performance is most likely to occur at moderate levels of arousal (Perkins et al 2001). With a drop in performance associated with low and high levels of arousal, hence the 'invert' U shape graph (see Figure 2.1.12). Although the model has drawn some criticism from sport psychologists of late due to its simplistic nature, it remains one of the most widely used models (Perkins et al 2001).

- The multidimensional theory of anxiety, and the catastrophe model are two other theories to emerge in more recent years due to this criticism.

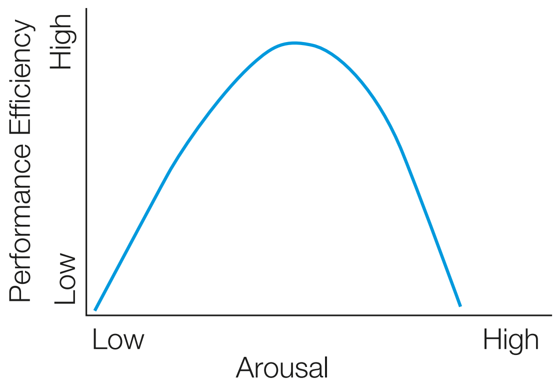


Figure 2.2.12: 'Inverted U hypothesis'

Figure 2.2.13: Mental imagery can have a cognitive or motivational function. Cognitive can improve the swimmer's technique, while motivational can decrease their anxiety and improve self-efficacy.

Why are mental rehearsal strategies successful?

- Mentally rehearsing a movement or game plan allows the athlete to iron out problems in the movement prior to competing. Imagery may function as a coding system in the brain to create a mental 'blueprint' (Yukelson 2013). Mentally devising a game plan ahead of the game allows you to think of all the possibilities that may arise; hence, a more flexible athlete develops who is less 'flustered' by unexpected changes in the game.
- The same area of the brain is activated during 'visualising or thinking' about a movement, as with the real movement (Cummings and Williams 2012). Consciously thinking about a movement activates the brain and the same neural pathways without the muscular contracts. So neural pathways could be strengthened by this process.
- Visualisation can relax the athlete. Stress/anxiety levels fall as the levels of uncertainty about the activities to come are decreased and self-confidence or self-efficacy increases.

Keep in mind, though, that if all competitors in a competition are mentally rehearsing or visualising, then it can only provide ultimate success for one individual or team. Hence, this process is not a replacement or easy fix for regular training. Consequently, mental imagery will be more successful when used in conjunction with physical practice.

Future research

If you wish to research the models or theories surrounding mental imagery in more detail, then you can start with Paivio's model (1985) and progress through the years looking at the adaptations that have been made by other researchers. Starting points (in chronological order) include:

- Hall, Mack, Paivio and Haasenblas (1998)
- Martin, Moritz and Hall (1999)
- Fournier et al (2008)
- or Murphy et al 2008.

Positive self-talk strategies

Positive self-talk strategies including using positive cue words and positive emotions to create self-belief.

Self-Talk

Self-talk is defined as

> 'Statements, phrases or cue words addressed to one self that can be said automatically (spontaneously) or very strategically, either out loud or silently. They can be phrased positively or negatively, having an instructional or motivational purpose' (Abdoli et al 2018).

Some ambiguity still exists in the literature regarding the best way to classify the types of self-talk (Hardy et al 2015). These range from broad, overarching terms like Instructional vs. motivation self-talk, or the more traditional Positive vs. Negative self-talk, to more complex and inclusive means of classification. For example, the Automatic Self-Talk Questionnaire for sport designed by Zourbanos and colleagues (2009) has further classified the spontaneous, positive self-talk into four sub categories and the negative into three sub-categories.

Figure 2.2.14

Pre-determined or goal orientated cue words (or phrases) are carefully chosen words designed to encourage ("I've got this") or improve technique or tactics ("Move the front foot"). The scripted 'encouraging' words are usually classified as **MOTIVATIONAL** self-talk. While the technique orientated words are termed **INSTRUCTIONAL** self-talk.

In comparison, spontaneous or automatic self-talk (unscripted, unintended words that just come to the athlete during the game), are repeatedly classified as **POSITIVE** ("excellent, nice shot") or **NEGATIVE** ("I've lost or I'm going to lose) (Latinjak et al 2017) depending on their content. An athlete's interpretation of self-talk is worth considering too though, not just the content. The reason is that some athletes might benefit from negative self-talk. They could use this as motivation to focus and increase their effort or workload.

Self-talk in sport plays a role in performance and self-regulation (Latinjak et al 2017), with numerous studies reporting benefits across a range of different sports (Abdoli et al 2018; Hardy and Oliver 2014). Yet the research would suggest that you need to distinguish between the type of self-talk (instructional vs motivational) before making such claims, as they appear to impact performance in different ways. The level of skill is also important to consider, as it's uncertain whether findings are interchangeable between skilled and unskilled groups.

Mechanisms through which self-talk appears to impact on performance or facilitate improvement as proposed by researchers (Theodorakis et al 2008) include:

- Improving attentional focus
- Improving confidence
- Regulating effort
- Regulating cognitive and emotional reactions to situations arising in a game or event
- Triggering an autonomous response

Figure 2.2.15

As mentioned previously, a distinction between the different types of self-talk and their impact on performance is important. The 'matching hypothesis' (Hardy et al 2009), looks at this very aspect of self-talk, whereby the task requirements are considered in relation to which type of self-talk would be more beneficial. The thinking is that instructional self-talk would be more beneficial for precision or accuracy tasks. Often these are fine movements or tasks. In comparison, the gross motor task, or strength and endurance motor tasks appear better suited to motivational self-talk. There is currently some intervention research to confirm this emerging view, particularly in relation to the instructional self-talk and fine motor tasks requiring control and accuracy (Hatzigeorgiadis et al 2011; Abdoli et al 2018), yet more research, across more sports would be needed to confirm this view.

Adding to the uncertainty is whether the benefits of self-talk are interchangeable between skilled and unskilled players. A study (Hardy et al 2015) looking at skilled athletes and the accuracy of their kicking revealed motivational self-talk was more beneficial than instructional self-talk. One theory is that the reduced effectiveness of instructional self-talk for skilled performers is in part explained by the theory of reinvestment. This states that a once automated response or action suddenly being consciously processed (thought about) leads to overthinking of a skill and skill decrement (Aboli et al 2018).

Instructional self-talk may also be less effective compared to motivational self-talk in improving performance in less skilled athletes. The thought being that if an individual is not familiar with a particular activity and doesn't know how a movement should look or feel (i.e. their kinaesthetic feel), then instructions are less meaningful. (Abdoli et al 2018).

Mechanism for Motivational and Instructional Self-Talk

- **Motivational** self-talk is hypothesised to improve performance through improving positive, mood, effort and arousal (Theodorakis et al 2000 in Hardy 2015). The performance of athletes would then improve as they are more attentive and have a greater 'readiness to participate'.
- **Instructional** self-talk can regulate the attentional focus of beginners or unskilled individuals by reducing the number or severity of interfering thoughts, thus improving attentional focus. The assumption is then that greater attentional focus (on the relevant cue), leads to more consistent and effective skill performance. (Hatzigeorgiadis & Galanis 2017)

Strategies

Self-talk is an internal dialogue you are having with yourself. In a sporting context we are interested in replacing negative self-talk with positive. Engaging in negative self-talk after making mistakes or falling behind opponents during a competition can lead to an escalation in frustration or anger. Alternatively, it could increase anxiety levels, all of which have physiological and psychological responses. Increased breathing, heart rate and increased muscle tension when standing over a golf putt to win the British Open isn't conducive to favourable outcomes. Loss of concentration or focus when playing the last 10 minutes of a netball final due to increasing negative thoughts again isn't favourable to successful performance.

In order to reduce these negative physiological and psychological responses, the aim is to develop positive self-talk strategies instead. The aim would be that these positive words lead to a similar belief in your ability. You are trying to increase or create self-belief.

Figure 2.2.16: Brittany Lang putting during the 2017 British Open.

One of the more popular strategies to achieve positive self-talk is using **cue** words. Although not confined to singular words, the strategy can also encompass phrases, acronyms and even images. The aim of saying or thinking about the words is to refocus, motivate, instruct, reduce anxiety or re-establish confidence. The word or phrase is generally unique to the individual athlete, as it must be relevant to them. Words must have immediate meaning to the individual when used late in a game or during a pressure situation.

Examples of self-talk strategies that could be used to improve self-belief:

- Stopping words: Using cue words like 'STOP' or images (stop sign or the colour RED) to halt negative feelings/ emotions as they start to develop. Then replacing or applying positive cue words to refocus attention towards more positive thoughts. Learning to recognise when the negative feelings are developing and how to refocus will require training. These strategies can sometimes be paired with behavioural cues too. For example, clapping, slapping yourself (on the leg), pinching yourself etc can also be used to stop the development of negative thoughts and refocus towards positive.

Figure 2.2.17

- Refocusing: the refocusing of attention can also be applied to scenarios where distraction (crowd noise etc) is becoming a problem (also refer to Focus Area 3.6: Selective attention). Compared to the previous example that looked at negative emotions and developing self-doubt, this is more about being distracted from the relevant cues. So instructional key-words to refocus an individual's attention to technique or tactical issues.
- Positive images or visualisation: using positive cue words to trigger or recall mental images of you doing the task correctly and successfully. This 'success' that you 'see' fosters greater self-belief. Motivation and engagement then feed off an individual's self-belief.

Figure 2.2.18

There are more strategies, but this gives you an idea and shows how self-talk can develop greater self-belief in an individual.

Self-confidence strategies

Identifying how thoughts can affect self-confidence, eg. Situation, thoughts, emotions and reactions, using affirmation to change personal reactions to situations.

Self-Confidence

Self-confidence is a belief in your own abilities and yourself. This is a fluid belief, meaning it changes depending on the situation at the time. Self-confidence can change between sports or even positions within a sport. For example, a netballer might be very confident in themselves and their abilities if playing in defence (Goal Keeper). Yet, this self-confidence may decrease very quickly if asked to play in attack (Goal Shooter). Suddenly a different skill set is required, and if the player believes their level of skill (shooting) isn't adequate, self-confidence can decrease.

Figure 2.2.19: Different positions with the same sport require different skills and strategies

Words are a powerful influence on an individual's self-confidence, whether that be internal words (self-talk) or from an external source. Negative words or actions are particularly influential. The brain is likened by one psychologist to being:

> "like Velcro for negative experiences, but Teflon for positive ones" (Hanson 2013).

The statement refers to the belief that the human brain has a negativity bias. So, in a sporting context this means it tends to remember and process negative experiences more so than positive experiences. You are likely to remember the one or two negative incidents in a past game more than the good things you did. Negativity or negative thoughts impact self-confidence and in turn, performance. Self-confidence plays an important role in moderating the effects of anxiety on performance. Less confidence can lead to avoidance behaviours. Behaviours which lead to athletes being less likely to undertake difficult tasks, having less persistence and lowering of expectations regarding goal attainment (Vealey 2009).

Self-Confidence Strategies

One strategy to improve confidence that links in with previous topics and mental imagery is the use of **'affirmations'**. Affirmations are positive statements that challenge negative thoughts. Through repetitive positive mental thoughts or words, one is attempting to reprogram their thought patterns about themselves.

Examples of affirmation would be phrases like:

- I have the skills needed to do this
- I can perform well under pressure.

Restoration of self-confidence through affirmations (or any other method), then allows athletes to better reflect on their performance. For example, losing a game of soccer, or worse, multiple games of soccer in a tournament could lead to negative thoughts and responses like anger or increased anxiety. Subduing these negative responses (through positive affirmations) allows for better processing of the entire game (more holistic), rather than fixating on the 'own goal' or 'umpiring decisions'. The reflection can then involve analysis of the failures with less bias and increase the likelihood of the individual or team adopting new strategies or procedures to combat failure in future games (Cowden and Worthington 2019).

Figure 2.2.20

Other self-confidence strategies (Beaumot et al 2015) that can be implemented in a sporting environment to modify the thoughts and emotions of individuals could include:

- **Tailoring to the individual**: assessing and getting an understanding of an athlete's confidence level (confidence profiling) before suggesting strategies unique to the individual athlete to improve self-confidence. The underlying theme to this idea is that each athlete is an individual, and a 'one size fits all' intervention or strategy implemented by coaches etc won't achieve maximum results. The suggested strategies (self-talk, visualisation etc) should be tailored to each individual athlete.
- **Targeting an athlete's strengths**: Getting an athlete to identify their own strengths or implementing feedback systems that highlight these strengths. Athletes can then focus on these strengths that distinguish them from others playing. This point of difference can then 'fuel' increased self-confidence.
- **Manipulating the coaching environment**: Creating an environment during training that:
    - Improves mastery of skills. Improved skills create more confidence in one's ability then to perform in a game environment.
    - Challenging (pressurised) environment: Athletes are more accustomed to competitive environments, so less anxious in the real game. There must be a balance though between pressure and positive outcomes (success). Too much failure due to pressure would be counter-productive in this scenario. This emphasises the importance of coaches using game-based models of teaching such as 'teaching games for understanding' (TGfU) and game sense etc.

Figure 2.2.21: Success in training can aid confidence in the actual game.

- **Logging evidence**: Data (in the form of times, distance achieved, video of performances etc.) is logged to show improvement over a time period. This allows for success to be gauged over a larger time span. Self-confidence is boasted by seeing the progressive change in times or distances achieved etc.

Focus Area 2: Through Movement

2.3 Barriers and enablers to physical activity

- Personal Strategies
- Social strategies
- Cultural strategies

Barriers to physical activity

Barriers are any constraints that make it harder for people to be physically active. These can be perceived (low self-efficacy) or actual physical barriers (lack of facilities, or transport to an event).

Figure 2.3.1: Men's 5000m T53/54, Jakarta, 2018.

Enablers to physical activity

Enablers are defined as anything or anyone that makes it easier for people to be physically active. Examples of enablers are access to good facilities, encouragement from peers, access to sporting equipment, fee subsides etc.

Within a constraints-led teaching approach (refer to Focus Area 1.4), coaches can manipulate constraints so learners must adapt their skills to find a solution to the changed conditions within the game. Individual task or environmental constraints can also be manipulated to increase inclusivity within a game and act as an 'enabler'. For example, a vision impaired student can be included in games of cricket through modifying the ball (bell inside) and bowling requirements.

Increasing regular physical activity levels in Australians is a national health priority, as it is seen as a major factor in curbing overweight and obesity statistics. However, despite evidence highlighting the benefits of regular exercise, many Australians fail to reach this goal. There are numerous barriers and enablers to physical activity. Some of the more commonly reported barriers are listed below. Most of these barriers become enablers if reversed. For example, a lack of encouragement and support can be a barrier to physical activity. Yet, increasing support networks and encouragement is an enabler.

Age and gender are two of the more consistent demographic correlates of regular physical activity in adults. Physical activity levels are generally higher in men than women and inversely associated with age. This means as adults get older, their physical activity levels decrease. The reasons behind this trend are linked to some of the other factors listed below (Trost 2002). For younger children, as they age and they get more commitments, whether that be academic (homework), or social (friends/parties), these too can impact on their level of regular physical activity.

Figure 2.3.2: Age and gender are two common demographic correlates of physical activity.

Focus Questions

1. Identify two reasons why as adults regular physical activity generally begins to drop off.

2. Identify two reasons why females tend to do less physical activity as adults (aged 20-40) than males.

3. **Self-efficacy** is a consistent correlate of physical activity levels in adults. Self-efficacy is a person's confidence in their ability to be physically active. Meaning they believe (or don't believe) they have the necessary skills for the demands of the activity they are undertaking. Adults with higher self-efficacy are more likely to be physically active (Trost 2002).

   Identify factors that may influence a person's self-efficacy

4. Explain whether a person's self-efficacy can be improved with training.

Lack of time, motivation or parenting commitments are commonly cited reasons for a lack of regular physical activity in younger adults.

Age: While for older adults, the more frequent reasons tend to revolve around poor health, injury or fear of injury (Booth 1997). In addition, a lack of interest in physical activity as people age is also a barrier to involvement.

Figure 2.3.3: More frequent injuries or taking longer to recover from exercise is a common barrier to older people participating.

Cost of participating in physical activity (Salmon 2003). Whether that be equipment, access to facilities, participation fees or transport cost, higher costs or perceived higher costs correlate to increased sedentary behaviour.

Environment: Weather as a barrier is frequently reported (Salmon 2003). Inclement weather, with cold and rain in particular being reported as barriers to physical activity (Owen 2000).

Figure 2.3.4: Wet and cold weather limits access opportunities for enjoyable physical activity.

Increased use of technology. Computers, and more recently smart phone use, often competes directly with physical activity for what limited time is available for exercise. Therefore, their use is associated with an increased likelihood of physically inactive (Owens 2000).

However, technology apps are very common today, and the ability to track friends and collect heart rate, GPS tracking etc can be an 'enabler' and encourage people to be active.

Figure 2.3.5: Support and companionship can increase participation rates.

Lack of encouragement, support or companionship is also associated with an increased likelihood of inactivity. For children, a lack of support is a major barrier to physical activity (sport related or organised sport). This is because parents or carers generally provide the finance and transportation.

Strategies

Due to the range of barriers that exist and the changing nature of the barriers (i.e. changes with age), there is unlikely to be a 'one type fits all' intervention that will remove all barriers or **enable** people to become more physically active on a regular basis.

There are however strategies that can be put in place at a **Personal**, **Social** and **Cultural** level to improve your chances.

Figure 2.3.6: Overcoming barriers.

Personal strategies

e.g. Enabling choice of activities to suit personal preference, acknowledging individual attitudes, values and beliefs.

Not everyone has the same interest in sport or physical activity, so allowing greater choice in the way in which people can become more physically active is more enabling. Greater choice allows for a greater range of personal preference and circumstances. For example, a local recreation centre just offering basketball on week nights might change, to alternating with badminton, futsal, volleyball etc. The greater variety potentially captures the interest of a more diverse group of people, offering the opportunity for more people to be active.

Figure 2.3.7: People have different preferences when it comes to physical activity.

Acknowledgement of the fact that individuals have different attitudes towards participating in regular physical activity is an important first step in trying to enable regular physical activity. People value the importance of physical activity in different ways, so interventions (attempts to improve people's physical activity) need to be tailored in some way to the individual. It can't be the same approach for everyone if you wish to maximise participation rates. A good example of not everyone being the same, is the inverse relationship that exists between age and regular physical activity. A community programme to improve physical activity in youth (e.g. skate or BMX park/track) isn't likely to be appropriate for much older citizens. This is because the fitness levels, motivation, time available etc will be much different.

At a school level, offering more co-curricular opportunities for students allows exposure to a wider range of options. The PE programme might experiment with less traditional school sports (handball, golf, wrestling etc). This increases exposure to a wider range of possible activities and could lead to a greater uptake of lifelong involvement (physical activity away from school) for students not interested in more traditional sporting activities.

Figure 2.3.8: Offering less traditional sports (handball) during PE, adds variety to the curriculum and more opportunities for the less active students to become engaged.

Parents who place greater emphasis on academic attainment don't value sport or exercise as highly. This increased value or attitude towards academic learning can pressure children into more study instead of physical activity. This creates a barrier to regular physical activity for these students.

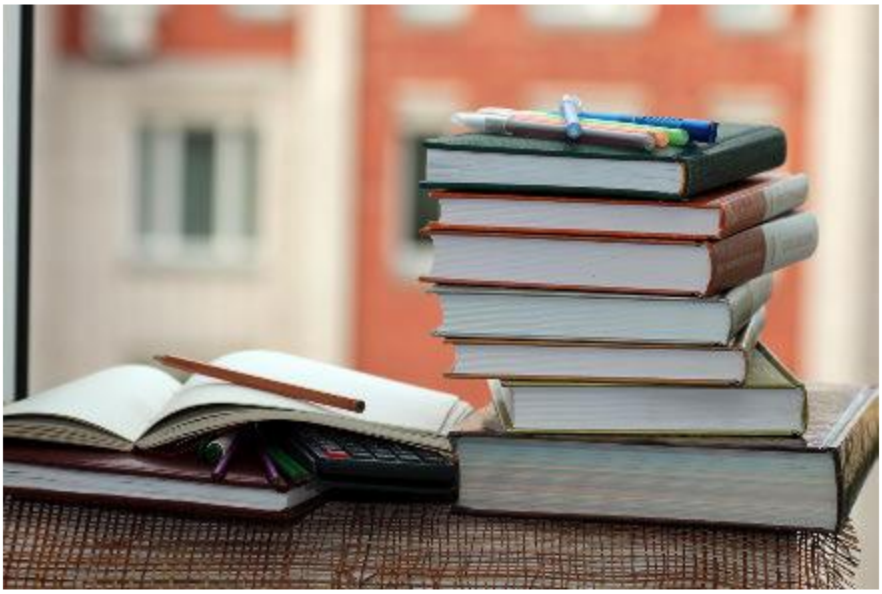


Figure 2.3.9: An emphasis on academic performance can create a barrier to physical activity.

Cultural values and beliefs may also create barriers to physical activity. Strong beliefs about females as primary caretakers in some societies for example, can determine the extent and type of physical activity conducted by women (Abasi 2014).

Strategies at a personal level

Motivation: The health benefits of regular physical activity are widely known, yet many people fail to reach the recommended daily or weekly levels of physical exercise. So, the motivation to undertake physical exercise must come from the individual if changes are to be made and maintained. Individuals choosing an activity that they enjoy, can afford and fits into their daily schedule is one way you can increase the likelihood of participation. Linked in with this enjoyment is choosing a sport that can be managed physically (both skills and fitness).

Setting realistic goals: Realistic goals are likely to lead to greater attainment. Successful attainment of goals is more likely to motivate someone to continue with their physical exercise program.

Social Strategies

e.g. Grouping and team selection, performance environment modifications, manipulation of rules and constraints in physical activity.

Figure 2.3.10

Social support strategies or interventions can be an important component of any physical activity intervention. These types of strategies can remove any safety concerns people might have, as they are now exercising in a group setting. They can also increase the interest and motivational levels of participants, again potentially enabling more regular physical activity. In a school or club setting this can be achieved through grouping like-students or players together. There is strong evidence (Maturo & Cunningham 2013) to suggest participating in physical activity with friends increases physical activity retention rates. At a community level or club level, focusing first on building social support networks (jogging or walking groups) can potentially lead to a greater longevity of the activity. The reason being, it becomes a social activity also. There are then two factors motivating them to continue participating (catch up with friends AND being physically active).

Figure 2.3.11

In a school setting, group formation is often randomly or semi-randomly assigned by teachers or a student led selection process. The method used to form groups can have implications for the overall work output. Researchers (Chapman et al 2006) looking at the influence of the group selection method, found students were less satisfied with their group if randomly assigned compared to self-selected. The desire to work and the pride in their work was reported to be higher in the self-selected groups. However, self-selection can often result in the same students being selected together (or being selected last). The same few students standing unpicked in a line up is a powerful visual representation of the groups' views on their perceived skills or social standing. This sort of scenario doesn't foster positive self-confidence or self-efficacy in these remaining students, particularly if repeated. As a result, participation rates, motivation or effort levels of these students can be reduced.

Manipulation of the environment or rules to allow for more group or team work in sports can add extra motivation and interest to an activity and potentially lead to more involvement. Doubles tennis or badminton competitions, for example, on a week night for adults might attract more people, as it becomes more of a 'team' activity than singles.

Rule modification may also act as an enabler, as it leads to more enjoyment. With the flow-on effect being increased and more regular involvement.

- Shorter halves or sets in a game for example elevates to some degree one of the main barriers to regular physical activity – 'Time.'
- Removing the contact in sports like Rugby (Walla rugby or flag football) might encourage a more diverse group of people to begin playing the sport.

Figure 2.3.12: Flag football removes the tackling element of the Gridiron game, so it becomes more inviting to students who don't enjoy the 'physical impact' aspect of the sport.

The aim of any modification or manipulation should be to increase the enjoyment and interest of the participants. This in turn increases the likelihood that they will undertake regular physical activity. For a greater understanding of the environmental modifications, manipulations of rules and constraints in physical activity, refer to Focus Area 1.4.

Focus Questions

5. List two other modifications to rules or sports that are aimed at enabling greater participation.

Cultural strategies

e.g. Community promotion and engagement related to physical activity, media and marketing strategies, rules, policies and procedures, risk assessment within a school setting.

Cultural barriers to physical activity could be as simple as a language barrier making it difficult to either find out about opportunities to be physically active or being able to participate fully in activities. Alternatively, it may be more complex, in that cultural differences don't allow participation in certain sports, or different beliefs or obligations restrict time available to participate in organised physical activity (i.e. regular sporting competitions).

Strategies, therefore, to remove these barriers can and may need to vary between cultural groups. Addressing the difference in language is a good first step and empowers people to begin to take a more active role themselves in finding new opportunities to participate in physical activity. Recognising and understanding the different cultural beliefs and traditions is another fundamental step needed in beginning to break down barriers to physical activity. Offering a one-size-fits-all approach to improving physical activity in our increasingly multicultural society is less likely to have the best results.

There is strong evidence in support of community-wide campaigns to disseminate information regarding physical activity interventions (Institute of Medicine 2015). However, mass media or communication strategies aimed at the community level, must ensure they are;

- Locally relevant – so the content for multiple campaigns across the state or country needs to be first assessed to see if it has relevance to the target community. What is relevant in South Australia, might not be in Queensland or Tasmania. Adjustments may need to be made between communities.
- User-friendly – this links back into the comment earlier about language barriers. The strategy can use written (newspaper) or spoken language (TV, radio), yet it can also include computer literacy. Older generations, on average, are less computer literate than their younger counterparts, so any online campaign may not reach older generations as effectively as traditional media campaigns.

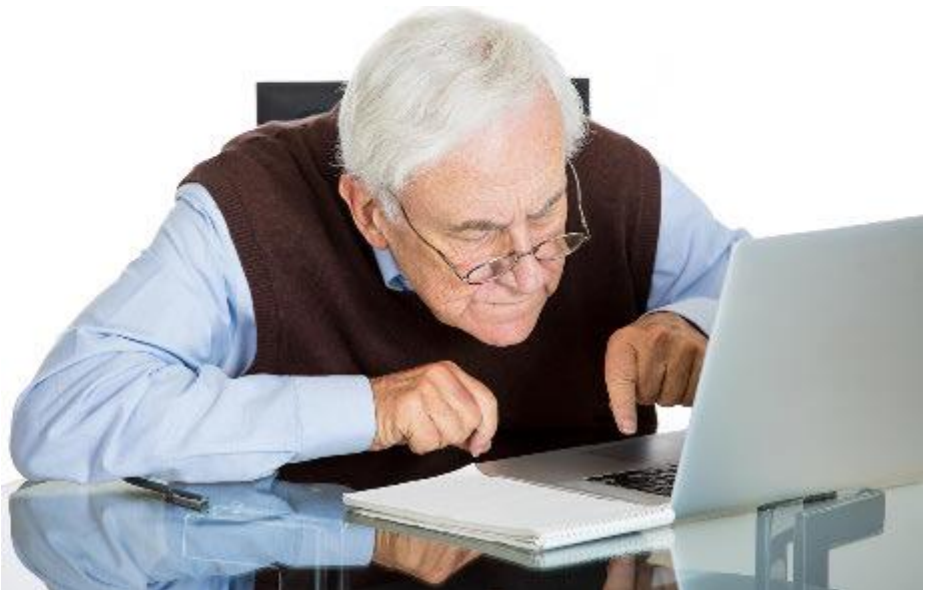


Figure 2.3.13: Computer literacy is lower in the elderly.

- Distribution – any cultural strategy must be widely distributed to ensure as many people as possible are informed. This in turn increases the chances of an intervention being supported by a greater number of the community.

The advantage of using mass media marketing strategies is the number of households that can be potentially reached. Most houses have a television or radio (also in cars), so traditionally this was the preferred method of information dissemination. Exposure to the message is generally through passive means, as an incidental effect of routinely using these devices each day (Wakefield et al 2010). Social media or email campaigns is a more modern and active means of exposure to media campaigns. These are considered more 'active' strategies as community members must 'click' on the link or open the page to view the message. Although they can reach the same number of people, it is contingent on community members 'opting in' to the messaging. It also relies on all members of the community having an electronic device capable of receiving the message in the first place.

Schools are in a unique position to administer physical activity interventions, in that students spend much of the year at school. Almost every child goes to a school and schools have facilities, equipment and PE or sporting programs already in place. Schools are then an environment where socio-economic barriers are reduced. They are therefore a great environment to encourage greater levels of physical activity.

Rules and procedures within schools need to reduce 'unnecessary opportunities for sedentary behaviour' (Kohl and Cook 2013). For example:

- reducing break times or eliminating recess should be questioned, as it reduces opportunities to be active.
- schools allowing technology (phones or computers) during recess can negatively impact physical activity behaviour (play).
- school driven competitions after school increase opportunities for students to be active. Providing access to school facilities after hours for community groups or school based groups (old scholars) removes barriers to participation.
- inviting community stakeholders (sporting clubs) and parent groups to be involved in, before or after school activities/competitions potentially improves the longevity of programmes.

These are a few examples of where policies or procedures in schools can impact on the physical activity behaviour of students.

Figure 2.3.14: Schools having policies in place that allow for recess and lunch breaks outside the classroom, foster greater physical activity levels in the students.

Extension activity

Investigate and design a community-based (or school-based) intervention to promote and engage more people into regular physical activity. Your intervention needs to focus on one group i.e. Year 12s, elderly, ethnicity, gender. You need to identify what barriers are current limiting their regular physical activity. Then create ways to enable their participation.

You could also look at media marketing and design a webpage or app that looks at informing the community of your health message.

Focus Area 3: About Movement

3.1 Energy sources affecting physical performance

- Sources of macronutrients for activity
- Nutrition and performance
- Aerobic and anaerobic energy - ATP-CP system, lactic acid system, oxygen system

Sources of macronutrients for activity

The human body requires a constant supply of energy to fuel daily bodily functions, which include:

- Growth and repair
- Temperature regulation
- Body functions (circulation, respiration, digestion, excretion and nervous control)
- Physical activity (muscular contractions).

This chapter will focus on the energy needs of the body as a result of muscular contractions, as these relate most directly to physical activity and performance.

As physical activity increases, so do our demands for energy. It is our capacity to extract energy from the food we eat and continuously transfer it to the contractile elements of the muscular system that ultimately determines our capacity for exercise.

It should be noted here, that the energy released in foods is not transferred directly to our body for energy and muscular contractions. Instead, the body takes the energy stored in foods (known as macronutrients) and transfers that energy into the energy rich compound called **adenosine triphosphate (ATP)**. The stored energy within the ATP molecule is then used to supply all the energy needs of the body - refer to Focus Area 1.1.

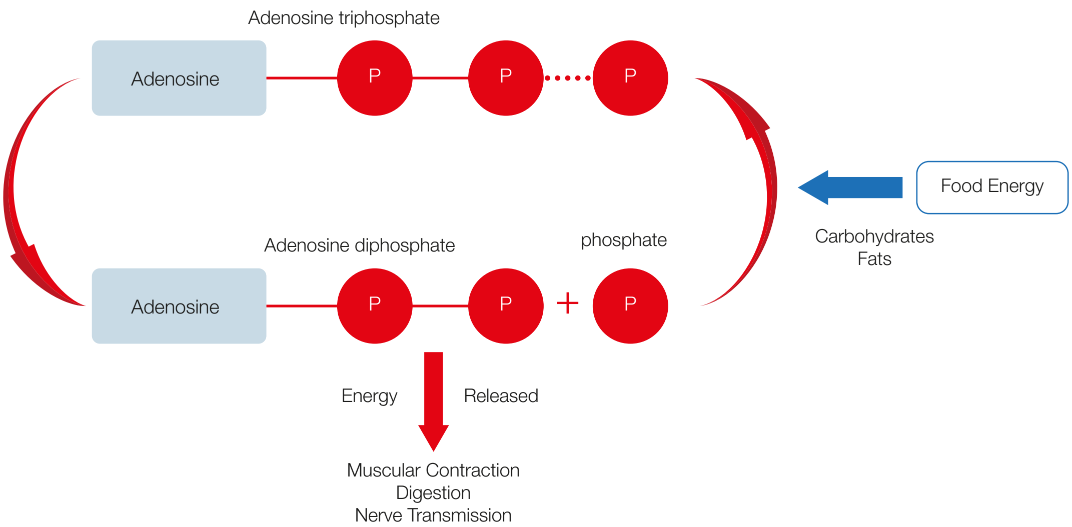


Figure 3.1.1: ATP is broken down to ADP releasing energy for muscular contraction. Food energy is used to rebuild ADP + P to ATP.

Macronutrients Provide Energy

The foods we eat in our diet contain **nutrients** which are chemical compounds that are needed for growth, energy and health.

Individual food items are composed of a complex mixture of these nutrients, the most common of which are referred to as **macronutrients** (macro = large) which are referred to as energy nutrients because they can be broken down in our cells to provide energy for the body.

The three macronutrients contained in the foods we eat are **carbohydrates**, **fats** and **proteins**. Most foods contain a mixture of more than one macronutrient, but they are generally classified as the one they contain most of.

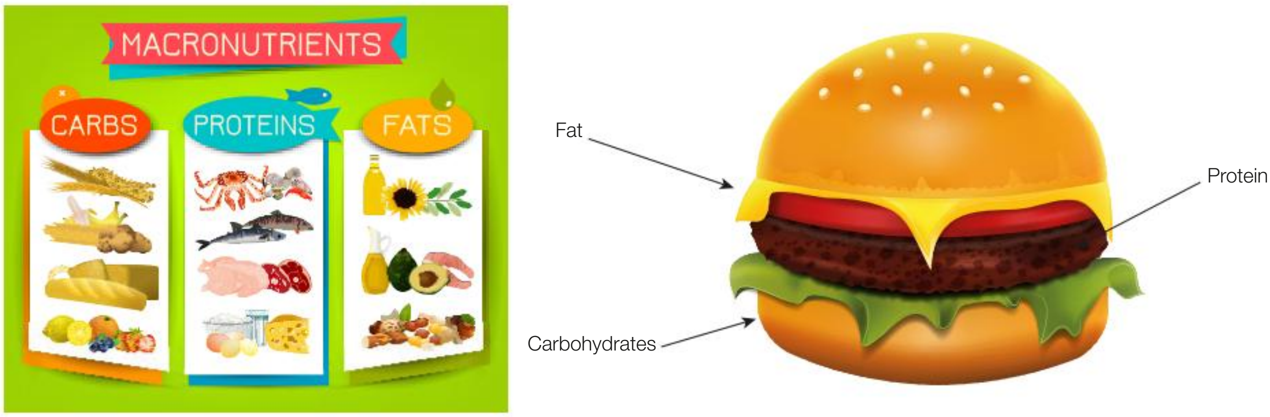


Figure 3.1.2 a and b: Most foods contain a mixture of more than one macronutrient.

When foods are eaten, they are broken down (digested) and energy released from the breakdown of the macronutrients are used to rebuild the energy rich compound called adenosine triphosphate (ATP). The macronutrients contained within an item of food will therefore determine the food's 'energy density' which is measured in kilojoules (kJ).

The greater number of kJ per gram of food, the greater its energy density:

- Carbohydrates - 16kJ per gram
- Proteins - 17kJ per gram
- Fats - 37kJ per gram.

Try calculating some of your own favourite foods!

For example, if you look at a food label and it lists 10 grams of carbohydrates, 0 grams of protein, and 0 grams of fat, that food would contain 160 kilojoules (10g × 16kJ/g = 160 kJ).

Carbohydrates

Atoms of carbon, hydrogen and oxygen combine to form the basic structure of all carbohydrate molecules. The classifications of carbohydrate range from a simple sugar molecule (**monosaccharide**) such as glucose, up to many sugar molecules linked together (**polysaccharides**) such as glycogen.

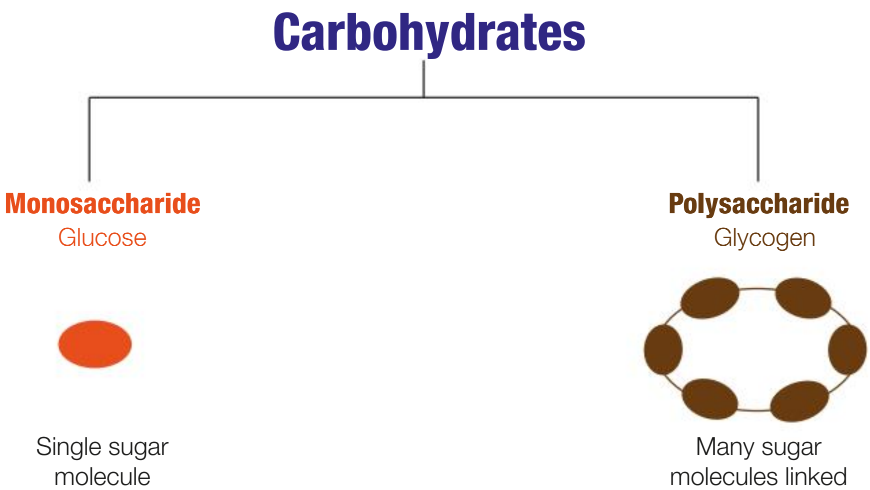


Figure 3.1.3: Carbohydrates range from simple sugar molecules, up to many sugar molecules.

Carbohydrates are found in food sources such as:

- Bread, pasta, rice, quinoa
- Potatoes
- Beans and pulses (chickpeas and lentils)
- Dairy foods (milk and yoghurt)
- Fruit
- Sugar and honey.

Figure 3.1.4: Carbohydrate foods provide energy.

Carbohydrates are transported as **glucose** (in the bloodstream) or stored as **glycogen** in the skeletal muscles and liver. If liver and muscle glycogen stores are full, excess carbohydrates consumed will be stored as fat (**adipose tissue**). Carbohydrates are the preferred source of energy, particularly during high-intensity exercise. Therefore, this macronutrient should contribute a lot to an athlete's dietary needs.

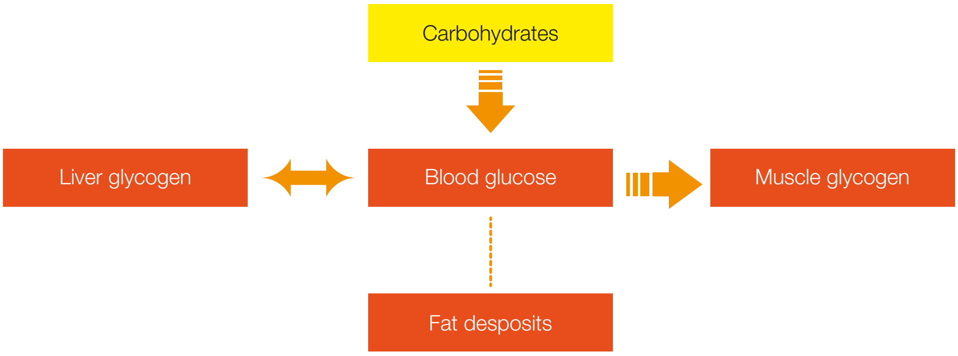


Figure 3.1.5: Carbohydrates are transported as glucose and stored as glycogen.

As can be seen in Table 3.1.3, the total stores of carbohydrates in the body (assuming a mass of 65kg with 15% body fat) are limited to approximately 375 grams (6000 kJ), which is only enough energy to fuel approximately 90 minutes of vigorous exercise, after which an athlete's depleted glycogen stores will cause significant muscular fatigue, often referred to as "**Hitting the Wall**".

Research has shown that the endurance capacity of an athlete is strongly correlated to their dietary intake of carbohydrates. For example, Figure 3.1.6 illustrates endurance times whilst cycling with a high carbohydrate diet are nearly three times greater than those on a low carbohydrate diet.

Adapted from Exercise Physiology: Nutrition, Energy, and Human Performance - By W. McArdle, F. Katch, V. Katch (Fig 1.9, page 19, 7th edition).

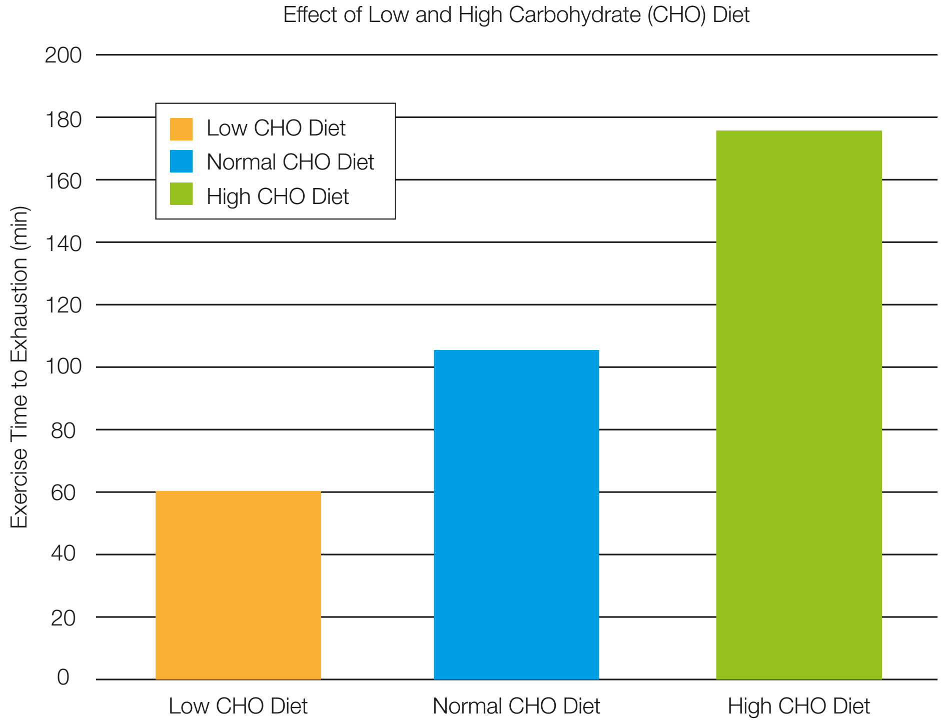


Figure 3.1.6: The effects of carbohydrate intake on exercise time to exhaustion.

Therefore, it is recommended that to maintain an athlete's relatively limited glycogen stores, a large proportion of an athlete's energy intake should come in the form of carbohydrates. Current recommendations for carbohydrate requirements vary depending on the duration, frequency and intensity of exercise. Generally, an athlete's consumption of carbohydrates should be similar to that recommended for the general population, at approximately 55-60% of energy intake. However, athletes who exercise vigorously for more than 90 minutes every day (such as endurance athletes) may need to increase their carbohydrate intake to avoid glycogen fuel depletion and maintain a high intensity during training and competition (refer to Figure 3.1.6).

Athletes are advised to adjust their carbohydrate energy consumption to suit their exercise level.

For example:

- Light intensity exercise (30 mins/day): 3–5 *g/kg/day*
- Moderate intensity exercise (60 mins/day): 5–7 *g/kg/day*
- Endurance exercise (1–3 hrs/day): 6–10 *g/kg/day*
- Extreme endurance exercise (more than 4 hrs/day): 8–12 *g/kg/day.*

** g/kg/day = grams carbohydrate consumed / per kg of athlete's body mass / per day*

When a food containing carbohydrate is consumed, it is quickly broken down into its smallest component (**glucose** - the immediately usable form of carbohydrate) and transported in the blood to the skeletal muscles for energy release. The rate at which glucose enters the bloodstream is affected by the type of carbohydrate contained within the food eaten.

Carbohydrates are classified according to how quickly they are broken down to release their energy into the bloodstream. This classification is known as the **'glycaemic index' (GI)**. Foods that are broken down to release their energy very quickly into the bloodstream (causing a spike in blood glucose) have a **high GI** rating, but they do not provide sustained energy. Contrastingly, foods that are broken down to release their energy slowly into the bloodstream over a long period of time have a **low GI** rating (refer to Figure 3.1.7).

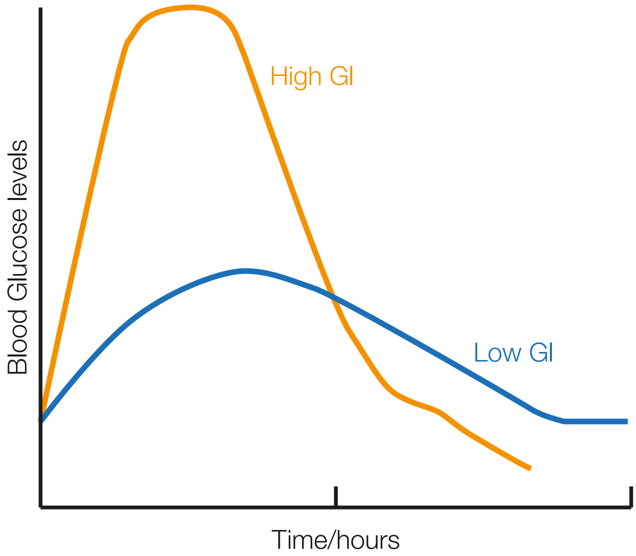


Figure 3.1.7: Glycaemic Index (GI).

High GI Foods = Include cakes, ice cream, jasmine rice, potatoes, soft drinks (full sugar), sports drinks, lollies, white bread, etc.

Low GI Foods = Include basmati rice, vegetables, whole grain bread, oats, etc.

In general terms, athletes are advised to consume low GI foods (like whole grain breads and oats), as the basis of their training diet to ensure their muscle glycogen stores are full prior to their next training or competition. Meanwhile, high GI foods (like white bread, jams and sports drinks) are often advised to boost the total intake of carbohydrate (glucose) during exercise to avoid muscle glycogen depletion (Hitting the Wall) or immediately following exercise to maximise muscle glycogen replenishment.

Fats

As with carbohydrates, atoms of carbon, hydrogen and oxygen combine to form **lipids** (fats), but fats have a higher ratio of hydrogen to oxygen. Lipid molecules consist of one molecule of **glycerol** and two molecules of **fatty acids**.

Once consumed, fats are converted into **fatty acids** in the bloodstream where they can be used as an energy source or they can be transported and stored in the skeletal muscles (as **triglycerides**) or stored as body fat (as **adipose tissue**).

Fats are ‘energy rich’ molecules, with each gram of fat containing 37kJ of energy - nearly twice the kilojoules (energy) of carbohydrate (16kJ) or protein (17kJ). Because of this, foods and drinks with too much dietary fat can easily lead to an increase in **Fat Mass.** An increase in fat mass generally decreases athletic performance, as it provides greater inertia (resistance to athletic motion) thereby requiring the athlete to increase the muscle force of contraction required to complete a task. For this reason, it is generally accepted that an athlete’s diet should contain less than 30% of energy requirements from fat.

Although the consumption of excess dietary fats can be detrimental to our overall health, they are also an important part of our diet used by the body as an energy source, energy reserve, storage for vitamins, the production of hormones, insulation and for the protection of our vital organs (heart, liver and kidneys etc).

There are ‘saturated’ dietary fats that are considered unhealthy, and there are also ‘unsaturated’ dietary fats that are considered healthy for the body.

Figure 3.1.8: Food containing a high amount of saturated fats.

Saturated fats are found in food sources such as:

- Meat fats
- Full-fat dairy products
- Coconut oil, peanut oil & palm oil
- Cakes & chips.

Figure 3.1.9: Foods containing unsaturated fats.

Unsaturated fats are found in food sources such as:

- Fish
- Avocados
- Vegetable oils (olive, canola & sunflower).

Although fats contribute the most amount of energy per gram (37kJ), exercise intensity ultimately limits their contribution as a fuel during intense exercise. The energy extracted from fat can only occur via aerobic pathways (with oxygen), so during moderate to high intensity exercise, there is simply not enough oxygen available to fuel the more complex chemical reactions involved to 'split' the larger fat molecules. Therefore, the contribution of fats during high intensity exercise is limited. Fats cannot be used to fuel high intensity anaerobic exercise.

Fat is however, considered the preferred fuel at rest and during low intensity exercise when the oxygen delivery systems of the body (circulatory & respiratory) are not under stress. Fats can contribute up to $\frac{2}{3}$ of energy requirements during rest and low intensity aerobic exercise such as walking.

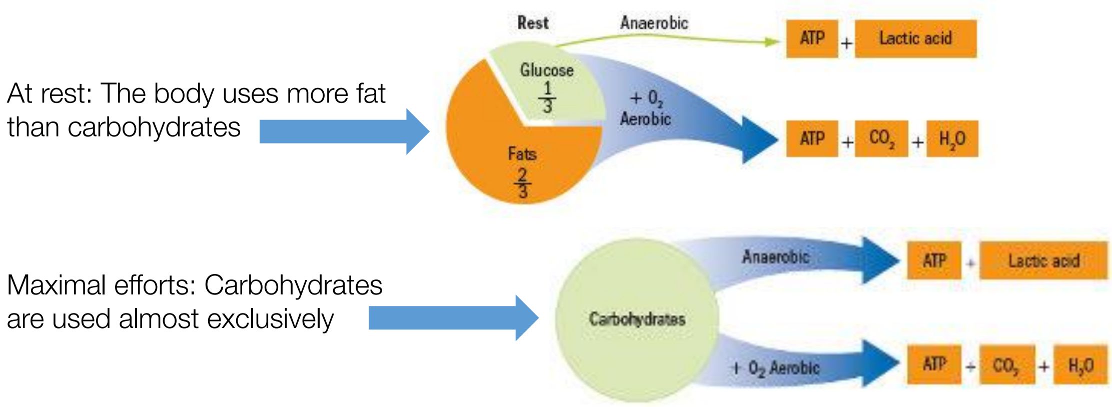


Figure 3.1.10: Fats are the dominant fuel used at rest and in very low intensity exercise. Carbohydrates are the dominant fuel used in high intensity exercise.

On occasions, fats may also become the dominant fuel during endurance sports such as cycling and marathon running if an athlete experiences fatigue when "**Hitting the Wall**". This usually occurs approximately 90 minutes into exercise when a sudden loss of fuel (muscle glycogen) severely decreases exercise intensity. When glycogen stores are depleted, the body has no choice but to use fats as the dominant fuel source, requiring a larger proportion of the oxygen intake, resulting in a significant drop in exercise intensity.

Proteins

Proteins (**amino acids**) are the building blocks of the human body and are used primarily for growth and repair of muscle and tissue. They are only used as a macronutrient fuel to replenish ATP in extreme circumstances (i.e. starvation) when the body is depleted of all carbohydrate and fat stores. Therefore, in the context of the Year 12 Physical Education course, the breakdown of protein to fuel energy requirements for the body will not be discussed.

Dietary proteins are found in food sources such as:

- Meat
- Fish and seafood
- Eggs
- Soy and tofu products
- Dairy - milk and yoghurt
- Beans and legumes.

Figure 3.1.11: Proteins are the building blocks of the body used primarily for growth and repair of muscle.

As with the other macronutrients, an athlete's dietary intake of protein should be similar to that recommended for the general public, with 10 to 15% of energy intake from proteins.

Strength, power and speed athletes may require higher levels of protein in their diet to meet their muscle building and post-exercise recovery and repair requirements. However, for most athletes, the amount of protein recommended for athletes will be met in the recommended Australian dietary intake guidelines.

Recent research provides guidelines for protein intake based on grams per kilogram (g/kg) of body weight as follows:

Table 3.1.1: Dietary protein requirements.

Athlete		Protein (g/kg body weight per day)
Recreational athletes Figure 3.1.12		0.8-1.0 g/kg of body weight
Non-endurance athletes Figure 3.1.13		1.0–1.2 g/kg of body weight
Endurance/Power athletes Figure 3.1.14		1.2–1.7 g/kg of body weight A power athlete (100m sprinter) as used in this example, may have a mass of 90kg - with a protein recommendation of 1.7g/kg this would calculate to 153g protein per day.

Table 3.1.2: How much protein is in food?

Individual foods that each contain approximately 30g of protein	
100g tuna	**Each of these food examples contain approximately 30g of protein**
70g of beef, pork or lamb	
6 slices of cheese	
200g tofu	

Energy Stored

As discussed previously, the amount of energy stored in the two main macronutrients is as follows:

- Carbohydrates (1g) 16 kJ
- Fats (1g) 37 kJ.

As can be noted from Table 3.1.3 below, the total stores of carbohydrates in the body are limited to approximately 375g or 6,000 kJ of energy – this would be equivalent to the energy needed to run 24km in 90 minutes of running (16km/h).

Figure 3.1.15: Carbohydrates are the dominant fuel during vigorous exercise.

Compared to carbohydrates, the amount of energy in total fat stores around the body is large and practically unlimited. Even on a lean individual with 15% Body Fat, fat stores can exceed 294,500 kJ of energy which could fuel over 238 hours of exercise! However, it would be 238 hours of slow walking because it takes substantially more O_2 to metabolise fats than carbohydrates, the energy release from fat is usually too slow to meet all of the energy demands in intense muscular activity.

Table 3.1.3: Approximate fuel and energy stores for an individual (mass 65kg with 15% body fat).

Nutrient	Amount stored (g)	Energy Stored (kJ)
	Carbohydrate	
Blood Glucose	15g	16 kJ × 15g = 240 kJ
Muscle Glycogen	250g	16 kJ × 250g = 4000 kJ
Liver Glycogen	110g	16 kJ × 110g = 1760 kJ
Total Carbohydrates	**375g**	**6000 kJ**
	Fat	
Adipose tissue	7800g	37 kJ × 7800g = 288 600 kJ
Triglycerides	160g	37 kJ × 160g = 5 920 kJ
Total Fat	**7960g**	**294 520 kJ**

Focus Questions

1. Explain the role of the following energy macronutrients within the human body:
   - Carbohydrates

   - Fats

   - Protein

2. Complete the table below, showing the location and type of fuel stores in the body:

Fuel	Stored as	Site
Carbohydrate	(a)	Blood
	Glycogen	(b)
	Excess stored as fat	(c)
Fat	(d)	Blood
	Triglycerides	(e)
	Adipose Tissue	(f)
Protein	(g)	Around body

3. Explain why protein is generally not used as a macronutrient fuel by the body?

4. Explain the dominant macronutrient fuel source when running at 85% maximum Heart Rate at a local 5km cross country race?

3

Food breakdown for energy

As stated previously, the energy stored in foods is not used directly by the body for biological work. Instead this energy is released to rebuild a chemical compound called **adenosine triphosphate (ATP)** - refer to Focus Area 1.1.

Carbohydrates and fats are the main nutrient fuels used to supply the energy needed for the resynthesis of ATP, but the relative contribution of carbohydrate and fat as a fuel will depend to a large degree on the exercise duration and intensity.

Fats can only be broken down to resynthesise ATP in a process requiring oxygen (aerobic) called **aerobic lipolysis**. Carbohydrates can be broken down in a process requiring oxygen called **aerobic glycolysis**, and also in a process without oxygen (anaerobic) called **anaerobic glycolysis**.

Figure 3.1.16 and 3.1.17 (below) represent the "**crossover**" concept, which is a theoretical means to describe the effects of exercise intensity and exercise duration on the relative contribution of carbohydrate and fat as fuels used during exercise.

Figure 3.1.16 illustrates that at rest, up to 75% of energy may come from fat and only 25% from carbohydrate; but as exercise intensity increases (measured as %VO_2 max), the reliance on glycogen as a fuel source increases. This is because fats are larger molecules and require more oxygen to break down. Therefore, fats tend to be more dominant at low intensity exercise when oxygen delivery is not a limiting factor. Because carbohydrates require considerably less oxygen to break down, glycogen usage tends to dominate with more intense exercise. For this reason, carbohydrate energy is more accessible during exercise than fat, and therefore carbohydrates are considered the body's primary exercise fuel.

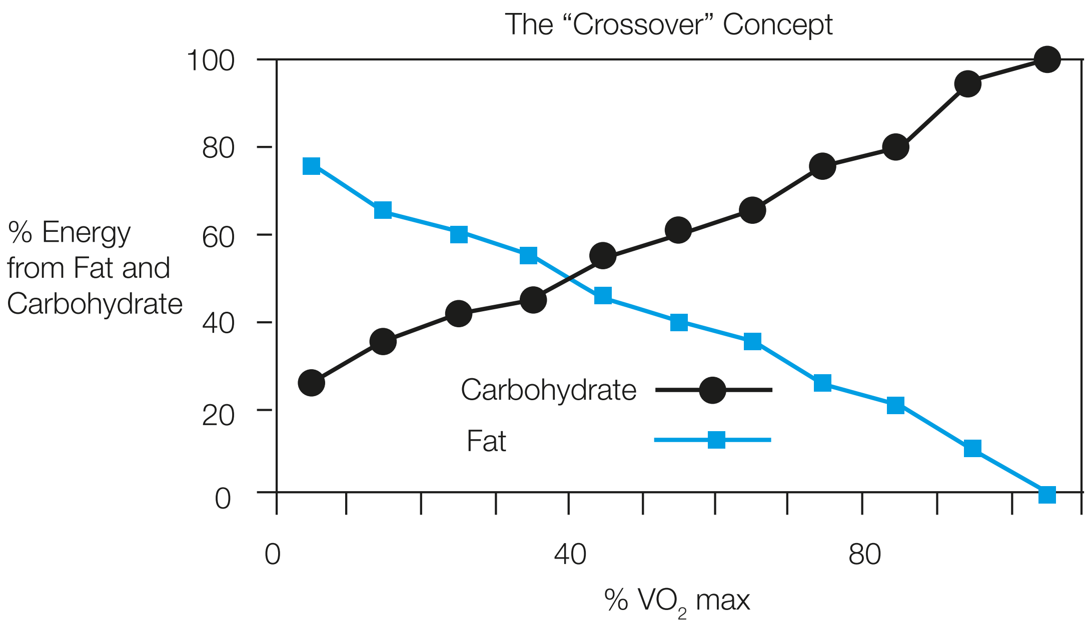


Figure 3.1.16: As exercise intensity increases, there is a progressive increase in carbohydrate as a fuel. Source: Adapted from Hawley & Powers (date unknown), Exercise Metabolism.

Although the preferred fuel for high level performance in a marathon or other long duration events would generally be carbohydrates (due to the high intensity requirements), the body has a limited supply of glycogen stores. As a result, when an athlete continues to exercise for an extended period of time, their muscle and liver glycogen stores will slowly deplete if they do not have a good nutrition strategy during the event. After approximately 90-minutes of intense exercise, glycogen stores will be depleted and the body must begin to rely on more fat as the major fuel source - "Hitting the Wall" (refer to Focus Area 1.1 Energy contributions and fatigue).

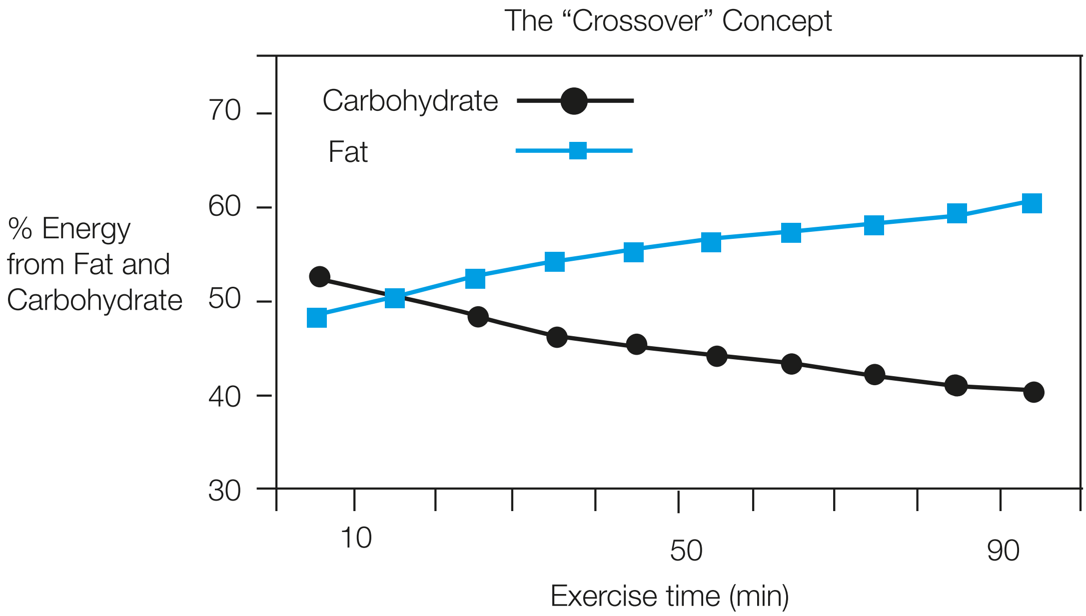


Figure 3.1.17: As exercise duration increases, there is a progressive use of fat as a fuel. Source: Adapted from Hawley & Powers (date unknown), Exercise Metabolism.

Table 3.1.4: Carbohydrates and fats.

Energy Source	
Carbohydrate	Fat
• Energy for aerobic and anaerobic energy systems • Does not need O_2 to break down • Quickly exhausted (without replenishment) during exercise • Quick to break down and use in high intensity exercise • Provide less energy than fats (only 16 kJ per gram of carbohydrate).	• Energy for aerobic energy system only • Needs lots of O_2 to break down • Slow to break down and can only be used in low intensity exercise • Provides lots of energy (37 kJ per gram of fat).

Focus Questions

5. Explain the following terms:
   - ATP
   - Aerobic lipolysis
   - Aerobic glycolysis
   - Anaerobic glycolysis

Focus Questions

6. Explain the relationship between carbohydrate and fat fuel in and the following conditions:

   (a) As exercise intensity increases

   (b) As exercise duration increases

7. Explain one advantage and one disadvantage of using fat as an energy source during exercise.

8. A 65kg athlete running a marathon at a moderate pace (14km per hour) would burn approximately 80 kJ per minute:

   (a) How many minutes of running at this pace could the athlete sustain using carbohydrates as a fuel? Show your calculations.

Hint: Look back at your notes and refer to Table 3.1.3.

9. (a) Identify the term often used to describe the period in an endurance event (greater than 90 minutes) when muscle glycogen stores have been depleted.

   (b) How would an athlete feel if they have reached the above-mentioned state?

   (c) Explain the reason why they would feel this way?

   (d) Suggest two strategies an athlete could employ to avoid this state.

Nutrition and Performance

A balanced diet is all about consuming the correct amount of energy from carbohydrates, fats and proteins, in the right proportions (Figure 3.1.18). However, athletes would normally seek to increase carbohydrates (65-70%) and proteins (12-15%) and reduce fats.

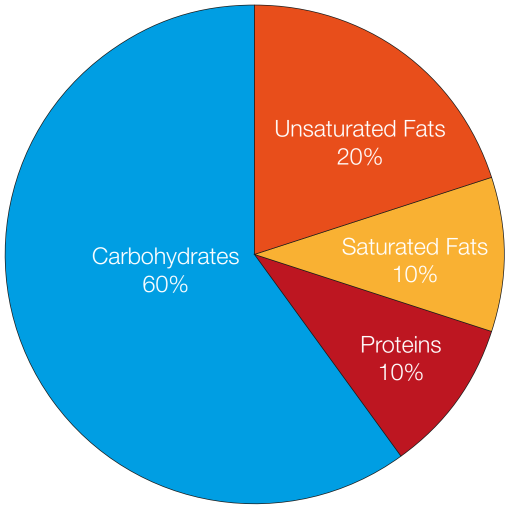


Figure 3.1.18: Recommended contribution of energy for each nutrient in a balanced diet - athletes may need more carbohydrates to fuel training and competition.

In addition, other essential nutrients required by an athlete will include:

- Vitamins and minerals: Vitamins and minerals do not provide energy but they are important, as vitamins act as catalysts in chemical reactions and minerals are important for normal functioning of cells.
- Water: Makes up approximately 70% of a person's body weight (blood is 75% water, muscle 78% water and the brain 92% water), so a loss of only 1.8% of water through dehydration will impair performance. Water is vital for cooling the body and maintaining blood volume. Loss of water reduces blood volume which reduces blood flow to muscles and skin. To maintain blood flow during dehydration, there must be an increase in heart rate and less blood flow to the skin. Less blood to the skin impacts cooling (Wilmore & Costill, 2004). Both these factors reduce overall performance.

An athlete's day to day diet must be balanced. They are either eating to recover from competition/training or are eating in preparation for training/competition.

Physical performance can be improved through good nutrition and consumption of the right nutrients pre-event, during, and post-event (recovery). Likewise, poor nutritional strategies can significantly impair performance.

Glycaemic index

In the past, carbohydrates were classified as 'short-lived' simple or 'long-lasting' complex carbohydrates; today the glycaemic index is a better way of classifying carbohydrates. As discussed previously, the glycaemic index is a system used to describe the rate at which blood sugar increases after eating. White bread is given an arbitrary value of 100, meaning a rapid rise in blood glucose levels. From this, scientists established three categories of glycaemic index – high GI >85, moderate GI 60-85, low GI <60.

Unfortunately, there can be considerable variation between individuals, along with people's definitions of the GI ratings. With the GI system of classification some foods previously considered complex carbohydrates rate quite high on the GI scale and if small amounts of fat are added to high GI foods the overall GI is lowered.

Pre Event Nutrition

An athlete's diet needs to be high in carbohydrates, moderate in protein and low in fat. A primary focus for an athlete prior to their competition is to fill muscle glycogen stores. Muscle glycogen is in limited supply, and an average athlete (mass 65kg with 15% body fat) stores approximately 250g glycogen in their muscles and 110g in the liver. Glycogen is the preferred fuel for energy as it is easily and quickly converted to ATP.

Before the event, athletes should focus on achieving 60-70% of their energy intake from carbohydrates in the low to moderate glycaemic index. The amount of carbohydrates consumed is determined by energy demands which are in turn determined by training intensity. Table 3.1.5 illustrates the approximate carbohydrate requirements for a male (70kg) and female (60kg) athlete based on training at a moderate (less than 1 hour) and high (for more than 4 hours) intensity per day.

Table 3.1.5 Training intensity and carbohydrate (CHO) requirements.

Training Intensity	CHO intake g/kg body mass per day	CHO intake/day Average 70kg male	CHO intake/day Average 60kg female
Moderate: less than 1 hour per day	5-7g	350-490g	300-420g
High: more than 4 hours per day	10-12g	700-840g	600-740g

In the time from 15 to 45 minutes prior to the activity, the athlete should be cautious. Carbohydrates consumed at this time can result in a sudden release of insulin which can lead to **hypoglycaemia**. The release of insulin encourages the muscles to use glucose too quickly leading to early fatigue. This is different for carbohydrates eaten during exercise/competition, as here they are replacing glucose that has been used for energy production.

Table 3.1.6: High/moderate/low glycaemic index foods providing 50g of carbohydrate.

	Food type	Portion size for 50g Carbohydrate
High GI >85	Potatoes	254g
	Bread	3.8 slices (28g each)
	Raisins	78g
	Cornflakes	59g
	Honey	3 tablespoons
	Jubes/jellybeans	60g
	Ice cream	250g
Moderate GI 60-85	Plain rice	169g
	Noodles	370g
	Oatmeal biscuits	79g
	Green grapes	310g
	Sweet potato	168g
	Baked beans	485g
Low GI <60.	Mixed grain breads	3 slices
	Milk	1 litre
	Flavoured Yoghurt	350g
	Banana	2 medium to large
	Pasta	200g

The pre-event meal should also be fully digested prior to the event. At this stage, it is recommended that this meal be low-fat, low-protein and contain 200-300g of carbohydrate that is low on the glycaemic index and be eaten 3-4 hours before the event. It is also important to consider that the athlete is also adequately hydrated prior to the event. No last-minute food will make up for a poor diet in previous weeks. Athletes should give themselves a serious head start by eating a high-carb diet during training.

During the Event

When considering nutrition during an event, one must consider the duration and intensity of the sport. When an athlete is involved in a series of games/competitions during the day, it will be important to refill muscle glycogen stores. If time permits, athletes can eat fruit, sports bars or confectionery during or between events, however this may make exercise uncomfortable for some.

As a general guideline for events under one hour's duration, (traditionally) water, to combat dehydration was all that was required.

Studies in the US have demonstrated that intermittent sports such as most field sports reported benefit, when a 6% carbohydrate solution was consumed at 15 minute intervals during which subjects ran at varying intensities and completed 40 vertical jumps at 80% intensity. The following benefits were observed:

- Enhanced performance of sprinting and jumping
- Enhanced performance of whole-body motor skills, requiring a combination of speed and agility
- Enhanced ratings of subjects' overall mood state late in exercise.

For extended events lasting a number of days, such as the Tour de France, it would be necessary to consume some additional carbohydrates during competition. Usually this type of carbohydrate would be in the high GI range in a form that is easily consumed and digested. Energy bars and gels are popular sources of such carbohydrates, as they rapidly replenish lost stores.

Post Event

Post event nutrition is also important, as the body must replace used energy stores and allow for growth and repair. Muscle glycogen stores can take days to replenish and given the number of training sessions and the time between games, for the professional sports person, glycogen stores need to be replaced as quickly as possible. Knowledge of the glycaemic index has made eating for recovery much simpler.

Glycogen resynthesis is at its highest about 1-2 hours after training/competition. At this point it is best to consume foods that are high on the glycaemic index. At the rate of 1g/kg of body weight. After this it is recommended that 50g of carbohydrate that is high to moderate on the glycaemic index be consumed every two hours. Sometimes this may be difficult to consume such quantities of food in the time available so often carbohydrate rich drinks such as 'Sustagen' can provide the required carbohydrate easily. The additional protein, along with carbohydrates in drinks like Sustagen maximise glycogen synthesis and promote muscle repair (Ivy 2004). Figure 3.1.19 illustrates the importance of replacing carbohydrate stores after exercise. Reduced fuel stores at the beginning of the exercise period will lead to fatigue much more rapidly.

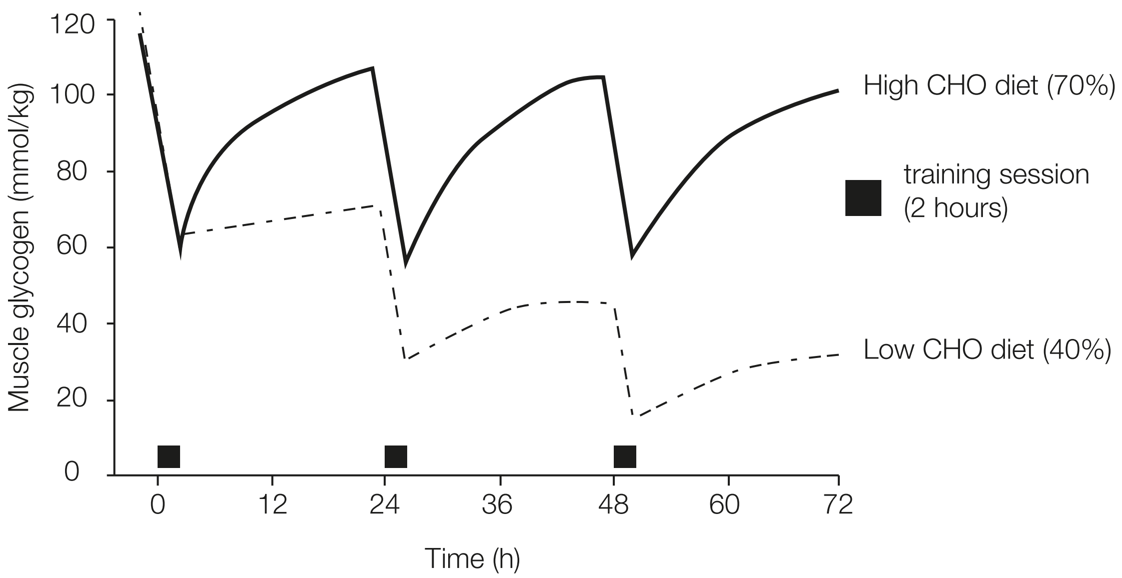


Figure 3.1.19: The influence of carbohydrate replenishment and muscle glycogen stores following successive training sessions. Source: Wilmore et al: Physiology of Sport and Exercise 4th Edition, page 330.

Hydration

As mentioned previously, fluid intake is of paramount importance during training/competition, to prevent fatigue. Prior to training/competition the athlete must be fully hydrated. The body is approximately 70% water. Two thirds of the water is contained within cells and the remaining third makes up plasma, surrounds the cells, the lymphatic system and other liquids.

Sweating makes up the majority of water-loss (91%) with the remaining 9% from respiration (7%), skin (1%) and urine (1%). This loss of water from blood plasma causes a reduction in blood pressure which in turn reduces blood flow to muscles and skin. The reduced flow of blood to the skin reduces the body's ability to cool itself and the reduced circulation to the muscle means a greater reliance on the anaerobic energy systems, thus leading to earlier fatigue (Wilmore et. al. 2008).

A loss of just 2% of body weight of this precious liquid will have a significant impact upon physical and mental performance. Table 3.1.7 and Figure 3.1.20 compare the oxygen consumption; heat output, energy consumed and sweat loss for a 70kg athlete at rest and running at 4 min/km pace. After only one hour our athlete has already lost 2% of body weight in water. The heat generated running at 4 min/km pace (1,100 watts) is equal to the heat output of a small fan heater. It must also be considered that not all the sweat would contribute to cooling the body because not all of it would be evaporated, some is likely to drip off the body. In warmer temperatures the body would be also gaining heat from the environment. In the event of high humidity even more water would be lost through sweat with little cooling effect (one only needs to consider how ineffective evaporative air conditioners are on humid days).

Table 3.1.7: Oxygen consumption, heat output, energy consumed and sweat loss for a 70kg athlete at rest and running at 4 min/km pace (Hamilton, 2005).

	Oxygen consumption	Heat Output	Energy	Sweat loss to balance heat gain
At rest	250ml/min	70 watts	262.5 kJ/hour	94ml/hour
4 min/km pace	4000ml/min	1,100 watts	4,200 kJ/hour	1500ml/hour

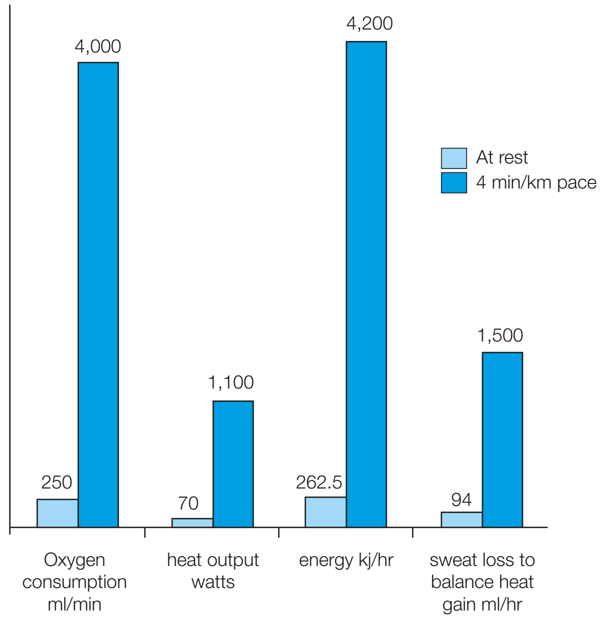


Figure 3.1.20: Oxygen consumption, heat output, energy consumed and sweat loss for a 70kg athlete at rest and running at 4 min/km pace (Hamilton, 2005).

Once the exercise is over, this lost fluid must be replaced. Glycogen stores must also be replaced and for each gram of carbohydrate that is consumed three grams of water are required to 'fix' it into the muscles. If your body does not get this water, it will draw it from other sources within the body. Water loss through sweating and urine also leads to the loss of valuable electrolyte minerals as shown in Table 3.1.8 and must be replaced.

Table 3.1.8: Electrolyte loss after 60 minutes of running at 4km/hr pace (Hamilton, 2005).

Electrolyte Minerals	Quantity
Chloride	1.48g
Sodium	1.15g
Potassium	0.23g
Magnesium	0.05g
Calcium	0.02g

Effects of Glycerol on Hydration

Theoretically, the addition of glycerol to water should allow greater absorption of water in the intestines and the retention of water in blood plasma. Water in the kidneys is also reabsorbed reducing diuresis (loss of fluids in urine) and promoting hyperhydration. Unfortunately, not all studies have found real benefits and potential side effects included 'headache, nausea, dizziness, bloating and light-headedness' (McArdle et. al. 2010).

Hyponatremia

In cases of extreme water loss, if water is replaced and the electrolyte minerals are not then the remaining electrolyte minerals are further diluted, leading to a condition referred to as hyponatremia. This condition is very serious. Symptoms can include confusion, headaches, swollen hands and feet, fatigue and reduced coordination. If electrolyte levels are too low there is a risk of seizures, coma and death. Under these circumstances an electrolyte replacement, such as a sports drink will be helpful. These drinks not only contain important carbohydrates but also the electrolytes needed. Also, because sodium promotes thirst it encourages the further consumption of water. The concentrations of the nutrients in some of these sports drinks has been calculated to optimise rapid absorption by the stomach (McArdle et. al. 2010).

Based on the most recent findings the guidelines for hydration are:

Pre Exercise

- Include adequate water as part of your regular diet
- Drink extra water prior to training/competition.

During Exercise

- If exercising beyond 30 minutes, drink 100-150ml of water/sports drink (little and often is best) every 15-20 minutes.
- Take into account the weather, high temperature and humidity require extra fluids
- Try different methods of hydrating during training to find which works best for you (it would be no good on the day of competition to find your stomach doesn't respond well to the drink you have chosen)
- If you don't like the taste of one drink, then experiment in training to find one you do like otherwise you're not likely to drink it.

Post Exercise

- Replace fluids lost (many teams are now weighing players before and after training/games to determine fluid losses)
- Continue to drink water as you replace carbohydrates
- Sports drinks/recovery drinks help replace fluids, electrolytes and carbohydrates (Hamilton 2005).

Helpful online resources

The Australian Institute of Sport and the Gatorade websites have are good websites to learn more about sports drinks:

www.ausport.gov.au/ais/nutrition/factsheets/hydration/fluid_-_who_needs_it

www.abc.net.au/health/talkinghealth/factbuster/stories/2011/07/21/3272459.htm

Supplements

Many athletes use supplements to improve body composition. This usually means anything that will increase muscle mass and decrease body fat. Unfortunately, this can come at the expense of energy intake. The latest scientific research indicates that athletes should concentrate more on 'appropriate energy intake and high carbohydrate and fluid intake' (Broad 2004). A balanced diet is usually the best way to achieve optimal performance. Supplements will not make up for lack of effort on the training ground. Supplements may be useful if there are diagnosed deficiencies in particular nutrients or it is necessary to consume large amounts of food that may be slow to digest. In this case supplements may be of some assistance.

Focus Questions

10. (a) You are a 70kg male soccer player training 3-4 times per week for 4 hours a session and a game on the weekend.

Complete the table below to calculate your carbohydrate/fat/protein requirements for training days.

g/kg of body weight

	g/kg of body weight	Total grams	kilojoules/g	total kilojoules
Carbohydrate			17	
Protein			17	
Fats			37	
Total energy consumption				

(b) Which food sources should be eaten to provide these nutrients?

(c) You have just arrived home from school and you have to be at training in 2.5 hours' time. Suggest a pre-training snack.

Focus Questions

(d) (i) What is the glycaemic index?

(ii) How might the GI help you plan your food selection and consumption?

(e) What are the characteristics of a recovery meal?

(f) (i) Why is hydration important?

(ii) What are the physiological effects of dehydration?

(g) (i) What are the advantages of consuming a sports drink during an extended exercise session?

(ii) Is a sports drink of any benefit to a 100m sprinter prior to their state final? Explain. (Their semi-final was 90-minutes earlier).

3

Aerobic and anaerobic energy

In relation to the chemical breakdown of macronutrients for energy, there are two main pathways that the body can use to extract energy from food to rebuild the adenosine triphosphate (ATP) molecule. These two pathways are termed **aerobic energy** (meaning with oxygen) or **anaerobic energy** (meaning without oxygen).

Within the two energy pathways there are three different energy systems (ATP-PC, lactic acid and the aerobic energy systems) used to provide energy for the rebuilding of adenosine triphosphate (ATP).

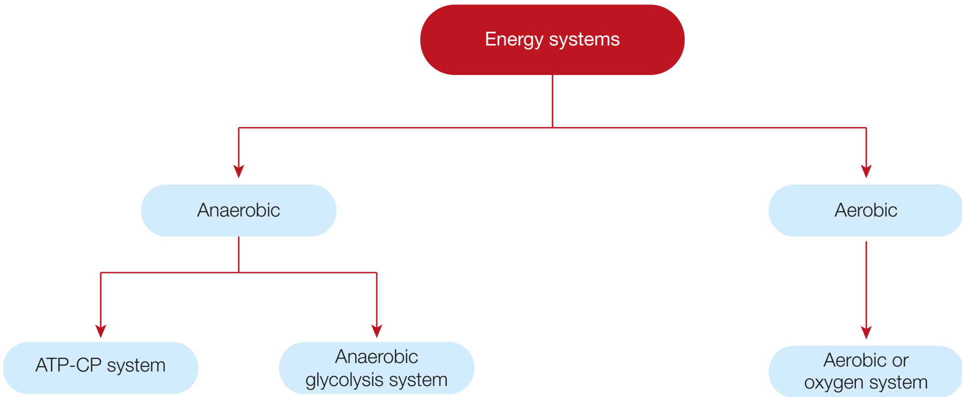


Figure 3.1.21: The energy systems.

Aerobic energy

The aerobic energy pathway requires oxygen for energy production and there is one energy system that provides energy with oxygen for low to moderate intensity and longer duration activities. The **aerobic energy system** relies on an adequate supply of oxygen being delivered to the active skeletal muscles (**mitochondria**) to break down the main macronutrients of **carbohydrate** (glycogen & glucose) and **fats** (triglycerides) to provide energy to rebuild ATP. Typically, the aerobic energy system is used most often in our day-to-day living and basic activities because it does not produce fatigue causing by-products and it can therefore provide energy for a long duration.

During exercise, the aerobic energy system is dominant in any low to moderate exercise intensity where oxygen supply is meeting oxygen demands (**steady state**) and the athlete is working **sub maximally**. The aerobic pathway is essential to energy production for endurance athletes who exercise for a long duration below their **lactate threshold** (refer to Focus Area 1.2 Application of energy sources affecting physical performance).

Table 3.1.9: Aerobic energy.

<table>
<tr><th colspan="2">Aerobic Energy</th></tr>
<tr><td colspan="2">• Requires oxygen to rebuild ATP
• Used in activities of a long duration
• Used in activities of submaximal to moderate intensity
• Can use carbohydrates (glucose & glycogen) and fats (triglycerides) as a fuel.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Figure 3.1.22: Marathon running</td><td>Figure 3.1.23: Triathlon</td></tr>
</table>

Aerobic energy takes place inside the **mitochondria** of the muscle cells.

With endurance training, athletes can make more mitochondria, larger mitochondria and more efficient mitochondria to increase the efficiency of their aerobic pathway in exercise at higher exercise intensities with less reliance on the anaerobic energy system that cause fatigue.

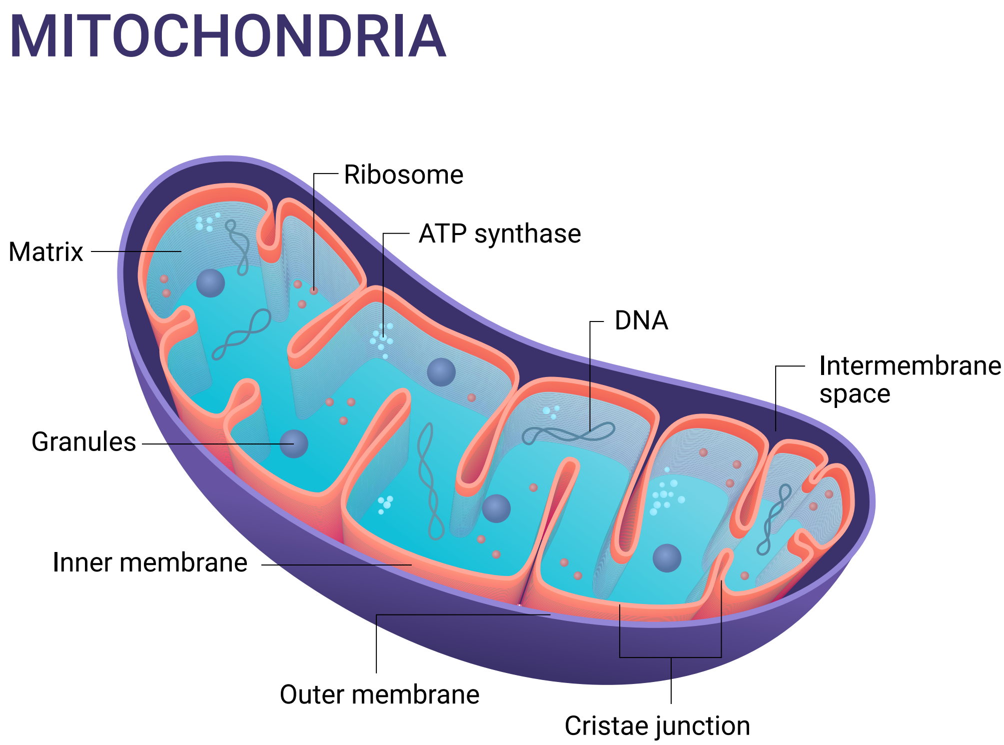


Figure 3.1.24: Mitochondria are the "powerhouse" of the muscle cells where aerobic energy production takes place.

Anaerobic energy

The anaerobic energy pathway does not require oxygen to rebuild ATP and there are two systems that can provide energy this way for high intensity and short duration activities. Firstly, the energy system known as the **ATP-CP** system relies on muscular stores of **creatine phosphate (CP)** as a fuel source for maximal efforts (95% +) over very short durations (< 10 seconds) such as a maximal throw, sprint or jump. Secondly, the **lactic acid** energy system relies on carbohydrates (glycogen and glucose) as a fuel source for high intensity efforts (>85%) over short durations (10 sec - 60 seconds) such as a 400m sprint or repeated high intensity efforts (refer to Focus Area 1.2 Application of energy sources affecting physical performance).

During high intensity exercise, not enough oxygen can be delivered to the active skeletal muscle to completely breakdown carbohydrates (unlike the aerobic energy system). Insufficient oxygen delivery results in the partial breakdown of a glycogen molecule, which results in the formation of a by-product called **lactic acid** which quickly moves into an athlete's bloodstream as **lactate** and **hydrogen ions** (H^+) causing fatigue.

The anaerobic energy systems are most often dominant during high exercise intensity where oxygen supply does not meet oxygen demands (**oxygen deficit**) and the athlete is working maximally above their **lactate threshold** or **OBLA**.

Table 3.1.10: Anaerobic energy.

Anaerobic Energy
• Does not require oxygen to rebuild ATP • Used in activities of short duration • Used in high to maximal intensity activities • Can use carbohydrates (glucose & glycogen) and creatine phosphate (CP) as fuels.

Figure 3.1.25: 400m Hurdles

Figure 3.1.26: High 'mark' in AFL

Contribution of aerobic and anaerobic energy

It should be noted, that at any one time, all three energy systems will be functioning and contributing to the supply of energy (this is the concept of **interplay)**. It is the intensity of exercise (how quickly ATP is required) and the duration of exercise (how much ATP is required) that will ultimately determine the dominant pathway (aerobic or anaerobic) and the dominant energy system in any activity (refer to Focus Area 1.2 Application of energy sources affecting physical performance).

As a general observation, it can be noted in Figure 3.1.27, that as exercise intensity increases, there will be a greater reliance on the more powerful anaerobic energy pathway (ATP-CP or lactic acid) and as the exercise duration increases there will be a greater reliance on the aerobic energy pathway.

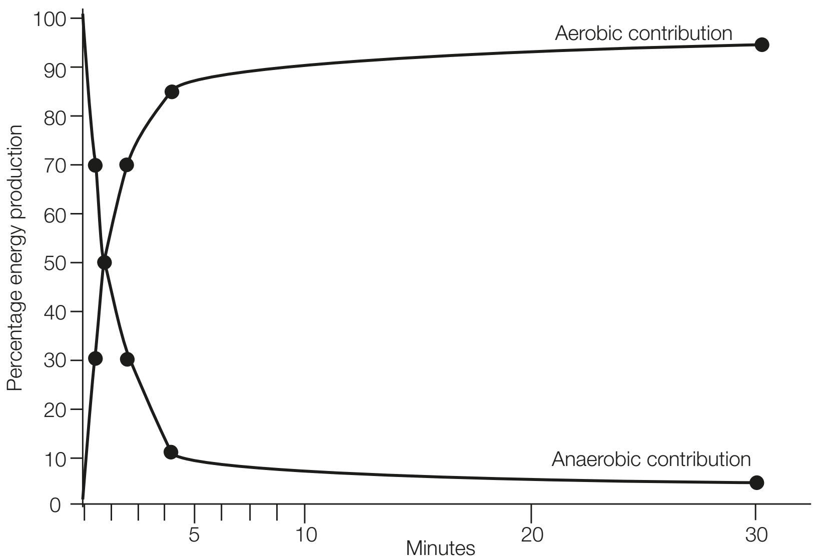


Figure 3.1.27: Aerobic and anaerobic energy contributions over time.

The approximate contribution of anaerobic and aerobic energy to maximal sustained efforts on a cycle ergometer is shown in Table 3.1.11. It can be seen that contributions from anaerobic energy pathways are dominant up to 60 seconds, after which aerobic energy pathways become the dominant energy pathway.

Table 3.1.11: Contributions of anaerobic and aerobic energy to maximal sustained efforts.

Duration of Exhaustive Cycling (seconds)	Exercise Intensity (%) of Maximum Power	Anaerobic	Aerobic
0-5	100	96	4
30	55	75	25
60	35	50	50
90	31	35	65
150	N/A	30	70
200	N/A	22	78

Adapted from: https://www.nsca.com/education/articles/kinetic-select/oxygen-uptake-and-the-aerobic-and-anaerobic-contributions-to-exercise/

Focus Area 3: About Movement

3.2 Physiological factors affecting physical performance

- Body stature and composition
- Barriers and enablers created by location, environment, and resource availability
- Fatigue and physical performance

Body stature and composition

Body composition is a term used to describe the 'make up' or percentage of various compounds in the human body. The main two components of interest are the percentage of fat and muscle. Body composition is seen as a key component for health (Wells & Fewtrell 2006), however, it is also important in elite sport. The amount of body fat a marathon runner is carrying for example, or the muscle fibre composition of a 100m sprinter are important factors influencing performance.

Somatotype is a measure of someone's body shape. It is independent of size or stature.

Somatotype

There are three different classifications of somatotype. The classification centres around certain physical characteristics. The 3D rendered figures (Figure 3.2.1 & 3.2.2) that follow, give an indication of the typical characteristics seen in each somatotype.

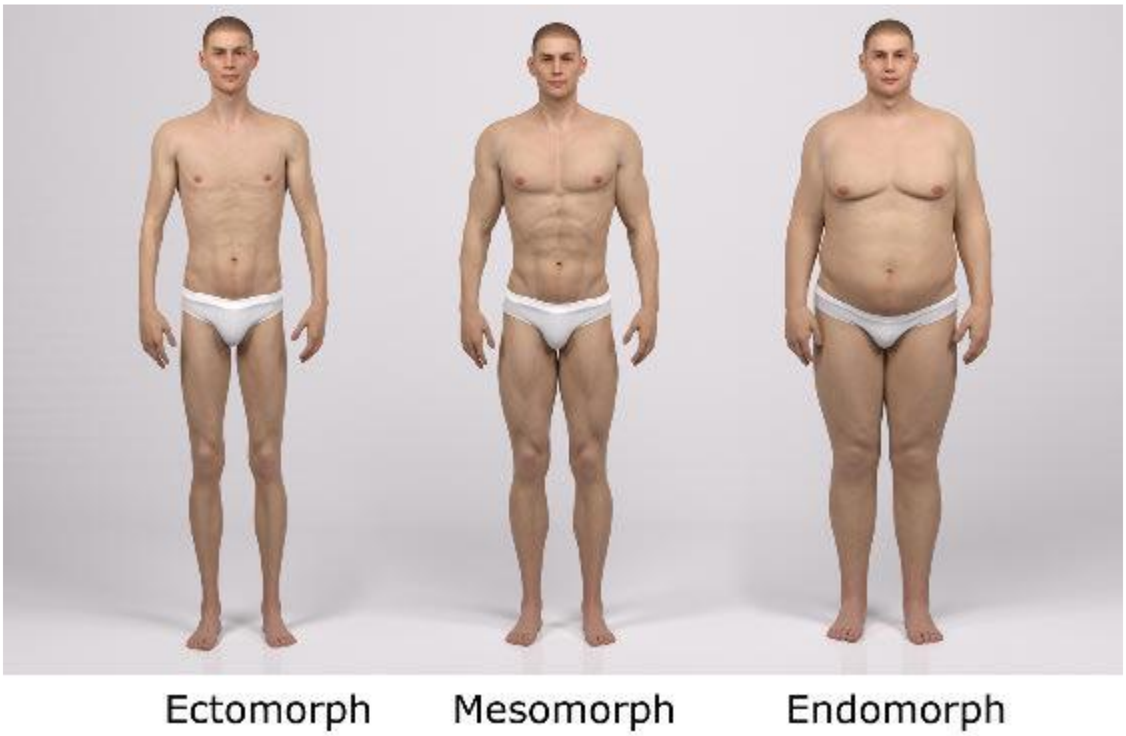


Figure 3.2.1

Figure 3.2.2

Figure 3.2.3: Mo Farah running the London marathon.

Ectomorph

In both examples, there is a tendency for the individuals to have less muscularity (not a lot of muscle mass) and very low body fat or percentage of body fat. This linear, thin body type is well suited to endurance events (see Figure 3.2.3). The lack of body fat is advantageous, as there is minimal 'dead weight' to carry while running long distances.

Endomorph

In comparison to ectomorphs, a typical endomorph will have a much higher percentage of body fat, to the point that they now have a rounded body shape. The larger body type is suited to very short activities, as the extra body fat would be a contributing factor to fatigue if running over longer distances. As there is often a larger muscle mass along with the body fat, endomorphs can still perform well in short, explosive events like shot put or hammer throw.

Mesomorph

As is evident in both examples (Figure 3.2.1 & 3.2.2), there is a much greater degree of muscularity, along with a lean body shape. A mesomorphic body type lends itself well to speed and power events, as the large muscle mass allows for the generation of large amounts of force or power. In addition, the lean body mass means less 'dead weight' (fat) to move over the course of a 100m or 200m sprint for example.

Figure 3.2.4: Michael Phelps 4 × 100m.

The classification of individuals into only one of the three distinct somatotypes doesn't occur. It is more common to see individuals classified as having attributes from two or more of the body types. Assessing or classifying individuals into a body type occurs through various measurements (skinfold, height, weight etc). Their results are then plotted onto a somatotype distribution graph (see Figure 3.2.5).

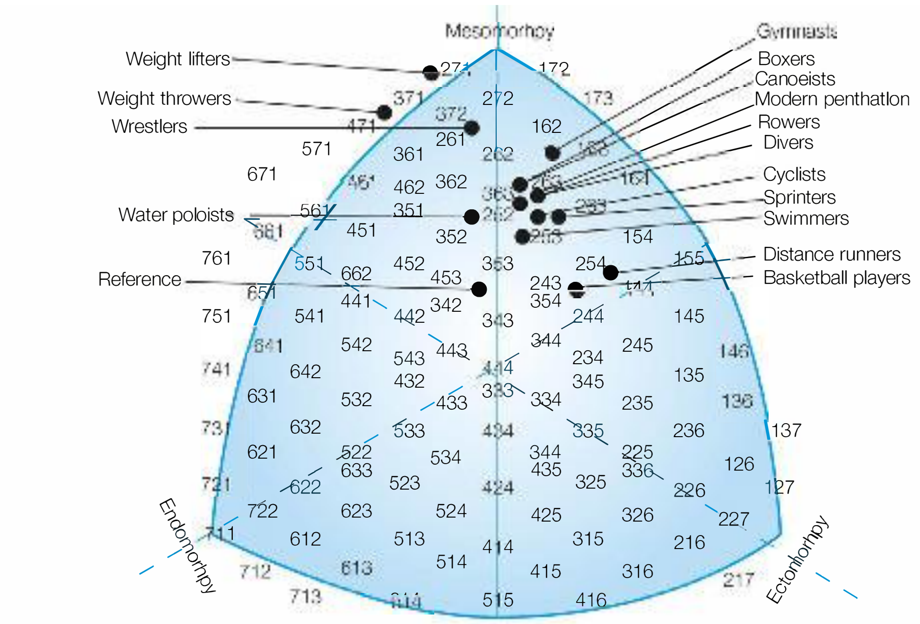


Figure 3.2.5: Somatotype distribution of mean somatotypes for various male sports groups and non-athletes. Source: Fox et al 1993

Somatotype have a 3-digit rating system to rate the degree of each body shape. Each rating is out of 7 and the order is Endomorph / Mesomorph / Ectomorph. Therefore, someone higher in muscle and lower in body fat may be 254. Plotted on the somatotype distribution graph, they would be positioned where 'X' is (Figure 3.2.6).

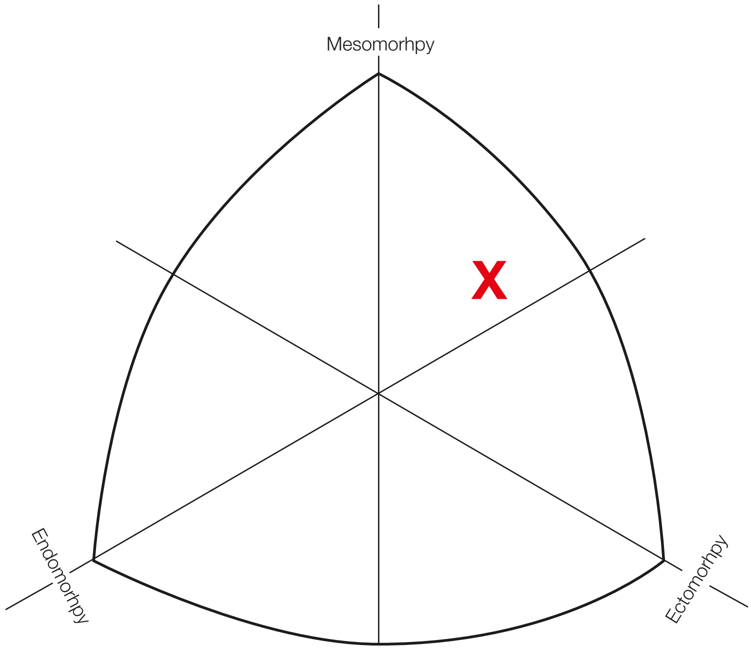


Figure 3.2.6: Somatotype distribution for 254.

Muscle fibre composition

The composition of the muscles or more specifically the fibre type is also an important factor for elite performance. In the human body there are two distinct muscle fibre types:

- Slow Twitch (Red Type I Slow Oxidative (SO))

  This fibre type is slower to contract and relies predominantly on the aerobic system (oxygen).

- Fast Twitch (White Type II Fast Glycolytic (FG).

  This fibre has a fast contraction rate and relies predominantly on the anaerobic glycolysis system.

Type II or fast twitch fibres can be further divided into two groups:

- Type II **A** considered to be intermediate in that it has the capacity to utilise both aerobic and anaerobic energy. They are sometimes called fast oxidative (FOG) fibres, as they can produce fast, powerful contractions and are more fatigue resistant than type II **B** fibres.
- Type II **B** possesses the greatest anaerobic potential and has true fast-glycolytic (FG) fibres.

Table 3.2.1: Characteristics of muscle fibre types.

	Type I (SO) Slow Oxidative (Red)	Type II A (FOG) Fast Oxidative (Red)	Type II B (FG) Fast Glycolytic (White)
Speed of Contraction	Slow	Moderate	Fast
Strength of Contraction	Low	Moderate	High
Resistance to Fatigue	High	Moderate	Low
Size	Small	Large	Large
Aerobic Power	High	Moderate	Low
Anaerobic Power	Low	Moderate	High

The amount of each fibre type is predominantly genetically determined. Athletes with a high percentage of fast twitch fibres are likely to be successful in activities requiring fast powerful contractions, whereas those with higher percentages of slow twitch fibres are likely to be better at endurance activities.

Figure 3.2.7: Shot put is an example of an activity that benefits from a greater percentage of fast twitch fibres compared to slow twitch fibres. This is because the event requires fast, explosive contractions to generate the speed and power at the point of release.

Selective Recruitment

Although there are two main muscle fibre types, the muscle fibres in a single motor unit will be of the same type. Subsequently, there are two types of motor units: slow twitch (ST) or fast twitch (FT). Each type of motor unit has a different recruitment threshold.

In a very weak muscle contraction, the smaller (and weaker) slow twitch motor units will be recruited first, while the large and strongest fast twitch motor units will only be activated during maximal contractions – this is known as 'selective recruitment'.

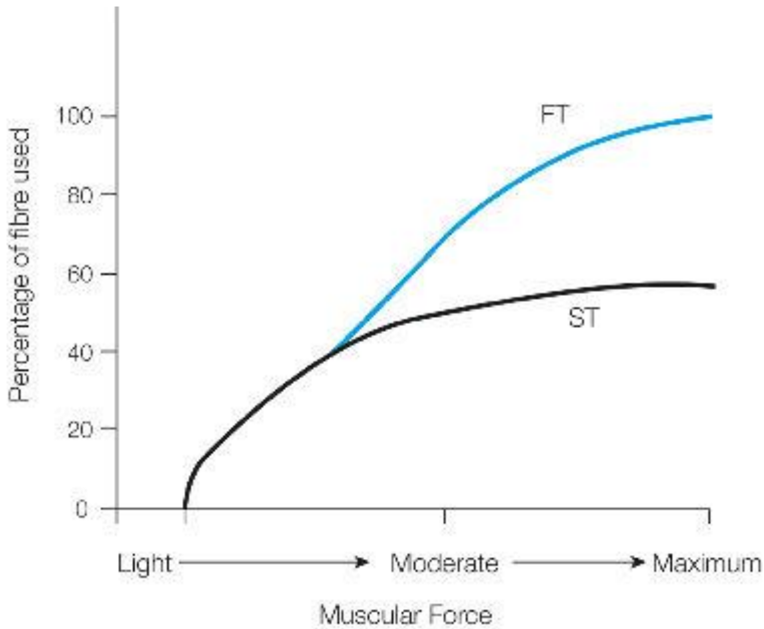


Figure 3.2.8: Motor unit recruitment where the larger fast twitch motor units are only recruited as the strength of the muscular contraction increases. Source: Adapted from Wilmore & Costill (1999), p. 261.

Height

The height of an athlete can affect their performance. For example, height is advantageous in sports like volleyball, basketball and netball. In volleyball, the height of the net makes it hard for shorter people to physically get above the net. This is important, as you need to be playing the ball downward into the opponent's side of the court if you wish to play attacking volleyball. A lack of height also limits the 'blocking' potential of the players when playing a defensive role in the front row.

Conversely, a shorter stature is advantageous in sports like diving and gymnastics. Shorter bodies are better for balance, as they have a lower centre of gravity. They will also have a lower rotational inertia (see Focus Area 1.3), so they can spin quicker through the air.

Figure 3.2.9: Height is an advantage in games like volleyball. Here the 3 Italian players executing a block are nearly 1 metre above the net, so easily counter the French attack.

Limb Length

Longer limbs create longer levers in sports like badminton or rowing. Longer levers generate more speed at the end of the lever. In a game of badminton this results in faster shuttle speed after contact. Shorter levers in sports like boxing and Taekwondo are a disadvantage as you have less 'reach'. This means to contact your opponent's head or body you must get in closer to them. This then exposes you to the possibility of suffering more blows in return. Please refer to Focus Area 1.3 – for more information regarding the impact of levers on performance.

Barriers and enablers created by location, environment, and resource availability

Due to the contribution physical inactivity has on the future health status of people (Bodde & Dong-Chal 2009), it's important to be able to identify and address barriers to physical activity and promote or encourage enablers of physical activity.

Location

In relation to locational barriers and enablers to physical activity, urban vs rural environments are most often cited. The findings generally point towards urban residents being more active than their rural counterparts (Trost et al 2002; Martin et al 2006). Rural areas have a lower population density, therefore travel distance for rural residents to physical activity is likely to be greater than in urban areas (Moore et al 2010). For children in rural locations that have no independent forms of transport (i.e. public transport) this is a major barrier. The lower population density in rural locations also means that the ability for a rural population to support enablers such as public transport or sporting facilities (i.e. swimming pool) are reduced. A town of 800 isn't likely to have an Olympic sized swimming pool, or an 18-hole golf course, unless there is financial support from the government.

Barriers to physical activity increase more in rural areas for physically disabled or intellectually disabled again due to the lack of facilities and infrastructure to cater for their increased needs. For example, public transport or specialised transportation vehicles are often needed. Yet due to the low demand in smaller populations they are unlikely to be available.

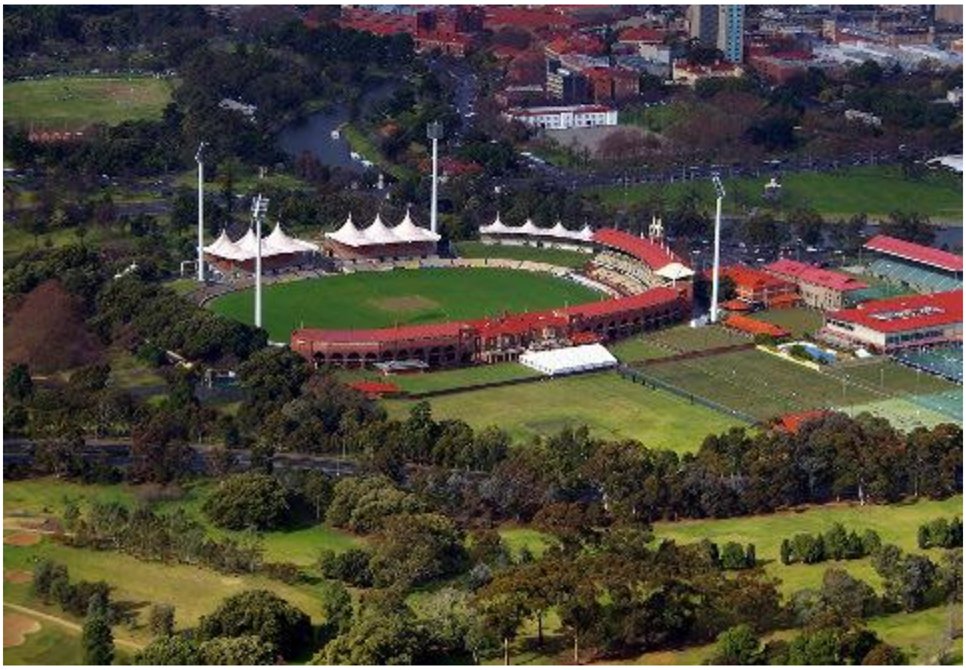


Figure 3.2.10: Adelaide Oval and Memorial Drive complex prior to the second upgrade. A city has many more sporting facilities and opportunities for physical activity than smaller towns.

Focus Questions

1. Describe a 'barrier' or an 'enabler' to physical activity in a sport of your choice that involves location.

Environmental

The area in which you live can impact on your willingness to participate in regular physical activity. Environmental factors can be split into two main areas:

- **Natural** (weather, geographical location, etc)
  - Hot, dry climates for example are conducive to dry, hard surfaces, often devoid of grass or other greenery. This makes playing on this surface less inviting. Alternatively, extreme cold (alpine areas) can also hamper physical activity.
  - Temperatures during summer can lead to a lot of sporting fixtures being cancelled
  - Wet weather during winter can result in damage to playing surfaces
  - Terrain. Do lots of hills inspire or discourage exercise?
  - Scenery – the natural environment in which you undertake exercise can improve or reduce your motivation.
- **Built** (how humans have impacted the natural environment)
  - Yard size. Average land size for homes is getting smaller in Australia, so proximity to other recreational areas is becoming more important.
  - Access to sporting or recreational facilities nearby your home
  - Satisfaction with those facilities i.e. are you are happy to be in those areas (safety, scenery, company etc.). Linked into this is location and weather.
  - Safety of the area. This might mean the streets (neighbourhood), are they safe to be in? Alternatively, it could be the quality of the footpath paving for the elderly, so they don't trip and fall.

Figure 3.2.11: Access to local recreational facilities was significantly associated with physical activity in the elderly (Trost et al 2002).

Resources

Resources are the means through which someone can be physically active. Equipment, facilities, finances and personnel are all examples of resources which enable or restrict participation in physical activity.

Some examples of resource-based barriers and enablers:

- AFLW – only one in four club level grounds across Australia in 2017 had changerooms appropriate for AFLW games (Urban 2017). Given the surge in popularity of the women's game, inadequate facilities could easily become a barrier to progressing the game for women and young girls. However, the AFL along with the Victorian and South Australian governments together have pledged $25 million (Urban 2017) to upgrade the aging facilities to make them suitable for women to use. This is an example of both a barrier (inadequate facilities) and an enabler (finances to upgrade facilities).
- Queenstown Oval – The barrier to cricket and football in Queenstown, Tasmania was the lack of an oval. Pollution from the mining processes made it difficult for grass to grow and the massive annual rainfall meant that any grass that did grow quickly turned into mud. However, the ingenuity of the mining town soon enabled the residents to be playing sport – their solution was a gravel oval. Yes, in this small mining town in Tasmania sport is played on a gravel oval.

Figure 3.2.12: The gravel oval of Queenstown, Tasmania.

Helpful online resources

The following video link is a little dated, but it's an informative look at a unique solution to a lack of facilities.

www.youtube.com/watch?v=467CHeaLkP0

The second link is from a more recent article the ABC did on the gravel field.

www.abc.net.au/news/2019-09-18/queenstown-gravel-oval-why-was-it-built/11499186

- Financial barriers – Children's sport at the base level can run into the hundreds of dollars, if not thousands. If the child then shows some promise and advances to an elite level of competition, these costs will rapidly rise. Weekly trainings become daily, volunteer coaches are replaced with full time coaches and it continues.

  In a NSW study, parents were spending up to $1100 (excluding transport costs) per person on average (Cull & Perry 2018). Registration fees were the major expense within that total, a finding replicated in Western Australia (Pownall 2016). Of the top 16 sports in 2017-2018, looking at all in costs (fees, equipment, coaching), golf, swimming and tennis were the most expensive. While rugby league and netball were the cheapest running about $1000 below golf. This difference may be due to the elite level leagues in rugby and netball contributing more to grassroots, or the cost of equipment etc, however, rugby at $342 (excluding transport costs) is still money that some families may struggle to find. So, finance becomes a barrier. Government subsidies (NSW $100, WA $200) in the form of a KidSport voucher to offset the cost of fees could well be the 'enabler' that gets some children on the field and playing.

Focus Questions

2. Research whether parents in South Australia can get a subsidy on their children's sporting fees
3. In a sport of your choice, identify the total approximate cost of a beginner first starting the sport and playing a full season. Include in your calculations the cost of equipment, and whether you think this amount is a barrier to participation.

Fatigue and physical performance

Fatigue during exercise is a complex issue to define or explain. This is due to a few reasons, those being;

- How to distinguish between peripheral fatigue (muscle weakness) or central nervous system (CNS) fatigue
- Environmental factors influence fatigue (i.e. temperature)
- Duration and intensity of the exercise
- The fitness level of the athlete at the time influences the risk of fatigue.

Adding to the complexity is the lack of a uniform definition for fatigue (Davis 2000, Phillips 2015). Some of the definitions include:

- reference to fatigue as a 'weakness' coming from

  "*repeated exertion or a decreased response of cells, tissues, or organs after excessive stimulation, stress or activity.*" Hirshkowitz (2013).

- reference to both the physiological and psychological factors associated with fatigue with

  "a change in psychophysiological state due to sustained performance [of one or more tasks at work]" van der Linden, Frese, and Meijman (2003).

- reference more to the outcomes or performance with

  "reduced force production, loss of exercise capacity, increased sense of effort or perception of force" Davis and Walsh (2010).

  or

  "...is the inability to function at the desired level due to incomplete recovery from demands of prior work and other waking activities. Acute fatigue can occur when there is inadequate time to rest and recover from a work period." Gander et al. (2011).

  or

  "decrements in performance on tasks requiring alertness and the manipulation and retrieval of information stored in the memory" Gawron et al. (2000).

The last three definitions are probably more in tune with Year 12 PE, as they look at the performance outcome i.e. a reduction in performance occurs when fatigued (refer to Focus Area 1.3). This focuses more on peripheral fatigue, rather than fatigue associated with the central nervous system. It is important though to look at both.

Central Nervous System (CNS) fatigue: this is a reduction in 'electrical impulses' to the muscle or can even relate to a lack of motivation relating back to the cerebral cortex (Davis and Walsh 2010). The psychological aspect (motivation) links in with 'Perception of effort' and 'Potential motivation'. Both factors that influence the point at which an athlete disengages or stops the activity (see the earlier section on perception of effort for more info).

Maximal exercise which leads to fatigue, is accompanied by a decrease in neural activity (McArdle et al 1991). This suppression of electrical stimulus suggests something within the central nervous system is involved. Yet, many people stop exercising when it starts to get hard (presumably their perception of effort has increased), well before their muscles lose the ability to produce the force required. This suggests central nervous system fatigue is not just a slowing or reduced ability to send electrical stimulus. It can also be a psychological change in perceived effort, motivation or even a difference in pain tolerance (Davis 2000).

Peripheral fatigue: is the fatigue associated with loss of force and power in the muscles. This can be due to:

- Fuel depletion
- Metabolic product (lactate and hydrogen ion accumulation)
- Changes at the cellular level i.e. disruption to calcium release from sarcoplasmic reticulum, or impaired interactions between myosin and actin filaments (Davis & Walsh 2010).

This workbook looks at the first two (fuel depletion and metabolic by-products) in detail. Detail regarding changes at a cellular level are beyond the scope of the current PE course.

Metabolic by-products

Metabolic by-products are the result of the breakdown of food (fuel) and the substances left behind (called by-products) can contribute to fatigue (i.e. lactate) The major by-products contributing towards fatigue that cause the most concerns are **lactate**, **hydrogen ions** (H^+) and **heat**.

Lactate and hydrogen Ions

Lactate and **hydrogen ions** are the result of the breakdown of lactic acid. Previously lactic acid received the blame for the burning sensation during events such as 400m sprint races. This is not entirely correct, as lactic acid is quickly broken down by the body into lactate and hydrogen ions and it is this that causes fatigue.

Hydrogen ions are now believed to be the major culprit contributing to fatigue. 'Most researchers agree that any negative effect on performance associated with blood lactate accumulation is due to an increase in hydrogen ions' (Davies 2010). Lactic acid is broken down into lactate and hydrogen ions and it's the presence of these hydrogen ions that lead to an increase in blood acidity or acidosis. The increased acidity in the blood, impacts on glycogen breakdown and muscle contraction. Athletes who regularly train the lactic system to exhaustion, can tolerate larger amounts of lactate. They can also raise their lactate threshold and delay the point accumulation begins.

For a Year 12 PE, the terms lactic acid, lactate or hydrogen ions could all be used to explain fatigue. There is no benefit in using one over the other, although lactate is probably the most widely used now.

Figure 3.2.13: Nea Mattila, 400m hurdles at World Championships, Finland. Lactate build up is a major contributing factor to fatigue in sprint events like the 400m.

Thermoregulation (Dehydration and increased body temperature)

Dehydration is the result of water loss. In sport, the body predominantly loses water through the act of sweating. Dehydration causes a reduction in blood volume, with the reduction in volume coming from the blood plasma (Hypovolemia). In response the blood pressure drops and the heart rate increases (Tortora and Grabowski 1993). Ultimately, there is a reduction in blood flow to muscles and skin. The combination of less water available for sweating and a reduced flow of blood to the skin reduces the body's ability to cool itself via the evaporation of sweat. In addition, the reduced blood circulating to the muscles means less oxygen, so a greater reliance on the anaerobic energy systems thus leading to earlier fatigue (Wilmore et. al. 2008).

A loss of approximately 4% of body mass (water) during sport is considered moderate - severe dehydration. At this level of dehydration, it begins to significantly impair motor skill performance (Gamage et al 2016, McArdle et al 1991). An endurance athlete's capacity (or an athlete playing a prolonged game) is going to be impaired then in hot weather if inadequate re-hydration occurs. This will be amplified if conditions are both hot **AND** humid.

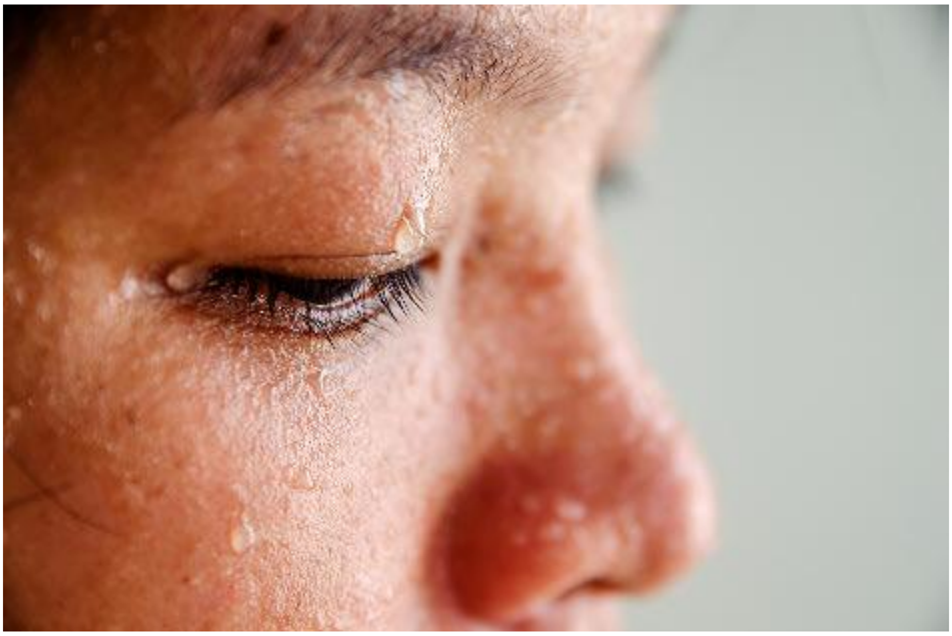


Figure 3.2.14: Heat is 'lost' from the body when sweat evaporates from the skin.

Muscular contractions generate heat through friction of moving fibres as well as a lot of the energy released in muscle cells (i.e. aerobic respiration) transformed into heat (Aleksander et al 2010). The body attempts to regulate this increase in heat through processes like:

- Conduction: Heat transferred through contact. The direction of the transfer is from the hotter source to the cooler source.
- Radiation: Heat is radiated away from the hot body into the cooler surrounding environment.
- Evaporation: Heat energy is drawn from the body to transfer liquid water (sweat) on the skin into a gas (water vapour). This evaporation process requires heat energy. The body therefore 'loses' (transfers) this heat energy at the surface of the skin when the sweat changes state (liquid to a gas) and evaporates.

However, in hot environments where the ambient temperature is hotter than skin temperature, processes like radiation and conduction are no longer efficient. This is because the body is now cooler than the surrounding environment. Essentially the body is 'absorbing' heat from the environment rather than 'losing' it. So, in very hot climates or environments the body's main method to regulate heat is through 'evaporation' of sweat on the skin.

If the environment is hot **AND** humid, then the body struggles to lose heat. Instead, extended exercise leads to heat storage (Aleksander et al 2010) or over-heating. Evaporation requires the water on your skin to be able to evaporate into the air. Humidity is a measure of water vapour already in the air. So, if the air humidity is 100% for example, it means the air is saturated with water vapour and can't take or hold anymore. So, exercising in highly humid environments will result in the sweat staying on your skin instead of evaporating. If sweat doesn't evaporate, then the body isn't being cooled as effectively as it requires.

Ultimately, a rising body temperature or exercising in hot environments leads to a reduced exercise duration. What is less certain is the exact cause of the fatigue. Exercising in the heat also accelerates the rate of glycogen use. Yet exercise duration in hot environments is reduced despite the presence of adequate glycogen stores (Tyka et al 2009), so factors other than glycogen availability must be related to fatigue.

Other considerations when looking at the reduced performance due to heat are:

- Higher ambient temperatures lead to an increased metabolic rate
- Vasodilation of skin blood vessels to cool the body, reduces oxygenated blood flow to inspiratory muscles. This in turn could lead to greater inspiratory muscular fatigue (Tyka et al 2009).

Figure 3.2.15: A 'runner' in the Oman desert marathon. Extreme heat reduces the duration of exercise. Appropriate rehydration strategies and pre-event heat acclimatization would be vital for an event like this to reduce the risk of premature fatigue.

Fuel Depletion

Phosphocreatine Depletion

Short high intensity activity (i.e. 100m sprint) rely pre-dominantly on the ATP-CP system to provide energy for ATP re-synthesis. The energy comes from the chemical breakdown of the phosphocreatine (or creatine phosphate) stores in the muscles. Phosphocreatine stores (PC) within the fast twitch muscle fibres are limited. Once phosphocreatine is no longer available for the resynthesis of ATP, the intensity of the activity reduces, when ATP resynthesis by the lactic or aerobic energy systems become more dominant. This means repeated sprints at the same intensity are limited unless enough recover time is provided between sprints. In sporting games like soccer or netball, often time isn't available to adequately recover, so the speed of the athlete drops.

Figure 3.2.16: Women's 200m final, Berlin 2018. The duration of a 200m final (approx. 20 seconds) is long enough for depletion of Phosphocreatine stores.

Glycogen Depletion

When phosphocreatine stores are depleted glycogen stores become the preferred fuel for high intensity activities. Glycogen remains the preferred fuel if the intensity of exercise is high. The graph below (Figure 3.2.17) illustrates the 'cross-over concept' that states 'as exercise intensity rises, so does the use of glycogen as a fuel source. The greater use of fats as a fuel at low intensity exercise allows for a much slower depletion of glycogen or 'glycogen sparing' for when the intensity increases again. Glycogen stores are limited to what can be stored in the muscles and liver.

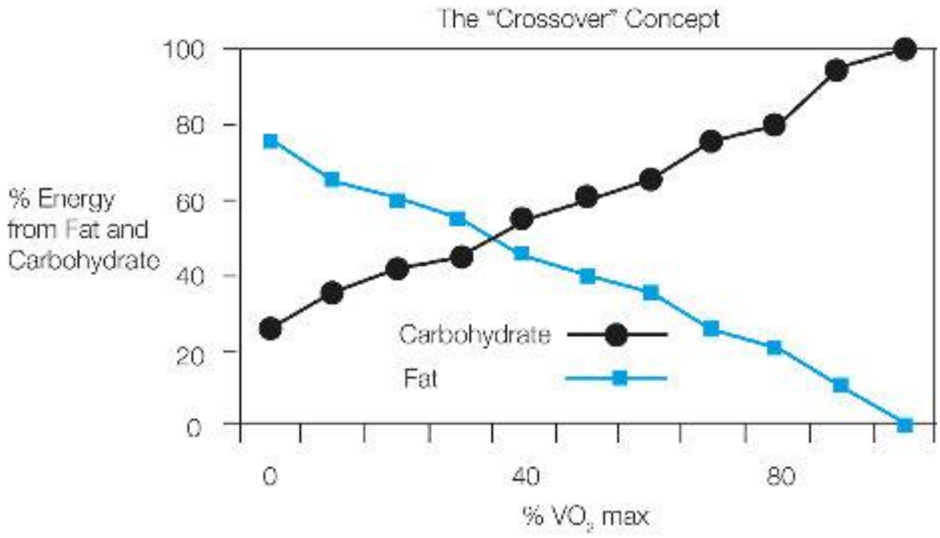


Figure 3.2.17: The 'cross-over concept'. Higher intensities (as indicated by % VO_2 max) result in greater glycogen (carbohydrate) use.

Marathon runners often deplete their glycogen stores and report 'hitting the wall' at between the 29km and 35km marks, this would be about the 1 hour 30 minutes to 1 hour 50 minutes mark. What is happening is that the glycogen stores in both the muscles and liver have become depleted or close to. As glycogen stores are depleted there is a greater reliance on free fatty acids. The amount of ATP required to maintain the high intensity work cannot be sustained when fats are the dominate fuel source, as breaking down fat requires more oxygen from the body. Therefore, there is decreased muscular power and the work intensity reduces. The sudden drop in speed during a marathon for instance is like the athlete had run into a wall and stopped – hence the saying 'hitting the wall'. Good nutritional strategies prior to and during competition will assist in prolonging the use of glycogen stores. Refer also, to Focus Area 1.1.

Figure 3.2.18: The Berlin Marathon is one of the world's top 6 major marathons. Each year approximately 40,000 participants enter the event. All of the runners are candidates for glycogen depletion if running at a high intensity without adequate glycogen replenishment strategies.

Focus Area 3: About Movement

3.3 The effects of training on physical performance

- Acute response to physical activity
- Chronic adaptations to aerobic and anaerobic training
- Acute responses to physical activity

Acute Circulatory and Respiratory Response to Exercise

Acute response: An acute response to exercise is something that changes as soon as you begin to exercise (i.e. heart rate increases from 62bpm to 135bpm), but once you stop exercising it will quickly return to its original condition.

The acute responses to exercise on the cardio-respiratory system are easy to remember as the majority 'increase'. This is a result of the body trying to deliver a greater volume of oxygen to the working muscles for aerobic metabolism.

Figure 3.3.1: Cardio-respiratory responses are in relation to a need for greater volumes of oxygen.

Increased Heart Rate

Heart rate (HR) is the number of times the heart beats per minute (bpm).

Because of the greater demand for oxygen during exercise, the heart will beat faster to ensure more blood is pumped per minute around the body. Resting HR averages around 65bpm, but even before the start of exercise, there is usually an 'anticipatory response' that may increase the HR significantly. During sub-maximal work, the HR will increase in proportion to exercise intensity until a 'steady state' is achieved. If exercise intensity is maximal, HR will continue to rise until the person's HR max of around 200bpm (predicted at 220 minus age).

Figure 3.3.2: Heart rate monitoring.

Increased Stroke Volume

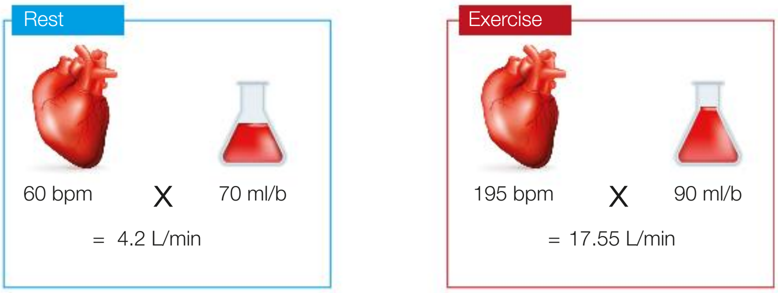
Stroke volume (SV) *is the volume of blood pumped from the left ventricle of the heart per beat.*

At rest, SV is around 70ml. To increase the volume of blood pumped around the body (to increase the availability of oxygen), the SV will increase with exercise intensity until a maximum of around 90ml per beat for the untrained individual. SV max is usually achieved during sub-maximal exercise intensities.

Increased Cardiac Output

Cardiac output (Q) is the volume of blood pumped around the body per minute (it is therefore the product of a person's HR and SV).

To increase O_2 supply to the working muscles, cardiac output increases proportionally with exercise intensity, up to approximately 17 litres per minute for the untrained individual.



Cardiac Output = Heart Rate x Stroke Volume
Q = HR x SV
Units L/min = bpm x ml/b

Figure 3.3.3: Acute effects of exercise on cardiac output.

Increased Arterio-Venous Oxygen Difference

The **arterio-venous oxygen difference (a-v O_2 diff.)** is the difference between the oxygen concentration of blood in the artery and the oxygen concentration of blood in the vein.

It reflects the amount of oxygen taken from the blood capillaries by the muscles. At rest, the blood's oxygen content varies from 20ml O_2 per 100ml blood in the arteries, to 14ml per 100ml blood in the veins. Hence, the a-v O_2 diff is 6ml of oxygen (20ml – 14ml = 6ml).

During exercise, the muscles require greater oxygen, so more oxygen is extracted from the blood as it passes through the capillaries surrounding the muscles. During maximal exercise, the a-v O_2 difference may increase to around 12ml of oxygen (20ml – 8ml = 12ml) for the untrained (refer Figure 3.3.5).

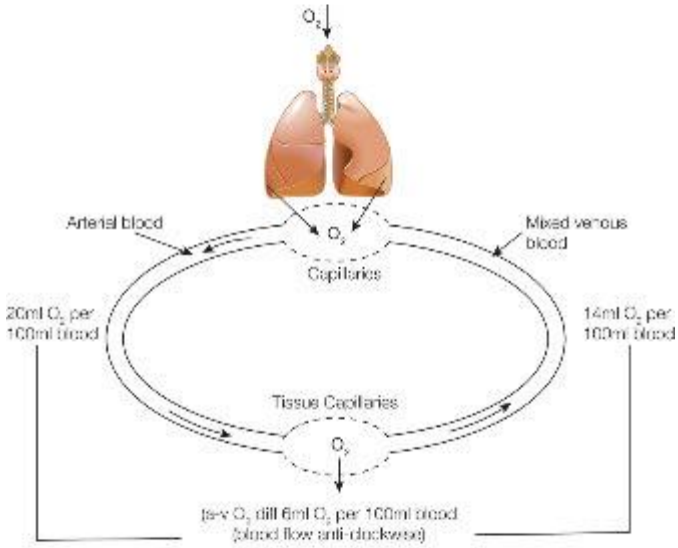


Figure 3.3.4: Arterio-venous difference (a-vO_2 diff.)

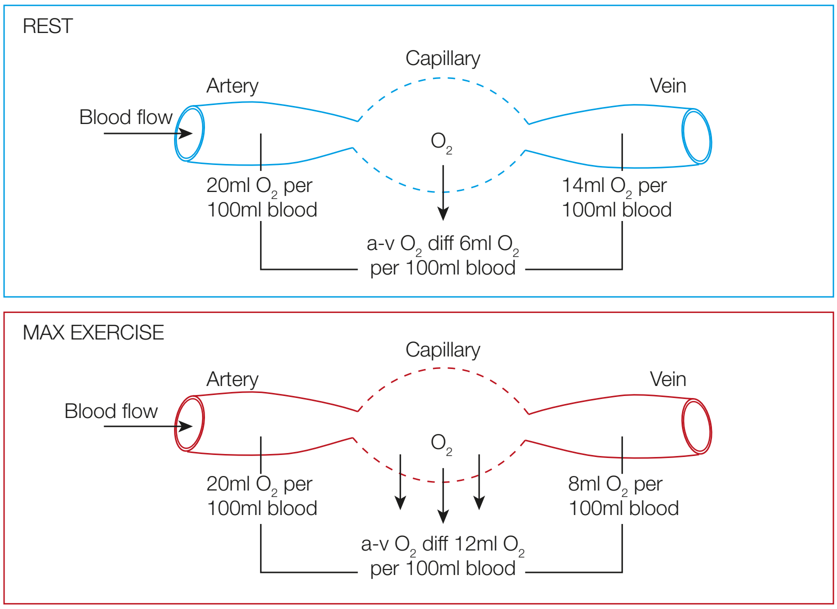


Figure 3.3.5: Untrained av-O_2 difference at rest and during maximal exercise. Source: Adapted from Wilmore & Costill (1999).

Increased Blood Flow

There is a limited supply of blood within the body. Therefore, during exercise, the cardiovascular system needs to redistribute blood volume away from areas with low O_2 demands to areas requiring high O_2 demands. During exercise, movement is away from non-essential organs such as the kidney and liver and towards the active skeletal muscles (used for movement). For example, at rest the skeletal muscles may receive only 15% of a small cardiac output (4.2L/min), but during maximal exercise this may rise to 80% or more of a much larger cardiac output (17.5L/min). The kidneys, on the other hand, may receive up to 20% of resting cardiac output, but during maximal exercise this drops to around 2%.

The redistribution of blood flow during exercise is achieved through a process called **vasodilation** and **vasoconstriction** of the blood vessel. The arterioles and capillaries of the muscles requiring more O_2 during exercise will expand (vasodilation) and allow greater blood supply; meanwhile, the arterioles and capillaries of the organs will narrow (vasoconstriction) to reduce blood flow to these organs.

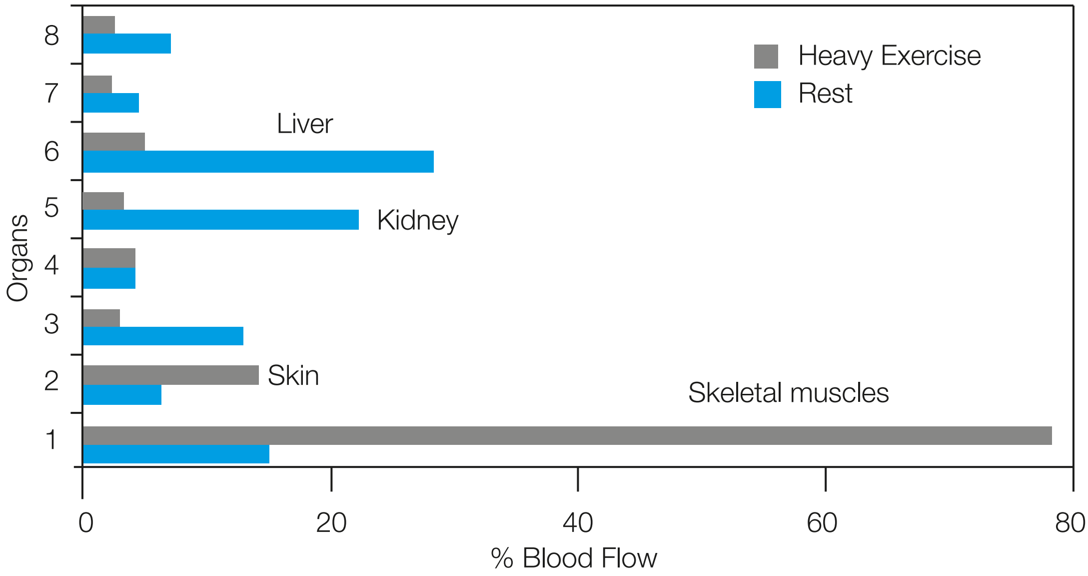


Figure 3.3.6: Distribution of blood flow to body organs during rest and heavy exercise.

Blood Pressure

Systolic blood pressure is the pressure exerted on the blood vessels when the left ventricle of the heart contracts. In aerobic-type activities, systolic blood pressure rises in proportion to the exercise intensity from an average of 120mmHg at rest up to 200mmHg during maximal exercise. This increase in **blood pressure** (**BP**) is a result of the increased cardiac output being pumped through the blood vessels (increased blood volume passing through the arteries creates greater friction and pressure on the artery walls). An increased systolic BP assists in the quick delivery of blood (and hence O_2) to the working muscles.

Diastolic blood pressure is the pressure exerted on the blood vessels when the left ventricle of the heart relaxes. At rest, diastolic BP is usually around 80mmHg. In a healthy individual, diastolic BP during aerobic-based activity changes little.

Increased Oxygen Uptake (VO_2)

A person's VO_2 is a function of their heart rate (HR), stroke volume (SV) and arterio-venous oxygen difference (a-v O_2 diff). It should therefore be no surprise that VO_2 will increase with the onset of exercise to increase supply of oxygen to the working muscles. At rest, a person's VO_2 is around 0.3L/min, but as sub-maximal exercise begins, a steady state will soon be reached where oxygen supply equals oxygen demand and the aerobic energy system is dominant. If exercise intensity were to continue to increase, VO_2 would continue to rise until the body could not deliver any more oxygen (VO_2 max), despite further increases in workload.

Changes in Blood Lactate Levels

Even at rest, it should be noted that there are low levels of lactate in the blood (approx. 1-2mmol/L). However, as soon as exercise begins, lactate will slowly rise as anaerobic glycolysis makes a greater contribution to ATP requirements. If the athlete works at a sub-maximal intensity, they will soon reach a 'steady state' and blood lactate will begin to drop away as the aerobic energy system meets energy demands. If exercise intensity were to continue to rise and approach VO_2 max they would exceed **lactate threshold (OBLA)** and the rate of lactate accumulation would outweigh the speed at which the body can process it.

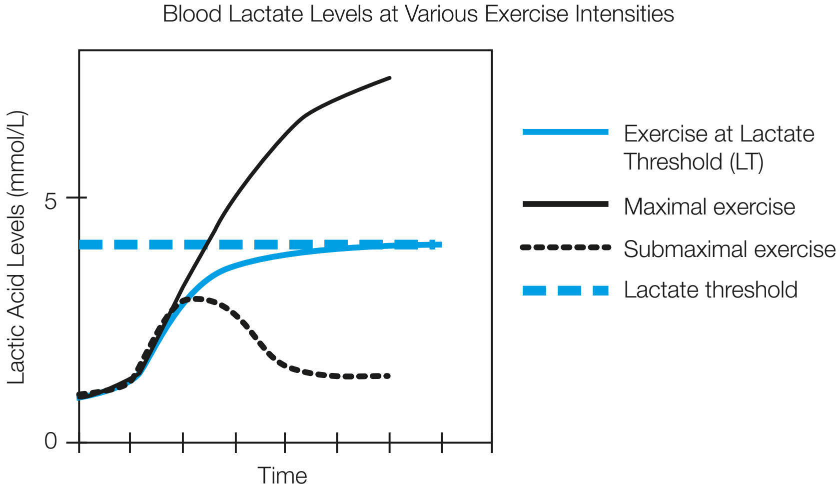


Figure 3.3.7: Blood lactic acid levels at varying exercise intensities. Source: Adapted from Shield & Young (1995).

Decreased Blood Volume

Almost immediately from the onset of exercise, there is a decrease in blood plasma volume. This is initially a result of water being forced out of the capillaries because of increased blood pressure; but with extended exercise, it may also be a result of fluid loss through sweating to maintain body temperature.

Increased Ventilation

Ventilation (VE) is the process by which air is moved in and out of the lungs per minute (in other words breathing). VE is a function of a person's **tidal volume (TV) –** the volume of air moved in and out of the lungs per breath – and their **breathing frequency (Bf)**, namely the number of breaths per minute**.** At rest, ventilation is around 6L/min (0.6L × 10 breaths/min). There is usually a significant increase in ventilation prior to exercise due to the 'anticipatory response', but during heavy exercise, ventilation may rise to 110L/min (2.5L × 45 breaths/min) in an attempt to increase the delivery of oxygen to the alveoli in the lungs.

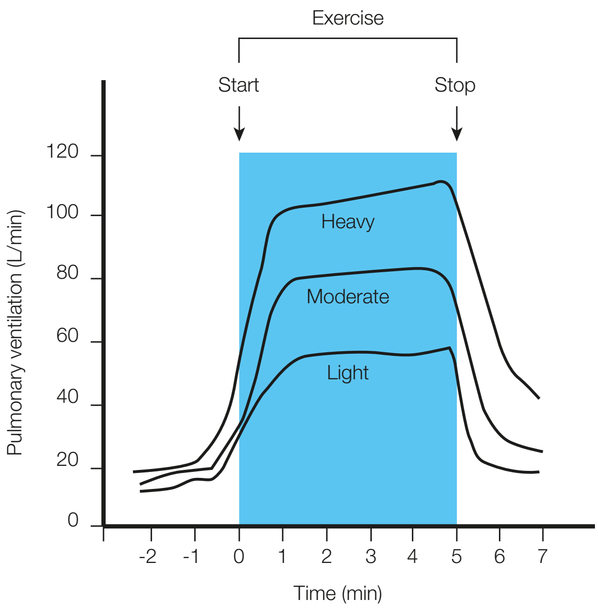


Figure 3.3.8: Ventilation rate prior to exercise, during and post exercise at varying intensities. Source: Adapted from Wilmore & Costill (1999), p.261.

Increased Lung Diffusion

There is a large redistribution of blood flow going to the lungs during exercise, which assists in an increased diffusion of oxygen from the alveoli to the blood as it passes through the lung capillaries that surround each alveoli.

Focus Questions

1. Explain the following terms:
   - Heart rate
   - SV
   - Cardiac output
   - a-v O_2 difference
   - Blood pressure
   - Tidal volume
   - Ventilation

Focus Questions

2. Complete the following table, looking at the acute responses of exercise on the cardio-respiratory system (increase, unchanged or decrease). Briefly explain why each change occurs.

	Response	Why?
Heart Rate		
Stroke Volume		
Cardiac Output		
a-vO_2 difference		
Redistribution of blood flow		
Blood Pressure (Systolic)		
Blood Pressure (Diastolic)		
VO_2		
Lactic acid levels		
Blood Volume		
Minute Ventilation		
Tidal Volume		

Acute Muscular Response to Exercise

The short-term (immediate) responses to exercise on the muscular system are a direct result of the body producing movement. The exact responses are, to a large extent, dependent upon the nature of exercise undertaken.

Increased Motor Unit Activation

A motor unit is a motor neuron (a nerve that activates muscle fibres) and all the muscle fibres it attaches to. A motor neuron affects all of the muscle fibres it controls in the same way. That is, if a motor neuron is stimulated to contract, all the muscle fibres in that unit will simultaneously contract at 100% effort. This is known as the **all-or-none principle**.

Figure 3.3.9: Physical activity requires muscular contraction.

Motor Unit Recruitment

All activities that involve movement require muscular contraction. The greater the force means more motor units are recruited to contract.

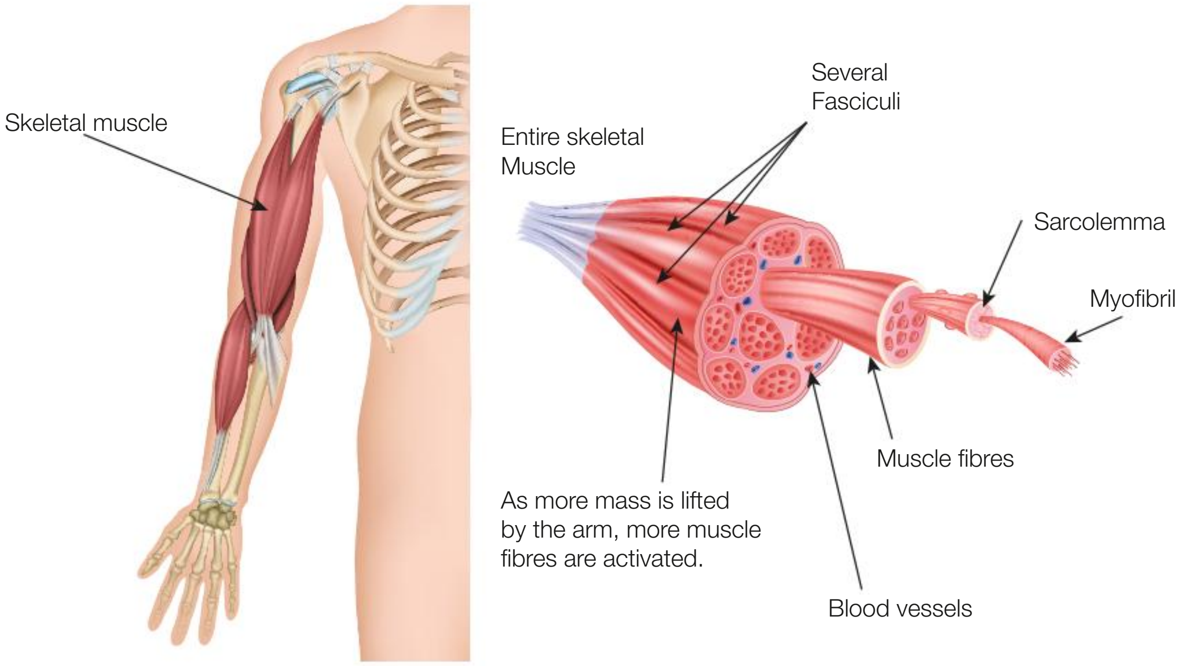


Figure 3.3.10:

It should be noted that not all muscle fibres are created equal – there are two main classifications of muscle fibres: **slow twitch (ST)** and **fast twitch (FT)**. The percentage of ST and FT fibres in each individual is different and genetically determined; that is, training cannot significantly alter a person's fibre type distribution. Refer to Focus Area 3.2 Body Stature and Composition for further details on muscle fibres.

Table 3.3.1 shows that the fatigue resistant/low force ST fibres are better suited to low-intensity endurance-based activities, while the easily fatigued/high force FT fibres are better suited to high intensity short duration power activities.

Table 3.3.1

	Type I (SO) Slow Oxidative (Red)	Type II A (FOG) Fast Oxidative (Red)	Type II B (FG) Fast Glycolytic (White)
Speed of Contraction	Slow	Moderate	Fast
Strength of Contraction	Low	Moderate	High
Resistance to Fatigue	High	Moderate	Low
Size	Small	Large	Large
Aerobic Power	High	Moderate	Low
Anaerobic Power	Low	Moderate	High

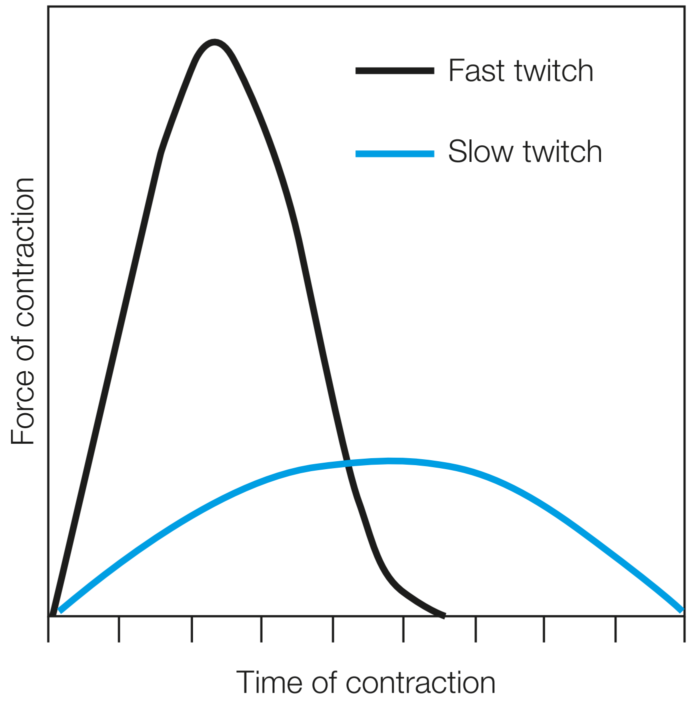


Figure 3.3.11: Force and speed of slow and fast twitch contraction.

Selective Recruitment

Although there are two main muscle fibre types, the muscle fibres in a single motor unit will be of the same type. Subsequently, there are two types of motor units: ST or FT. Each type of motor unit has a different recruitment threshold.

In a very weak muscle contraction, the smaller (and weaker) ST motor units will be recruited first, while the large and strongest FT motor units will only be activated during maximal contractions – this is known as '**selective recruitment**'.

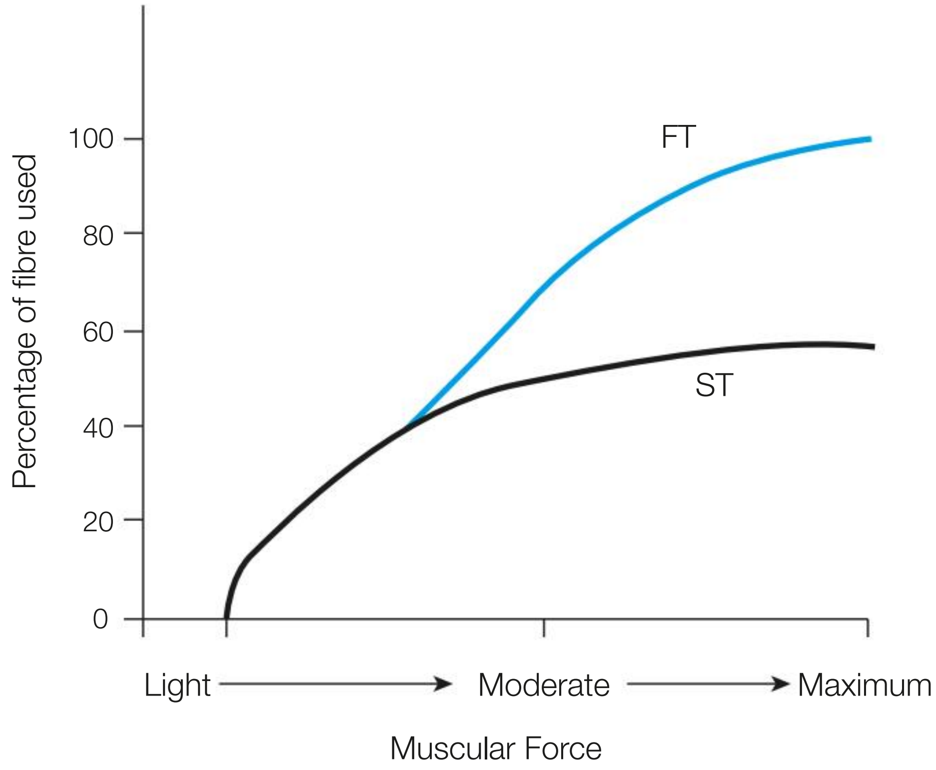


Figure 3.3.12: Motor unit recruitment where the larger fast twitch motor units are only recruited as the strength of the muscular contraction increases. Source: Adapted from Wilmore & Costill (1999), p. 261.

Increased Muscular Temperature

An increase in muscle contractions results in a rise in muscular temperature because:

- increased demand for oxygen means greater blood flow past muscle cells (blood is the main means of transport for heat energy).
- ATP resynthesis generates greater heat output (aerobic respiration).

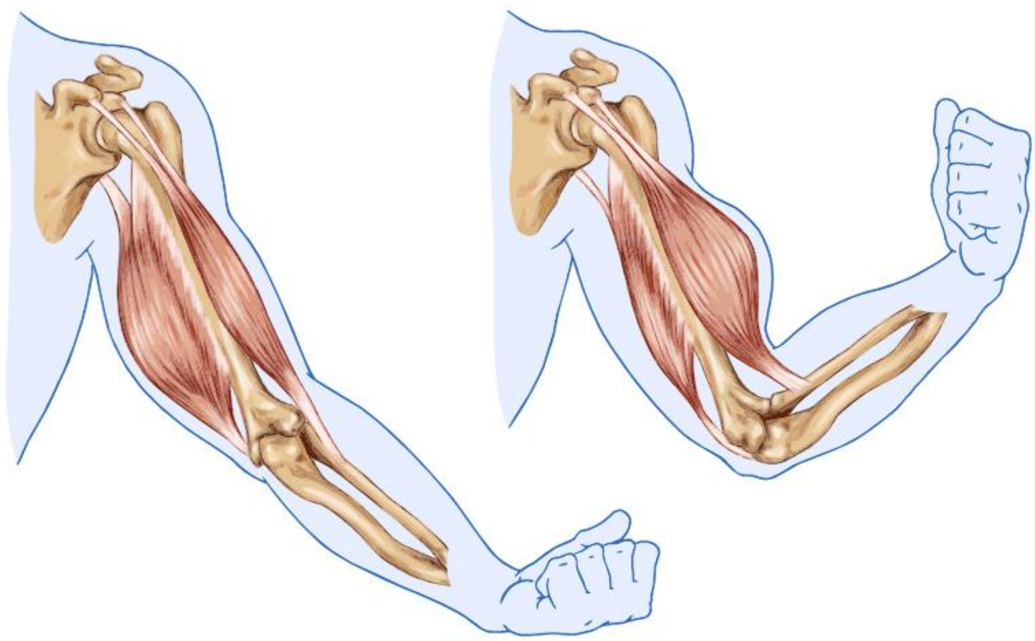


Figure 3.3.13: Muscle temperature rises with contractions.

Decrease in Fuel Stores

With exercise, comes a decrease in stores of:

- CP (creatine phosphate)
- Glycogen
- Triglycerides

All three fuels suffer some degree of depletion as they are utilised (broken down) to release energy to resynthesise ATP molecules.

ATP stores are also depleted to varying degrees (remember they are the only source of energy for muscular contraction).

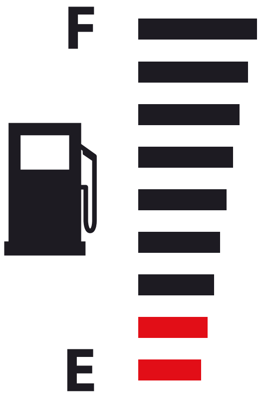


Figure 3.3.14

Increased Enzyme Activity

Enzymes responsible for speeding up the rate of reaction (i.e. glycolytic enzymes) within the skeletal muscles increase their activity level.

Remember, the extent of the short-term responses will depend on the type, duration and intensity of the activity. For example, Triglyceride stores will decrease at vastly different rates when comparing activities like a 60m sprint and a walk down to the corner store.

Focus Questions

3. Explain the following terms.
   - Motor Unit

   ....

   ....
   - Selective recruitment

   ....

   ....
   - Enzymes

   ....

   ....

Focus Questions

4. Complete the following table looking at the acute responses of exercise on the muscular system (increase, unchanged or decrease). Briefly explain why each change occurs.

	Response	Why?
Motor Unit Recruitment		
Muscle temperature		
Fuel stores		
Enzyme activity		

5. Refer to the table below outlining cardiac output utilised by body tissues during rest and activity. Percentage of cardiac output utilised by different body tissues at rest and during activity.

Tissue	At Rest (%)	During Activity (%)
Muscle	20	84
Heart	4	4
Skin	6	2
Brain	14	4
Kidney	22	1
Liver	27	2
Other	7	3

(a) Explain why cardiac output to the muscles during activity increases significantly.

(b) Identify three acute body responses that would enable cardiac output to increase to the muscles during activity.

Chronic adaptations to aerobic and anaerobic training

Chronic response: These are the result of repeated training sessions over a period of time, which cause adaptations to occur in the body that are more permanent. These adaptations are often termed the '**training effect**'.

Figure 3.3.15: Circuit training.

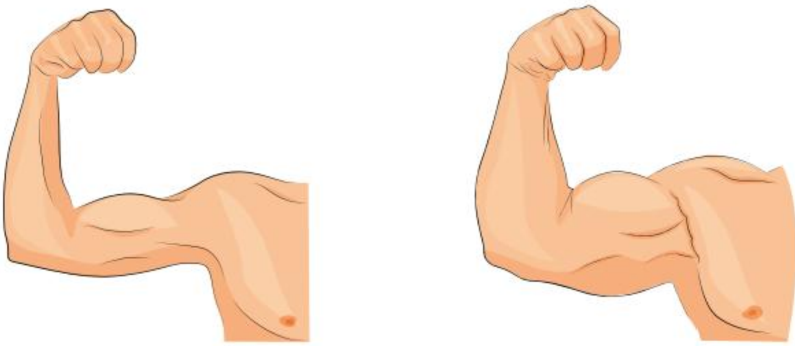
Chronic Responses to Anaerobic Training (ATP-CP System)

Increase in Muscular Strength

Probably the most important adaptation from strength and power training is an increase in muscular strength. This is a result of:

- muscle hypertrophy – an increase in the cross-sectional area of the muscle (bigger muscle). This is primarily a result of the preferential hypertrophy of fast twitch fibres. Slow twitch fibres generally remain unchanged following anaerobic training.
- the ability to recruit a greater number of motor units (muscle fibres) to produce a more forceful contraction.

Associated with an increase in muscle bulk is the term **hypertrophy.**



Atrophy — With injury or lack of training comes a reduction in muscle bulk.

Hypertrophy — increase in muscle bulk through resistance training mainly due to an increase in the cross-sectional area of the muscle fibres.

Figure 3.3.16: Atrophy and Hypertrophy.

In addition, strength training will also slowly increase the amount and strength of surrounding connective tissue, i.e. ligaments and tendons.

Increased Fuel Stores

ATP and CP stores in the skeletal muscle are increased with anaerobic training. However, this is associated with an increase in overall muscle size rather than an overall increase in the relative concentration of ATP-CP; i.e. the duration of maximal alactacid activity does not increase beyond 10 seconds.

In addition, there is some evidence to suggest that there is an improved capacity of the ATP-CP system due to increased activity of the alactacid enzymes (responsible for the breakdown of ATP and CP) in response to anaerobic training.

Chronic Responses to Anaerobic Training (Lactacid System)

The chronic responses to anaerobic training include:

- increased anaerobic enzyme activity (to breakdown glycogen at a greater rate to resynthesise ATP)
- increased glycogen stores
- increased blood lactate tolerance (so an athlete can exercise with higher levels of muscle and blood lactate)
- increased lactate utilisation (muscle's improved capacity to metabolise lactic acid – converting it back into pyruvic acid and glycogen).

Focus Questions

6. Complete the table by placing a tick in the box (or boxes) that best describe the changes (chronic) after anaerobic training.

	Increase	**Decrease**	**Unchanged**
Fast twitch hypertrophy			
Slow twitch hypertrophy			
Ability to recruit motor units			
Connective tissue strength			
ATP and CP stores • Concentration (%) within muscle • Total stores in muscle			
Glycolytic enzymes			
Glycogen stores			
Lactate threshold / OBLA			
Lactic acid tolerance			

Chronic Responses to Anaerobic Training (Flexibility)

Adaptations from flexibility training are the result of:

- increased joint range of movement (ROM)
- increased resting length of muscles, tendons and ligaments
- decreased resistance to joint movement.

Figure 3.3.17: Flexibility training can increase the range of motion at a joint.

Chronic Responses to Aerobic Training

Aerobic training is generally about improving the cardio-respiratory system to enhance the delivery of oxygen to the working muscles. With a quicker and improved delivery of oxygen, the aerobic energy system becomes more efficient and capable of a greater contribution to energy demands. The main adaptations are listed on the following pages.

Figure 3.3.18: The heart and lungs are major components of the cardio-respiratory system, responsible for delivering oxygen to the working muscles.

Cardiac Hypertrophy

Regular endurance training causes an increase in the size and volume of the left ventricle of the heart (the left ventricle pumps oxygenated blood around the body). This results in more blood being pumped out per beat (i.e. an increase in stroke volume) allowing more oxygen to be delivered to the skeletal muscle cells.

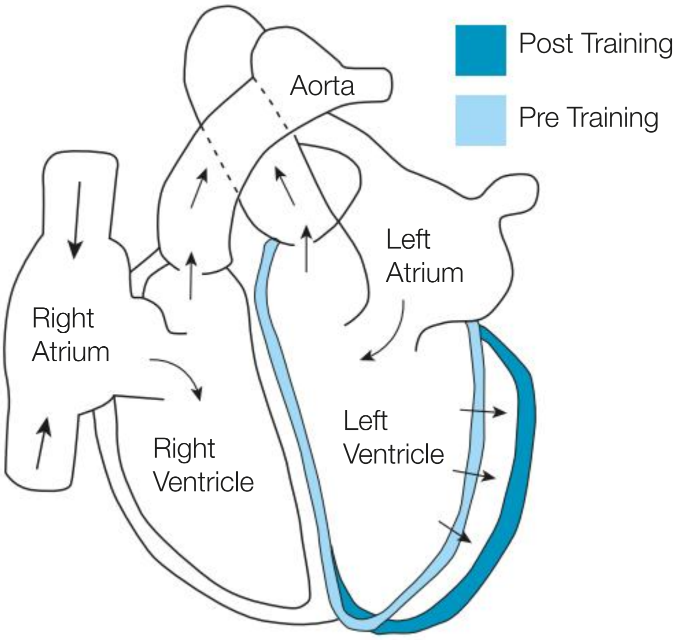


Figure 3.3.19: Increase in cardiac left ventricle volume.

Increased Blood Volume

In response to regular endurance training, there is an increase in blood volume. A larger volume of blood means more red blood cells, therefore more haemoglobin (the oxygen carrying component of blood). This results in a greater capacity to carry oxygen to skeletal muscle cells. In addition, blood plasma also increases (generally to a greater degree) so that the blood's thickness remains low and provides less resistance to flow.

Interestingly, although the total number of red blood cells increases with endurance training, if red blood cells (RBC) are expressed as a percentage of total blood volume their numbers may actually appear to drop from pretraining levels. This is simply a result of the comparatively greater increase in blood plasma volume (in terms of total red blood cell numbers, there is an increase).

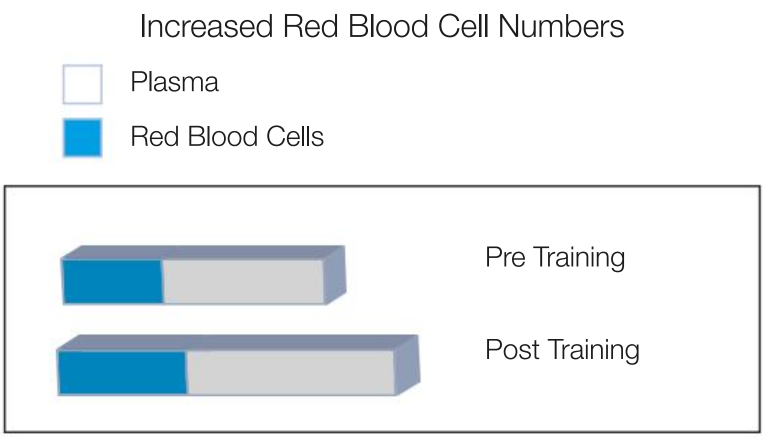


Figure 3.3.20: Increase in RBC and blood volume.

Increased Number and Size of Mitochondria

Mitochondria are the site of aerobic metabolism within the muscle cells. They are sometimes referred to as the 'powerhouse' of the cell.

Increased numbers and size of mitochondria within skeletal muscle cells results in a greater capability for aerobic respiration. In addition, there is also a greater concentration of aerobic enzymes to increase the efficiency of aerobic metabolism.

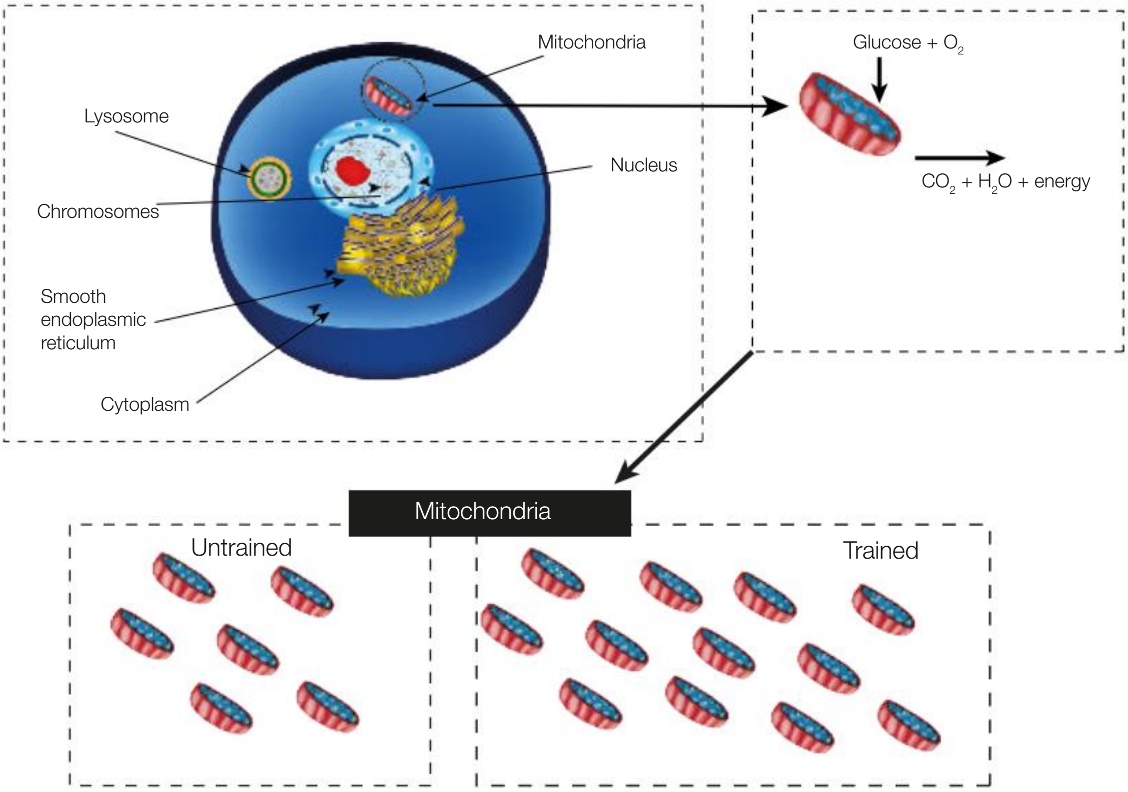


Figure 3.3.21: Mitochondria are the site for aerobic metabolism.

Increased Oxygen Delivery

With aerobic training there is an increase in the delivery of oxygen to the active muscles. This is the result of several adaptations including:

- *Increased capillarisation* – The density of capillaries surrounding the trained muscle tissue increases significantly with endurance training. This ultimately results in an increase in the a-v O_2 difference because there is a greater ratio of blood capillaries to muscle fibre to allow for a greater exchange of oxygen from the blood to muscle cells.
- *Increased red blood cells* – As discussed previously, more red blood cells mean more oxygen is 'picked up' from the lungs and more is delivered to the working muscle cells.
- *Increased myoglobin* – The main function of myoglobin is to transport oxygen from the blood to the mitochondria in the cells. An increase in myoglobin results in greater O_2 being delivered to the mitochondria.
- *Increased pulmonary diffusion* – Endurance training improves the ability of oxygen to diffuse from the alveoli in the lungs across the pulmonary capillaries into the blood for transport to the active muscles.

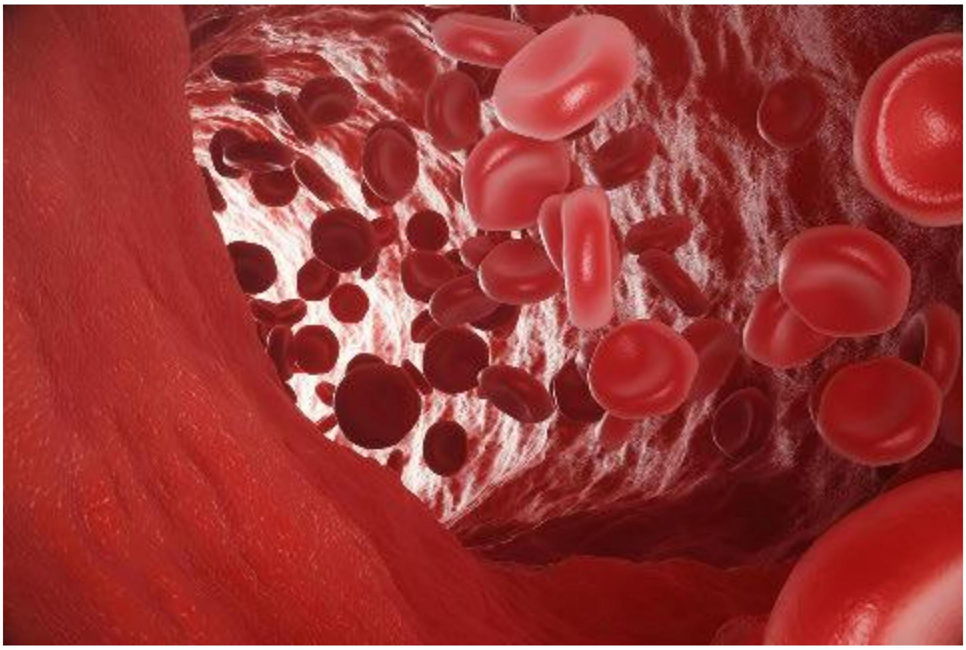


Figure 3.3.22: Increased oxygen delivery to muscle cells through a greater number of red blood cells.

Increased Fuel Stores

With regular endurance training there is a continual depletion of fuel stores within the body. Moderate increases in the stores of muscle and liver glycogen help deal with this.

In addition, there may also be an increase in intramuscular fat stores and fat burning enzymes, which result in the increased oxidation of fat during sub-maximal exercise. This results in a 'glycogen sparing' effect, where glycogen is preserved for longer periods of time during the exercise session.

Increased Respiratory Function

With exposure to repeated endurance training, there is likely to be an increase in the strength of respiratory muscles that expand and raise the thoracic cavity (ribs). This may result in a small increase in a person's **vital capacity** (the maximum volume of air that can be breathed out after a maximal inspiration) and a decrease in their **residual volume** (the volume of air remaining in the lungs after maximal expiration).

In a healthy lung, ventilation is never considered to be a limiting factor in athletic performance because a person's **tidal volume** (volume of air breathed in and out per breath) will always be lower than their vital capacity (even when exercising at maximal levels).

Other Changes

Decrease in total body fat and an increase in lean body weight.

Lowering of cholesterol balance.

Focus Questions

7. Explain the following terms:
   - Haemoglobin

   - Myoglobin

   - Pulmonary diffusion

   - Vital capacity

   - Residual volume

3

Heart Rate/Stroke Volume/Cardiac Output

Endurance athletes experience an enlarging of the left ventricle chamber, with a subsequent increase in their stroke volume.

At **rest**, the oxygen demands of the body are similar (whether trained or untrained) and therefore cardiac output (and VO_2) remains largely unchanged. Because of the higher SV of the trained athlete, the resting cardiac output is now achieved with a lower heart rate.

Therefore, we sometimes hear stories of elite endurance athletes with extremely low resting heart rates of 36 bpm. It is simply a function of their unchanged oxygen requirements at rest, and their increased heart efficiency (stroke volume), meaning they can get the job done with less beats per minute! For this reason, changes to an individual's resting heart rate can be a useful indicator to improvements in their aerobic conditioning.

A low resting heart rate (less than 60bpm) is termed Bradycardia, and at times can affect maintenance of suitable blood pressure with dizziness, light headiness and fainting.

Cardiac Output		=	Heart rate	x	Stroke volume
	Q	=	HR	x	SV
Units	L/min	=	bpm	x	ml/b

Due to the larger left ventricle, the stroke volume (ml per beat) increases and since the cardiac output required at rest is the **same** then the resting heart rate will fall.

Pre trained	4.9L/min	=	70bpm	+	70ml/b
Post-trained	4.9L/min	=	55bpm	+	89.1ml/b

Figure 3.3.23

When performing exercise at **sub-maximal** levels, the demands for oxygen are nearly identical when comparing a subject in a trained or untrained state (if they are still of similar size and weight). Therefore, the cardiac output is generally unchanged.

Even after regular endurance training a person's heart rate at **maximal** levels tends to remain unchanged (predicted at 220 – age). However, some studies have demonstrated that in highly conditioned athletes, heart rate max may decrease slightly to allow for the ideal combination of heart rate and stroke volume – it is thought that a slightly lowered heart rate max may allow more time for the left ventricle to fill (maximising stroke volume), supplying the greatest cardiac output possible.

As at rest and during sub-maximal exercise, stroke volume increases largely as a result of the increased blood volume and a stronger heart (left ventricle). Maximum heart rate is constant, so if stroke volume increases, then so will the maximum cardiac output.

Q = HR x SV

Maximum HR value remains constant

Pre-training	20000 ml/min	=	200 bpm	x	100 ml/b
Post-trained	28000 ml/min	=	200 bpm	x	140ml/b

Figure 3.3.24

Blood Pressure

Endurance training may decrease the blood pressure of people with hypertension (high blood pressure) or perhaps prevent hypertension in others, but for the average person there will generally be no real long-term change in blood pressure. As the vasodilatation of blood vessels during exercise can generally compensate for any increase in blood flow, blood pressure generally stays the same across all exercise intensities.

Figure 3.3.25: Blood pressure generally remains unchanged with training.

Blood Flow to the Working Muscles

Considering that the muscle cells are better at extracting oxygen from the blood, less blood needs to travel to the muscle cells during **sub-maximal** exercise. This improved extraction is a result of:

- Better use of oxygen by the mitochondria within cells
- More mitochondria within cells
- More myoglobin
- Increased capillary density surrounding muscle fibres
- Improved blood distribution.

A greater number of muscle cells are working though at **maximal** intensity, so the demand for oxygenated blood has increased. Consequently, blood flow to the active areas increases at **maximal** exercise levels.

Blood Volume and Haemoglobin

There is an increase in blood volume (mainly plasma) with aerobic training. An overall increase means more red blood cells and haemoglobin – resulting in a greater capacity to carry oxygen at all exercise intensities.

Arterio-Venous Oxygen Difference

The a-v O_2 difference increases at a **sub-maximal** and **maximal** intensity level because of a better ability to extract oxygen. This is largely the result of the higher diffusion gradient of oxygen that occurs because of the following:

- Better use of O_2 by the mitochondria
- More mitochondria within the cell
- More myoglobin
- Increased capillary density surrounding the skeletal muscle fibres.

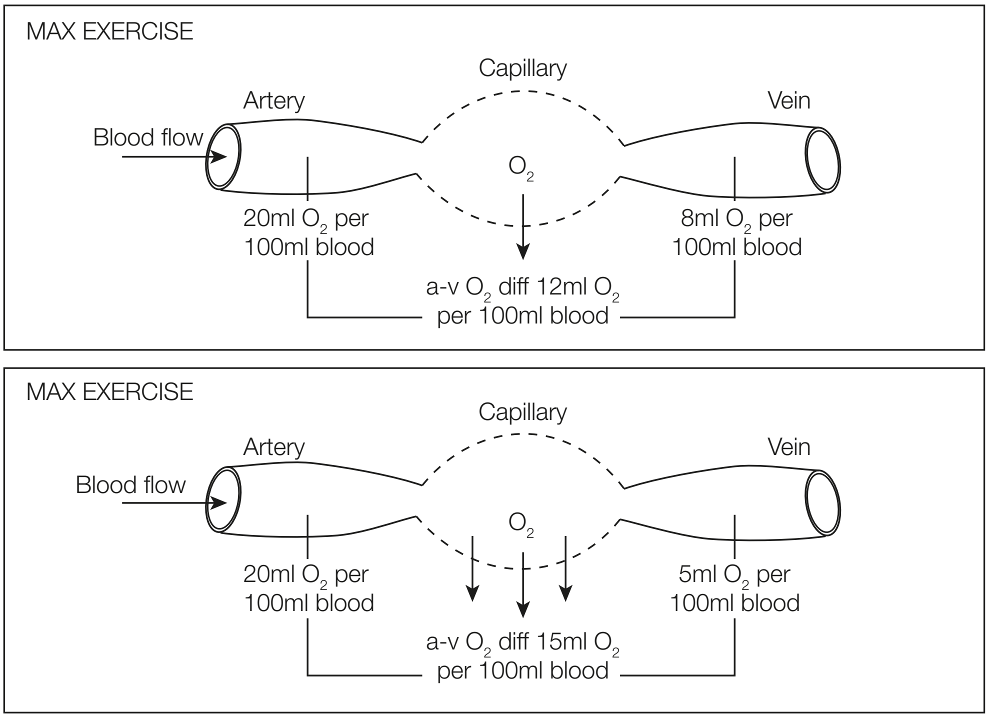


Figure 3.3.26: a-vO_2 difference pre (top) and post (bottom) aerobic training.

Minute Ventilation (VE)

Minute ventilation is the amount of air inspired and expired in one minute. Increased depth in each breath may mean fewer breaths are needed at a **sub-maximal** level.

An increase at the **maximal** exercise intensity is due to the following:

- VE = Tidal volume × Breathing Frequency
- Tidal volume increases
- Breathing frequency increases.

Muscle Glycogen Depletion

There is a decrease in the amount of muscle glycogen used as the body gets better at utilising **fatty acids** as an energy source at **all** intensity levels, saving glycogen for more strenuous activities (perhaps the final 'sprint' in a cycling race). Endurance training can therefore have a '**glycogen sparing**' effect which will ultimately delay fatigue.

Figure 3.3.27: Endurance training can have a 'glycogen sparing' effect.

VO_2 (Oxygen Consumption)

In theory, the oxygen requirements (VO_2) for an individual performing **sub-maximal** exercise should remain unchanged from pre-test to post-test. However, regular aerobic training may result in a small decrease in VO_2 for a given amount of work because:

- Increased mechanical efficiency means less oxygen is required because a better technique has been developed through training
- Decreases in total body fat and an increase in lean body weight means less dead weight to move (greater efficiency = less oxygen required).

The VO_2 of an untrained person at **maximum** intensity (**VO_2 max**) can increase by 15% to 20% with regular endurance training over an extended period of time. It is generally the sum total of all responses mentioned that increase the delivery and extraction of O_2 to the working muscles.

Figure 3.3.28: Cross country skiers have some of the highest recorded VO_2 max values.

Lactic Acid Production/Accumulation

Lactic acid production falls during **sub-maximal** exercise for the following reasons:

- Increased mitochondria for greater aerobic respiration, leading to less reliance on the lactic acid system
- Smaller oxygen deficit at the start of the exercise period (refer Figure 3.3.29)
- Greater use of lactate as a metabolic fuel
- Increased reliance on fatty acids as a fuel source means less reliance on glycogen, thus reducing lactate accumulation.

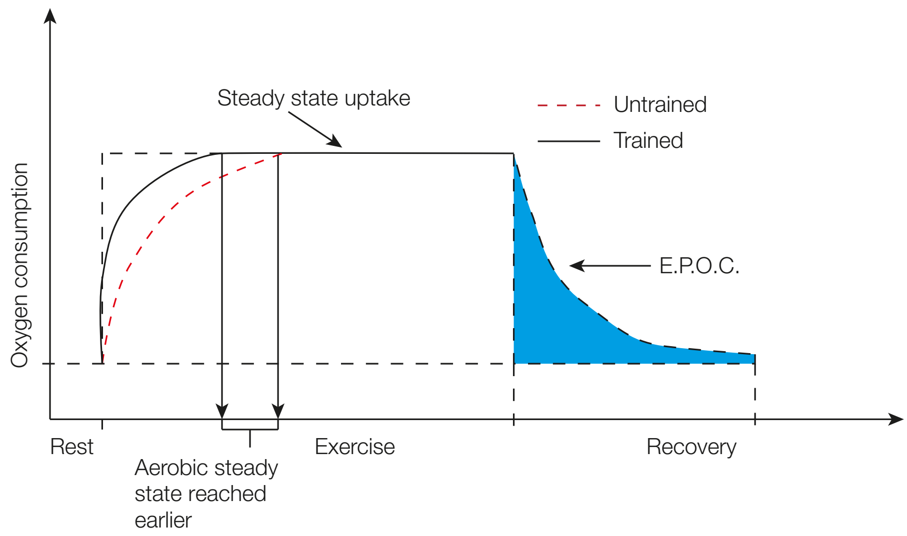


Figure 3.3.29: Oxygen deficit for trained and untrained individuals.

The graph below (Figure 3.3.30) shows a shift to the "right" when comparing the pre-training and post-training lactate curve. Consequently, this means the **Lactate threshold** (LT) / **Onset of Blood Lactate Accumulation** (OBLA) of a trained individual has been delayed.

If the aerobic energy system is able to remain the dominant energy system for a longer period of time at higher exercise intensity, there is a corresponding reduction on the reliance of the lactic acid energy system (and subsequent accumulation of lactate and H^+). This will delay the onset of fatigue and improve performance.

A more efficient cardiovascular system contributes to delay lactate formation, increase the rate of lactate clearance and ultimately, tolerate higher levels of lactate accumulation during intense exercise.

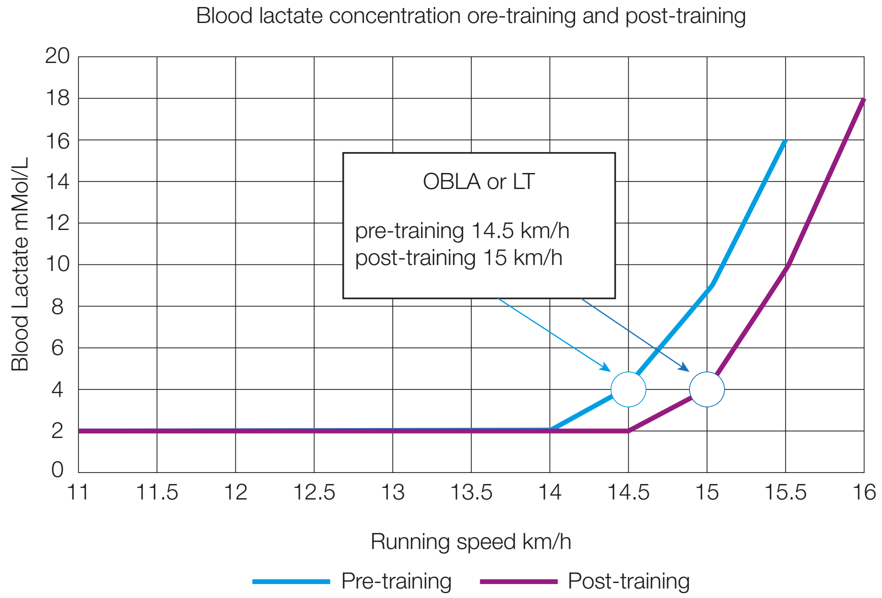


Figure 3.3.30: This graph illustrates the generalised effect of all chronic adaptations to pre-training and post-training blood lactate accumulation during progressively increasing exercise intensity.

Focus Questions

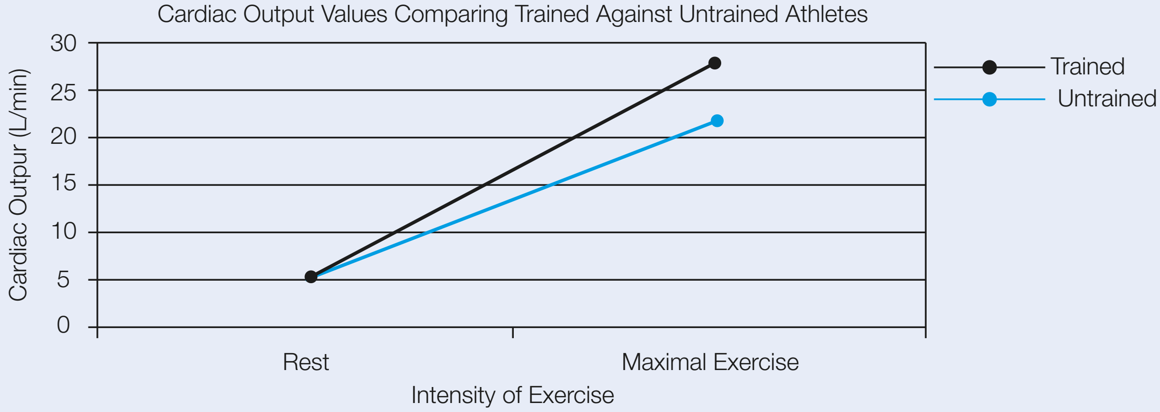
8. Multiple choice:
   (a) Chronic changes that would occur following a long-term, sprint-training program include:
      (a) muscle atrophy, mostly of the FT fibres
      (b) muscle hypertrophy, mostly of the red fibres
      (c) the ability to recruit a greater number of motor units (muscle fibres)
      (d) an increase in total blood volume
   (b) One chronic effect of a long-term, endurance-training program would be:
      (a) a decrease in total blood volume
      (b) an increase in muscle stores of CP
      (c) a decrease in the capillary network surrounding the muscles
      (d) an increased utilisation of fat during sub-maximal exercise
   (c) When comparing a trained athlete with an untrained person, which statement is correct in relation to body functions at rest:
      (a) The trained athlete would have a higher HR
      (b) The untrained person would have a higher SV
      (c) They would both have similar cardiac outputs
      (d) They would both have the same SV
   (d) After undertaking 6 months of intense aerobic training, an individual's oxygen consumption (VO_2) at rest would most likely:
      (a) Increase
      (b) Decrease
      (c) Remain unchanged
      (d) Fluctuate
   (e) Which of the following responses is both an acute and chronic response to exercise:
      (a) Increase in a-v O_2 difference
      (b) Increase in HR max
      (c) Increase in blood volume
      (d) All of the above
   (f) During maximal exercise, ventilation can increase from 5 litres per minute to 115 litres per minute. This is due to:
      (a) Increases in tidal volume and residual volume
      (b) Increases in tidal volume and breathing frequency
      (c) Decreases in residual volume and total lung capacity
      (d) Increases in tidal volume and a-v O_2 difference

3

Focus Questions

9. Refer to the graph below for the following questions, which compare the cardiac output of a trained athlete and an untrained person.

   (a) Describe one relationship shown in the above graph.



   (b) The untrained individual undertakes 3 months intensive aerobic training and then participates in sub-maximal exercise. Explain the physiological changes that would be evident in the subject's:

   (i) Cardiac Output

   (ii) Stroke Volume

   (iii) Heart Rate

   (iv) Muscle Glycogen use

Focus Area 3: About Movement

3.4 Technological developments in biomechanics

- Current technology in biomechanics
- The influence of technological developments on learning, performance development, and performance enhancement

Current technology in biomechanics

Technology in sport is ever changing as teams or individuals strive to be the best. Most changes are small, but even 0.1 of a second improvement in some sports is the difference between winning and losing. However, occasionally there is a large change. Some of the larger changes in the past that have revolutionised the way the sport is conducted include:

- The introduction of the Fosbury Flop in high jump
- The Clap skate in sprint skating
- LZR racer swimsuit
- Derailleurs (or gears) in cycling
- Carbon fibre (and similar materials) in motor racing, skiing, tennis racquets etc.
- Kinetic energy recovery system (KERS) in motor racing.

Helpful online resources

Video of high jump history:

www.youtube.com/watch?v=CZsH46Ek2ao

Figure 3.4.1: Carbon fibre body panels make up most of a modern day racing car, as the material is lightweight, yet stronger than steel for its weight.

The next section is a brief look at some of the more current technologies in sport. It's by no means an exhaustive list, and most of the examples have been chosen from less common sports in Australia. This provides you with the opportunity to research technology in a sport of your choice.

Hydrofoils

The hydrofoils in the water act like aeroplane wings and generate lift once a certain speed is reached. This lift generated by the foils raises the hull of the boat completely out of the water. With no hull in the water it means much less drag as the yacht moves through the water, so it travels much faster. Due to stability issues with the new technology, the wider hulls of catamarans or even trimarans are used now instead of the traditional yacht.

Lift is generated by the hydrofoil, as the aerofoil shape means that water travels faster over the top of the foil than it does under the foil. Faster moving water creates an area of lower pressure, so the pressure over the top of the foil is lower than the pressure under the foil. As objects move from areas of high pressure to areas of low pressure, the foil (and boat) are lifted.

Figure 3.4.2: Oracle Team USA, the hull of the catamaran is completely out of the water due to the lift from the hydrofoils.

Helpful online resources

The following YouTube clip about the creation of New Zealand's entry into the America's Cup (sailing competition) helps explain how the foil works:

www.youtube.com/watch?v=bxoKcWyNYuk&feature=youtu.be

Tracking Software

Tracking software is another area of sport biomechanics that in the past few years has become quite prevalent. Tracking sensors are now available for both players and equipment. Some of the more recent innovations in tracking motion in sport include:

- Sensors in balls: Basketballs have sensors built into them that track your shooting or training sessions. The 'Wilson X connected' or the 'Dribble up' ball are two examples of basketballs. The Adidas MiCoach soccer ball is linked to a smartphone with sensors inside the ball detecting speed, spin, strike and flight path.
- Body sensors: The 'Adidas MiCoach' system, 'Blast Basketball', 'Zebra Motion Works', 'Nike plus clip on sensor', are all examples of personal tracking systems. These systems can provide data on a range of variables including heart rate data through to speed, acceleration, height jumped etc.
- Equipment sensors: Smart sensors (Zepp Lab or Easton Power Sensor) can be retro fitted to golf clubs, baseball bats and tennis racquets to monitor speed. Other companies like 'Babolat' built their early sensors (Babolat Play) into their racquet (axis sensors, accelerometers and gyroscope) to send data to a smartphone
- Ball tracking software: Hawk-eye type technology, that predicts or extrapolates data to predict ball movement continues to make inroads into various sports.

Figure 3.4.3: 'Hawk-eye' technology was one of the earlier versions of ball tracking to become available.

Impact absorbing helmets

In American football, blows to the head and the subsequent fears over long-term concussion injuries have led to a rethink on helmet design. Helmets have evolved from padded leather shells to hard plastic shells with foam padding inside. A new helmet design – the '**Vicis Zero1**', looks the same as the traditional hard-shell design. However, the outer shell is softer to allow for distortion on impact. In addition, the creation of column-like structures inside the helmet that can move in any direction, are designed to buckle and break on impact. As with the softer outer shell, these columns or filaments are 'absorbing' the impact energy.

As explained earlier in Focus Area 1.3: Biomechanics, the distortion of the product means that the impact force is being applied over a greater time period. The product of force and time is **IMPULSE**. With impulse, the **FORCE** and **TIME** components are inversely proportional to each other. So, by increasing the time over which the force is applied (helmet shell and columns distorting), the magnitude of the force will be reduced. A lower force being applied to the brain results in a reduced risk of concussion related injuries.

Figure 3.4.4: Traditional American Football helmets were made of a rigid plastic, outer shell. This design limited any ability to 'absorb the impact'. Instead the hard outer shell meant that the time over which the force acted was small. As time and force are inversely proportional to each other in the IMPULSE equation, the force acting on the brain remains high.

Helpful online resources

A good video explaining the design of this new helmet is available via the attached link:

https://www.siliconrepublic.com/machines/american-football-nfl-iot-tech

Impact Sensors

Along with helmet design, advancements in monitoring technology for head impacts has also developed in recent years. Companies like X2 biosystems, Bio Stamp (MC10) and Linx (IAS) have all developed wearable patches that have impact sensors to measure blows to the head.

Focus Questions

1. In a sport of your choice, identify and describe one current piece of technology that is changing the way the sport is played or conducted.

The influence of technological developments on learning, performance development, and performance enhancement

Here are some examples of technological developments in sport and how they influence learning or performance development.

Motion Sportswear

Sportswear suits that have visual markers (lines or dots) that represent key points of the body. When moving, coaches can see in real time how the athlete's body is operating. A good example of this can be seen in the following video clip of a rower wearing the motion rowing suit. Two reference points (circles) can be seen on the hip and the waist (side profile). These are two important reference markers for coaches. A good technique will have the rower bending from the hip reference point, not the waist reference point. The two visual markers on the suit make it easy for the coach to see in real time. The advantage of this technology is that feedback can be given immediately to the rower, without the need for analysis of video footage etc after the event.

Helpful online resources

https://www.youtube.com/watch?v=bcyMO4N-NLU

Figure 3.4.5: The 776bc 'Motion Rowing Suit' allows coaches to easily see errors in body movements through the use of visual reference markers (yellow circles and lines).

Video analysis

Video analysis is nothing new, it has been around for a long time. However, the quality of the footage, the analysis software and the capturing devices are constantly evolving.

The use of video capturing during sporting activities allows for an objective record of the athlete's performance. Some advantages of videoing performances are:

- Some movements aren't readily visible to the naked eye. Videos allow for slow motion playback, or even 'freeze frames' of a movement to make it easier to see subtle movements. High speed cameras are particularly good for movements that are too fast to capture with a normal video camera.

  The ability to capture footage of fast-moving objects and slow them down, allows for greater learning and performance opportunities. Coaches and athletes can now see aspects of their technique frame by frame, so are better able to pin point small errors often missed in real time. The footage can also show the athletes the outcome of their actions or movement. For example, the spin or angle through the air of a discus or object once release can now be seen. This allows the athlete to learn how technical changes to techniques impacts the flight of objects etc.
- Multiple cameras in multiple positions allows coaches to see a performance from various perspectives. This eliminates the possibility of missing some small error. For example, drones now allow for footage from above the athlete. Small portable cameras like a GoPro attached to the mast of a sail (windsurfing) or surfboard also allow for different perspectives of a movement, one an athlete would never get to see without video.

Figure 3.4.6: Drones can capture footage from above.

Athletes can learn from these new 'viewing angles' as they can now see what they look like when completing a movement. This footage can then be compared to that of an elite performer, so modifications to the technique can be made.

Figure 3.4.7: Small, portable and waterproof cameras like the GoPro now allow almost any athlete to capture footage of their performance for later analysis.

- Video footage can be continually replayed, compared to asking the athlete to continually repeat the action. The latter would result in the athlete becoming fatigued. Fatigue often results in changes to the technique, so accurate analysis of the movement would be compromised. The footage can also be used to compare to later footage to check for improvement. This would mean it has a performance development (technique) aspect as well as a motivational aspect.
- Underwater footage. Some sports make it hard for coaches to see all aspects of a technique. Swimming is a good example of this, where seeing what the body is doing under the water is difficult for coaches. With the advent of waterproof cameras like the GoPro, almost any coach now can have access to footage underwater.

  This footage influences the technological development of the swimmer, as now the coach can accurately analyse and prescribe solutions for technical errors in the movements. Prior to cheap, portable technology like the GoPro, this type of analysis was restricted to more elite environments. Athletes can now capture their own footage and compare it to footage of elite swimmers thanks to platforms like YouTube. Amateur swimmers could teach themselves to a degree now, thanks to advances in technology.

Figure 3.4.8: Turning in swimming

Figure 3.4.9: Underwater footage of a swimmer.

Figure 3.4.10

- Instant replays: Capturing footage with a smartphone, coupled with WiFi / Bluetooth means you can instantly replay the footage on laptop, tablet or the phone itself. This advancement in technology has the potential to lead to improved performance. Athletes can complete a movement or skill, get immediate feedback, then try the movement again with the modification needed. Accurate interpretation of the footage and quality feedback resulting from this, should increase the rate at which skills are developed. There are a variety of apps that are useful for students to use with this process e.g. 'Hudl', 'Coach's eye' etc.

Virtual Experiences

The ability to simulate sporting movements and experiences has been something that has developed over the past two decades. Virtual reality is the more common variant of this technology, yet two more emerging variations now exist. Although they all create experiences without actually conducting the sport, there are subtle differences.

Virtual reality

A virtual reality experience involves a computer-generated environment. Through a headset, your vision of the real world is blocked, replaced instead by a computer-generated vision of the world around you. Using a headset connected to a computer, you are transported into this space.

Figure 3.4.11

Augmented Reality

This experience is a mix of reality AND computer-generated data or details. So, you get to see the real world along with additional features added in by computer. A popular version of this type of reality is Pokémon Go.

Figure 3.4.12

Mixed Reality

Mixed reality is similar to augmented reality, except the computer-generated images / data can interact with reality, or the real world.

Figure 3.4.13

For ease of discussion, the term virtual reality will be used to encompass all three of the variations. In a sporting context, virtual reality is becoming more popular as it can provide visual simulations in immersive and interactive environments (Farley et al 2019). Some advantages of this are that athletes and coaches can:

- Replicate competition, therefore repeat the sequence of events or passage of play. This includes the ability to replicate parts of a play that would be difficult to accurately repeat in real life. For example, environmental conditions (wind or wave formation) in sports like surfing or sailing.

Figure 3.4.14

- Practice under game like pressure. In contact sports like American football, or Australian rules football, this means practicing without the fear of injury.
- Practice anytime. Opponents, team mates and facilities aren't needed.
- Reduce cost of training. For example, in car racing you don't need to hire the track, pay for fuel or new tyres. In alpine sports like ski jumping, it means you don't need to travel to alpine areas and pay for accommodation, facility hire etc. In both these examples, the risk of injury is also high, so again virtual reality means training without the injury risk.

Figure 3.4.15

In terms of learning and performance development, virtual reality has the potential to improve an athlete's

- Mental 'toughness'. Through practicing game like pressures in the virtual environment. A stronger mental aspect of an athlete's game means less potential for a detrimental effect on technique and decision making during a game.
- Understanding of team plays or strategies. In team sports like American football where there are numerous different play patterns and variations, virtual reality has been used by quarterbacks to mentally replicate plays. This mental rehearsal helps quarterbacks learn plays, potentially enhancing their game day performance. Motor racing drivers can also use repetitive virtual reality to learn. In this case they are learning the intricate twists and turns in a race track. In this example, drivers can mentally practice where to place the car on the road when going through corners improving their race line and hopefully their lap time.
- Technical skills. Currently, there are limited controlled trials that have assessed whether virtual reality training directly transfers skills (improvement in technique) across to the real world. One of the more recent trials (Michalski et al 2019) was reported to have shown a significant increase in skills compared to a control group

(no training) in table tennis. Yet without a group that also received 'real' training (from a coach) to compare to, the authors of the study conceded that the positive change in the virtual reality group may have been due to improved reaction times or coordination as a result of the virtual training. A faster sensory processing time is a plausible explanation along with an increased ability to detect relevant stimuli and in turn speed up the sensory processing could occur through repetitive virtual reality training. Computer generated environments that focus the athlete on the main cues or relevant cues, would also help the learner recognise the relevant cue in the real world faster, speeding up the processing time and allowing more time to get into position to play a shot.

Motion Tracking Software

With the advent of WiFi and smartphones, access to tracking data can now occur in real time. The advantage of this is that the athlete can implement the feedback straight away while the movement (or feeling of the movement) is still fresh in their mind (concurrent feedback). Improvements in software programming also mean that many of the tracking and movement programmes can now provide the feedback (either auditory or visually) without the need for a coach to first interpret the data. This potentially has greater impact in the amateur or semi-amateur scene, where the cost of coaches is beyond many of them.

Numerous sports have begun to take advantage of this technological advancement to aid performance. One such sport where tracking software aids performance is in kayaking. Software programmes like 'Motionize', have a sensor positioned on the paddle shaft which sends information to a receiver. Feedback is immediately displayed on a smartphone, waterproofed and attached on the front deck of the kayak. This software package provides visual representation via the smartphone screen of:

- Exit position of the paddle
- Distance achieved per stroke
- Strokes per minute
- Stroke length
- Paddle depth.

This information allows the paddler to adjust their stroke immediately. A correct stroke or technique means greater efficiency, so less likely to fatigue. In addition, a paddler is more likely to generate more power in each stroke and therefore finish a race quicker.

Helpful online resources

The following YouTube clip explains in more detail the 'Motionize' software:

https://youtu.be/eV4rY3OY7KY

Figure 3.4.16: Motionize kayak tracker (https://www.motionizeme.com/kayak-tracker/).

Focus Questions

2. In a sport of your choice, identify and explain how a technological development has influenced the athletes':

- Learning
- Performance development
- Performance enhancement.

Focus Area 3: About Movement

3.5 Psychological motor-learning theories

- Cognitive theory perspective
- Ecological (dynamical systems) theory perspective
- Comparing theories

In general terms, **motor learning** definitions often refer to an internal process that is associated with practice or experience, leading to a relatively permanent change in the capability for skilled performances. However, there are many different definitions available. Some of the variations in the definition of motor skill learning are formed from the different theories on motor learning that have evolved to explain how we process information from the sporting environment and learn skills. Generally, there are two main theories to explain how movement skills are learned. Each theory uses different skill learning terms and progression models to describe learning and prescribe the most effective ways to teach motor skills (called coaching methodologies). In relation to the Year 12 Physical Education course, this chapter will focus on two main theories used to explain how people learn movement skills.

The more 'traditional' approach to explain motor skill learning follows the **cognitive theory perspective,** whilst a more 'contemporary' approach advocates the use of an **ecological (dynamical systems) theory perspective**.

Cognitive theory perspective

The **cognitive theory of learning** is the more 'traditional' approach to explaining skill learning and it is based on the premise that a player's movement originates from the central nervous system (CNS), with the brain coordinating a set of actions from the muscles to create a movement. It explains skill learning in much the same way as a computer would process information, with a player taking in information from the sporting environment and then processing this information as they pass through a series of hypothetical stages to produce a skilled action.

Although there are variations of the information processing models that have been developed (refer to Focus Area 3.6: Information processing), each model essentially follows the stages of input, decision making, output and feedback as described in Table 3.5.1.

Table 3.5.1: The information processing model (from the cognitive learning theory) states that skilled movement originates from processes in the brain.

Input	***Perception*** - A player takes in information from the sporting environment to decide upon a response. • Input involves the recognition, assembly and identification of environmental information • This information is referred to as cues or stimuli and includes all information whether it is relevant to the skill (ball movements, player movements, opponent positions etc) or irrelevant to the skill (crowd noise etc.) • The information is largely collected from the senses of sight, sound and touch.
Decision-making	***Response Selection*** - A player processes the relevant cues to make an appropriate response. • Will a response be made? • A motor plan is decided upon and sent to the effector muscles.
Output	***Response*** - A player 'activates' the physical response that was decided upon. • A decision is made and passed on to the required muscles to perform the skill.
Feedback	***Feedback*** - A player receives information about their activated response. • Feedback is used to assist further decision-making by either reinforcing the action or forcing changes to the action • Proprioceptors send information back to the CNS, which stores relevant information about the skill execution for subsequent performances.

In the cognitive theory perspective, the processing of information from the sporting environment (input) can be a limiting factor for skilled performance because it requires a great deal of attention and processing, which are limited due to restrictions in a player's working memory capacity (refer to Focus Area 3.6: Selective attention). Subsequently, because a player (especially a non-elite player) is only capable of processing a limited amount of information at any time and at a limited rate, there is the possibility for 'information overload' in a game. It is advocated however, that learning can allow a player to develop strategies to overcome the limitations in attention capacity and information processing rate. During the earliest stages of skill learning, for example, it is important for a coach to reduce the attention demands on learners to a level that they can reasonably handle by using a variety of different 'practice strategies' and some of these are discussed in greater detail in Table 3.5.2 and also in Focus Area 3.6: The learning process.

Table 3.5.2: The stages of information processing can be manipulated by a coach to allow skill progression for a beginner learner - this is an example for tennis.

Cognitive Theory Perspective - Information Processing Model		
	Characteristics of the stage	**Coaching points**
Input	Player views the sporting environment to detect the 'cues' or 'stimuli' using their senses (sight, sound, touch etc.): • Ball - speed, direction and spin? • Opponent - court position, speed, direction of motion? • Weather - wind moving the ball, sun in eyes etc.	Coach will try to simplify the sporting environment to avoid information overload: • Use a smaller racket, brighter easier to see balls etc • Slow down the ball i.e. low compression tennis ball = slower hit and lower bounce = more time to see stimulus and detect the 'signal' • Coach 'feeds' the ball to the player in a predictable practice 'drill' • No distractions (noise/spectators etc).
Decision- Making	Stimuli from the sporting environment is used to make a decision regarding the most appropriate action to employ and is based on: • Player's abilities (strength/weaknesses) • Opponent's abilities (strength/weaknesses) • Stage of the game • Score? • Fatigue etc.	Coach will provide the learner more time to make a decision or give them less decisions to make: • Drills where a coach 'feeds' the ball to recreate 'shot' opportunities to practice • Part practice (e.g. ball toss, arm action, and then contact, follow-through of a serve etc) to learn the subroutines of an 'executive motor programme' • Repetition of skills for the executive motor program to enter a player's 'long term memory' for easier and quicker retrieval • Simplified, smaller court 'games' in a closed environment = less decisions to make • Coach provides information on skill execution, tactics and stimuli for a player to look for etc.
Output	The period of muscle movement where the chosen action is executed: • Footwork • Court positioning • Timing, speed and placement of shot etc.	Coach will make sure the player has enough time to execute a 'technically' correct skill: • Repetition of one type of shot (reducing the number of choices - 'Hick's Law') • Player will start a 'shot' in a pre-prepared 'ready' position • Cones placed to show 'target' areas to hit etc.
Feedback	The player receives information about their activated response: • Knowledge of results (was the shot successful?) • Knowledge of performance (the coach says "extend elbow more") • Player develops a 'kinaesthetic feel' of the movement to adjust and self-correct shots during the game etc.	Coach will try to provide high quality feedback on technique to develop 'textbook' stroke production and tactical play: • Knowledge of performance feedback • Positive feedback • Negative feedback only in a 'feedback sandwich' • Video analysis of technique • Allow a learner to concentrate on the areas that require improvement etc.

Using the information processing model as a guide, Table 3.5.2 shows how a coach is able to manipulate the different stages of the processing model to make a skilled movement easier to perform based on the ability (or stage of learning) of a player. In this manner, the cognitive theory perspective advocates that a player is able to slowly develop their skills and the processing of information if a coach teaches skills sequentially, repetitively, with perfect technique in closed and predictable environments progressively through to more open and dynamic game situations - refer to Focus Area 1.4: Coaching methodologies and Focus Area 3.6: Signal detection and selective attention.

Within the cognitive theory perspective, skill learning is viewed as a **linear** and stage-like process of gaining expertise. Aligned with the information processing model are the stages of skill learning, as described by the psychologists Fitts and Posner (1967), that describe the gradual process of skill acquisition using a 'three-stage model' to classify learning into 'phases' from beginner **cognitive** learners along a continuum of **associative** and finally expert or **autonomous** learners (refer to Focus Area 3.7: Stages of learning).

The cognitive theory perspective advocates that many hours of 'perfect practice' are required before a player enters the **autonomous** stage of learning and can execute their skills 'automatically' (this is often referred to as the 10,000-hour rule). Once a player has mastered the subroutines of a skill to create and store an executive motor program into their long term memory, a player can reduce the amount of attention (working memory demands) dedicated to programming a response during the game and instead, apply a greater focus to tactical decision making and stimuli identification. Being able to use fewer cues or stimuli from the sporting environment enables a player to correctly anticipate and predict game play scenarios and initiate an appropriate response earlier - providing them with all of the 'characteristics of a skilled performer' - refer to Focus Area 1.4: Practical application of learning theories and Focus Area 3.6: Selective attention.

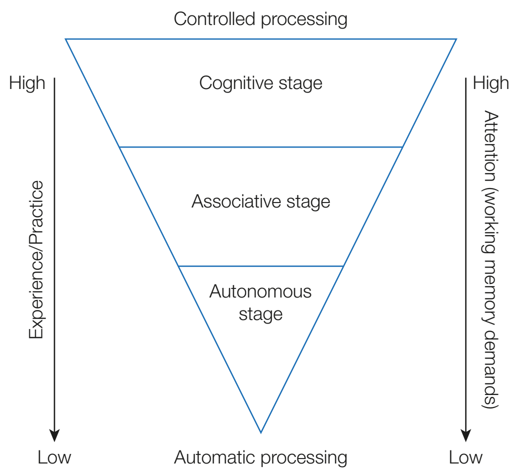


Figure 3.5.1: Fitts and Posner's (1967) model of skill acquisition as a function of the attention demands (working memory) placed on the learner and their level of experience. Adapted from "The role of working memory in sport" Philip Furley and Daniel Memmert, 2010 International Review of Sport and Exercise Psychology, 2010.

Ecological (dynamical systems) theory perspective

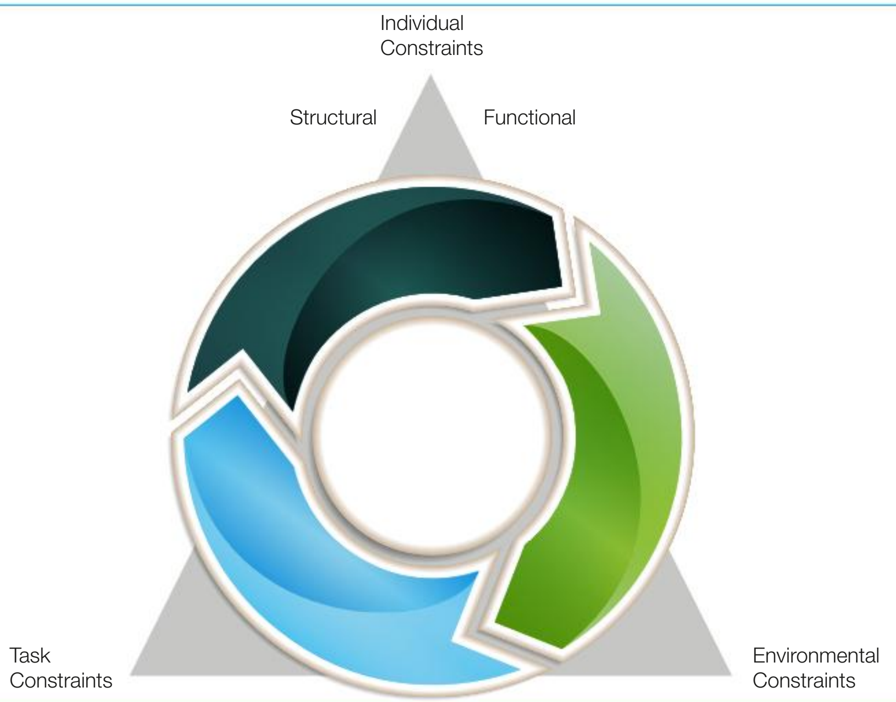
The **ecological (dynamical systems) theory perspective** combines concepts from *ecological psychology* and *dynamical systems theory* to explain how individuals control actions and develop perceptual-motor skills. For the purpose of this chapter, it will be referred to as dynamical systems theory.

The dynamical systems theory states that during a game, a player's movement patterns are not simply the result of a recall and application of pre-learned 'executive motor programs' from the long-term memory, as described within the cognitive learning theory. Instead, the movement solution that eventually emerges for a player will be formed spontaneously as a function of the player's physical and informational constraints in the game (which include the structural characteristics of the player, their personal characteristics, the sporting environment, and the rules of the game).

Ultimately, this means that instead of recalling a pre-learned and rehearsed skill, a player will figure out how to best coordinate their many moving body parts to successfully achieve a tactical goal. Achieving the tactical goal (by any technique possible) is what drives movement and textbook technique, per se, is less important. In the game of tennis, for example, players are faced with a variety of game-play scenarios in every point, but the overall tactical goal is always to keep the ball in play. In any situation, there will be a variety of shots, along with a variety of tactics that a player can apply to achieve this goal. Instead of trying to make a pre-learned tennis 'shot' fit the different game situations, the dynamical systems theory states that achieving the tactical goal is what will drive a player's movement, and the optimal movement solution (the tennis shot) will be based on the interaction of each individual's unique physical constraints, and the informational constraints present in the environment at that time.

Although this model places less emphasis on rehearsing ideal movement patterns (skill technique), it is still assumed that each individual will have an optimal coordination pattern for any given task. The challenge for all learners will be to find the personal coordination pattern that is optimal for them. In this way, the dynamical systems theory affords a player (and their body systems) high levels of freedom (known as **degrees of freedom**) to generate creative and unique solutions to game-based problems. Because some patterns of movement will obviously be more effective and efficient than others for an individual, the focus of teaching within a dynamical systems theory is not teaching skills but allowing learners opportunities to find their own optimal coordination pattern. To achieve this, it is advocated that coaches use problem-solving within constraints-led games (refer to Focus Area 1.4: Coaching methodologies - linear and nonlinear). This will enable individuals to become perceptually attuned to information from the sporting environment (game) and develop their ability to solve sporting problems with high exploration of creative and unique movement pattern solutions (and therefore using high degrees of freedom).

The dynamical systems theory is the more ‘contemporary’ model of skill learning, and it advocates that skill learning is not a gradual and consistent (linear) progression, but instead, a dynamic and **nonlinear** series of progressions and (regressions). The dynamical systems approach to learning describes learners moving up and down through Newell’s 3-stage learning model (refer to Focus Area 3.7: Stages of learning - ecological).



Dynamical Systems Theory

Individual players are complex, non-linear dynamic systems composed of many interacting parts (muscles, nerves and senses etc).

Players have many unique individual characteristics (such as height, muscle fibre type and fitness etc) that afford opportunities for movement.

When a player’s complex dynamic system interacts within a task and the environment, instability is created, resulting in the system reorganising itself and creating movement.

Figure 3.5.2: Constraints from all sources (individual, task and environment) will influence the range of movements that a player can effectively use to accomplish a task goal.

Further information on dynamical system theory and coaching methodologies can be found in Focus Area 1.4: Coaching methodologies - linear and nonlinear and Focus Area 1.4: Game-based approaches and pedagogies.

Affordances are 'opportunities for action' within a game. Affordances will shape a player's decision making.

For an average size 12 year old, a smaller size 4 basketball 'affords' opportunities to dribble at speed or take a shot, whereas the full adult size 6 ball does not.

Figure 3.5.3: Size appropriate equipment will afford greater 'opportunities for action'.

Rate Limiters - these are the specific constraints that act as barriers and will 'limit' how we learn and our performance.

They may include:

Individual (body structure, fitness, coordination, perceptual ability, decision making ability, confidence, motivation etc.)

Task (size, height & mass of equipment, playing field dimensions, rules etc.)

Environmental (playing surface, weather, instruction, cultural expectations, teammates ability).

Figure 3.5.4: A 'rate limiter' is a barrier to learning.

Figure 3.5.3 and 3.5.4: Terminology used in the Dynamical Systems Theory - Affordances versus Rate Limiters.

Focus Questions

1. (a) What is an affordance for an 'acting half' to carry the ball and run forward in a game of touch football?

(b) The 'acting half' decides not to carry the ball and run forward when afforded the opportunity in the game. Explain two possible rate limiters.

Comparing theories

Table 3.5.3 highlights some of the key differences between the two theories of motor learning. Although both theories have key differences, either can be applied by students in a coaching/instruction session to assist individuals and/or teams to learn, improve and apply motor skills to game situations.

In addition, it is recommended that students go to other parts of this workbook where different aspects of the two learning theories are discussed in further detail. These being:

- Focus Area 1.4: Practical application of learning theories
- Focus Area 1.5: The role of feedback and its effect on learning and performance
- Focus Area 3.6: The learning process
- Focus Area 3.7: The learning journey.

Table 3.5.3: Comparing the Motor Learning Theories.

Motor Learning Theories	
Traditional approach	**Contemporary approach**
Cognitive Learning Theory	**Dynamical Learning Theory**
Information Processing Model • Input • Decision making • Output • Feedback.	**Ecological Model** When a player's complex dynamic system interacts within a task and the environment, instability is created, resulting in the system reorganising itself and movement emerging.
Linear Learning Skill learning improvement is directly proportional to the time spent practicing with reliable and predictable progress - with the 10,000-hour rule for skill 'mastery'.	**Non-linear Learning** Skill learning is unpredictable and involves progressions and regressions based on constraints from the learner, and environment.
Stages of skill learning	
• Sequential stages of learning developed by Fitts and Postner (1968): ○ Cognitive Stage ○ Associative Stage ○ Autonomous Stage.	• Non-sequential stages of learning developed by Newell (1991): ○ Coordination Stage ○ Control Stage ○ Skill Stage.

<table>
<tr><th colspan="2">Motor Learning Theories</th></tr>
<tr><th colspan="2">Teaching Approach</th></tr>
<tr><td>
• Direct methods of teaching and instruction from an ‘expert’ coach i.e. Skills - Drill - Game.
• The skills of the game are taught:
○ Sequentially (simple - complex)
○ Repetitively (drill)
○ Isolation (closed/part practice - open/whole)
○ Perfectly (correct technique is important)
○ Explicit learning of the sub-routines to build an executive motor program stored in the player’s long-term memory.
</td><td>
• Player-centred methods of coaching where learning is focused on movement outcomes rather than skill techniques.
• A constraints-led game approach (individual, task and environment) to allow players to fully explore their ‘perceptual-motor workspace’ to detect opportunities (affordances) for perception-action coupling in the game.
• Implicit learning with no ‘expert coach’ required to teach a ‘textbook’ technique.
</td></tr>
<tr><th colspan="2">Feedback</th></tr>
<tr><td>
• Extrinsic - Directly from coaches in the form of Knowledge of Performance to improve skill technique
• Intrinsic - A ‘kinaesthetic feel’ will slowly develop as a player masters an executive motor programme
• Internal focus - attention drawn to the execution of the skill (e.g. “extend your elbows, faster”).
</td><td>
• Extrinsic - Questioning players into ‘self-discovery’ within Teaching Games for Understanding (open ended questions on Time, Space, Risk & Execution)
• Intrinsic - A player is a ‘dynamical system’ showing self-organisation in direct response to information from the sporting environment
• External focus - Attention drawn to the ‘outcome’ of the movement (e.g. “hit the ball high like a rainbow”).
</td></tr>
<tr><th colspan="2">Intelligent Performers (tactical awareness + technical proficiency)</th></tr>
<tr><td>
Limited:
• Skills not often taught in game-related practice
• Tactical awareness is taught when skills have been ‘automated’
• Advanced players with improved signal detection and selective attention apply tactical decision making
• Coaches will often teach the basic ‘tactical’ plays for players to ‘memorise’ and look to apply in a game
• Automated responses instead of tactical appropriateness.
</td><td>
Advanced:
• Constraints-led game practice allow players to become perceptually attuned to information from the game and develop perception-action couplings with high creativity and adaptability
• Prepares players for a variety of movement solutions to cope with ‘open’ and dynamic games.
• Intelligent and adaptable game performers.
</td></tr>
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3

Focus Area 3: About Movement

3.6 The learning process

- Information processing model and perceptual motor workspace
- Signal detection, selective attention, attentional focus

Information processing model

The **information processing model** is based on the **cognitive theory perspective** of motor learning (refer to Focus Area 3.5: Cognitive theory perspective) and refers to a series of models that are used to describe how a player takes in information from the environment (a game) and then makes a decision about 'what-to-do' within the game based on their interpretation of that information.

Although there are different models available, essentially, they all use hypothetical 'stages' to represent what is taking place within an athlete's **central nervous system** (CNS) as they perform a skill. The stages of motor skill represented in a simplistic 'Information Processing' model are:

1. Input
2. Decision Making
3. Output
4. Feedback

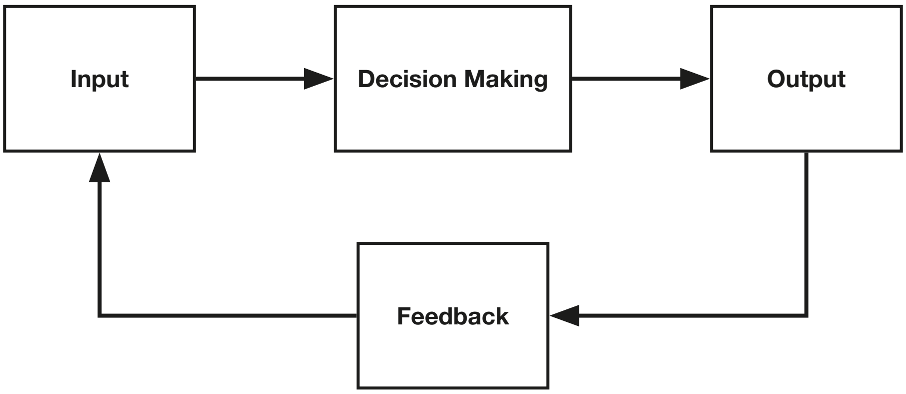


Figure 3.6.1: A simple Information Processing Model.

Central Nervous System (CNS) = brain and spinal cord

Peripheral Nervous System (PNS) = nerves from the CNS to the muscles

Input (Perception)

This is where a player takes in information from the sporting environment to decide upon a response. The collection of this information is largely gathered through the senses of sight, sound and touch.

- E.g. a soccer goalkeeper will track the flight path of a soccer ball (using their sight) as the ball is kicked across the goal box from a corner kick.

Decision-making (Response Selection)

This is where a player processes the relevant cues to make an appropriate response and a motor plan is decided upon and sent to the effector muscles.

- E.g. the goalkeeper realises the ball is spinning towards the goal and decides they will need to 'punch the ball' away from attackers looking for an opportunity to score.

Output (Response)

This is where the player 'activates' the physical response (via effector muscles) that was decided upon.

- E.g. the goalkeeper comes 'off their goal line' and punches the ball away from the attackers and prevents an attempt at goal.

Feedback (Evaluation)

This is where the athlete receives information about their activated response. This feedback is used to assist further decision-making by either reinforcing or forcing changes to the action.

- E.g. the goalkeeper receives positive feedback if the ball was successfully punched away from the attackers (knowledge of results), but also realises the timing of their 'punch' to clear the ball was poor (knowledge of performance) and will use that kinaesthetic feedback to modify their technique for next time.

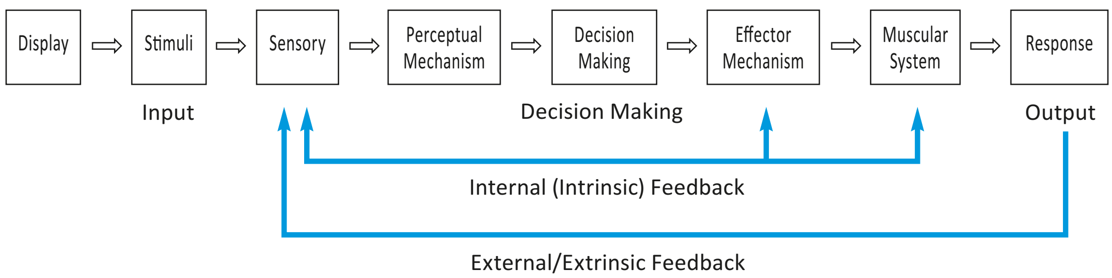
Note

More information on the **Information Processing Model** and the two major forms of **feedback** can be found in Focus Area 1.5: Psychology of sporting performance.

Although there are actually a number of different Information Processing Models available to use, they all have the same basic elements to them. Table 3.6.1 represents a more detailed version referred to as Whiting's Information Processing Model.

Table 3.6.1: Description of Whiting's more complex Model of Information Processing Model.

Whiting's Model of Information Processing Model

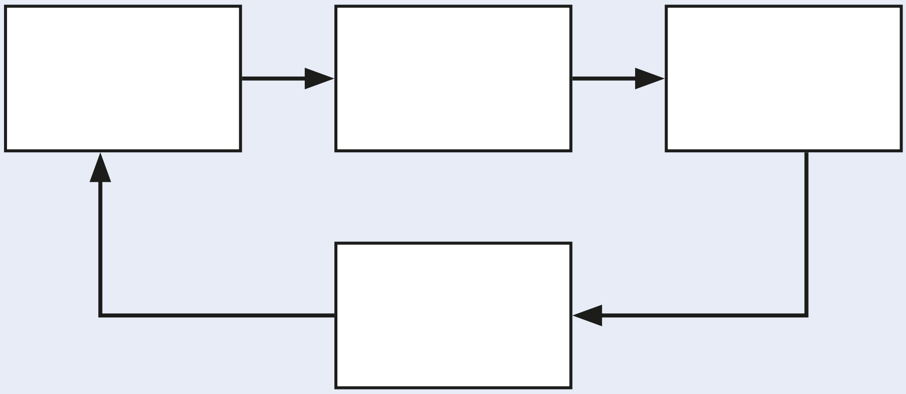


Source: Adapted from Davis, Kimmet & Auty (1990)

Display	All information in the sporting environment: • Sights (crowd, players, opponents, ball etc) • Sounds (player communication, crowd, ball being hit, sirens etc) • Touch (player marking, holding a bat/racket etc) • Kinaesthetic 'feel' (feeling balanced etc).
Stimuli	Aspects of the 'display' that the player needs to focus on to perform a skill.
Sensory	Processing of the stimuli to the Central Nervous System (CNS).
Perceptual Mechanism	Interpretation of the sensory information is filtered by **selective attention.**
Decision Making	Processing the sensory information to make an appropriate response and a motor plan is decided upon and sent to the effector muscles.
Effector Muscles	Based on the decision-making process, a motor plan is built informing the muscles of the required action.
Muscular System	The muscles and peripheral nervous system (PNS) activated to produce the action.
Response	The skill is performed (output) based upon the whole information processing system (CNS + PNS).
Internal (Intrinsic) Feedback	Feedback from the proprioceptors ('kinaesthetic feel') - Knowledge of performance.
External (Extrinsic) Feedback	Feedback about the success of the response - Knowledge of results.

Focus Questions

1. Identify the components of a simple Information Processing model (below) by placing the correct term in each of the four boxes.



Factors Affecting the Input

There are numerous cues or signals (pieces of information from the sporting environment) available to a player which are relevant to or can improve the execution of a skill. It is vital for an athlete to be able to detect these cues or signals; this is called **Signal Detection**. In addition, with practice and experience, a player will begin to also know which cues are important and which cues are not. Being able to attend to only the relevant cues and ignore the rest, is called **Selective Attention**.

Selective Attention

Within a sporting environment, there are many stimuli or cues being detected by a player's sensory system and this is fed directly to the player's central nervous system (brain) for processing. In a game situation, the quantity of this information can be enormous and overwhelming for an athlete. For example, in cricket, a batsman can be at the crease for many hours during play, needing to focus and switch attention from the ball, to the run-up of the bowler, to their grip on the bat, to the movement of a fielder or to the flags waving and noise coming from the crowd.

A player's ability to effectively utilize information from the sporting environment is dependent upon their memory processes:

- Short-term sensory store
- Short-term memory
- Long-term memory.

Information from the environment is initially received by the short-term sensory store (STSS) via the sensory organs (sight, sound, touch etc.). The STSS can receive unlimited information from the environment, but the ability to hold this information is very poor. Information will only stay in this store for approximately 1 second. If in this time, it is not processed onto the next level of storage it will be lost. The loss of this information happens before an athlete is even conscious of it happening.

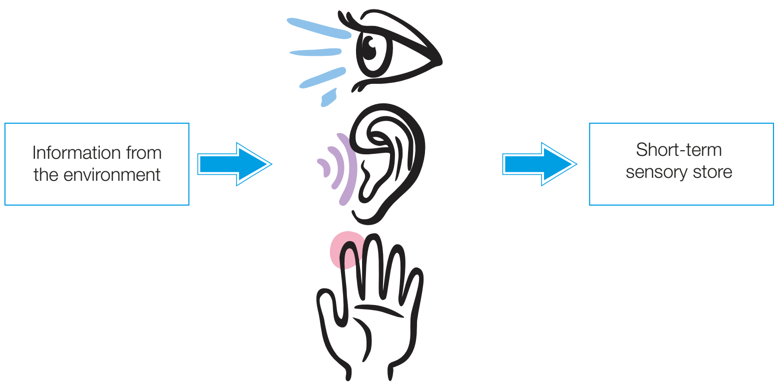


Figure 3.6.2: The short-term sensory store (STSS).

Because new information is constantly coming into the short-term sensory store, there isn't the time to process everything, and so **selective attention** now plays a vital role. The brain can't afford to waste time on information that is irrelevant and of no use to the player's skill execution, and so, via selective attention, the brain has the ability to selectively attend to only the information that is deemed relevant and required for further processing.

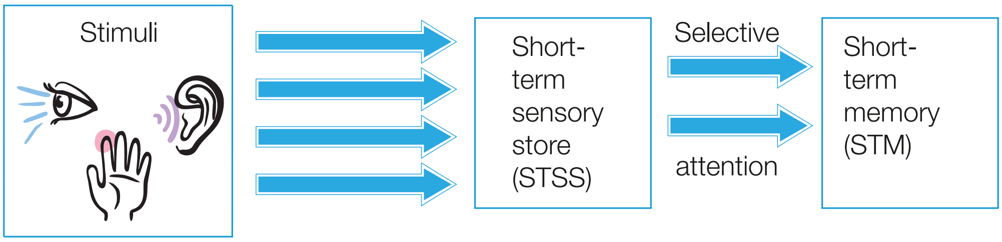


Figure 3.6.3: Information from the STSS is 'filtered' via selective attention to enter the short-term memory.

Selective attention is very important when accuracy or fast responses are required and the process can be improved by learning through past experience and interaction with the long-term memory. Effective selective attention can also help to reduce reaction time.

Selective attention is a process used to 'filter' relevant from irrelevant information from the sporting environment, allowing an athlete to focus on specific cues being presented by their opponent.

For example: A tennis player receiving a serve needs to focus on the grip, ball toss, angle of racquet, position in relation to service court etc, whilst also ignoring other aspects of the environment which may distract such as the crowd noise or a spectator moving in the background etc.

This will prevent a potential information overload.

Figure 3.6.4: Selective attention can help prevent 'information overload' from the sporting environment.

Information that is deemed important for the correct execution of the skill moves onto the next stage of memory retention – **short-term memory** (STM). The STM has a more permanent storage system than the STSS; yet, again, if the information isn't processed or acted on it will soon disappear. Around 60 seconds is the average time that information will be stored in this section. There is also a limit to how much information can be processed in the STM with only 7±2 bits of information able to be processed at a time. For information to be retained from the STM, it must be acted on and transferred into the **long-term memory** (LTM).

The short-term memory is important from a coaching perspective. Information can be given to the athlete about how to improve a technique and because the feedback can stay in the memory for 60 seconds, it allows the athlete time to practice again with the feedback fresh in the memory.

There is a limit to how much can be processed in the STM and only 7±2 bits of information can be processed at a time. This may require a coach to use processes such as 'chunking' of information to make it more manageable for an athlete to process.

Figure 3.6.5: Feedback must be short (only 7±2 bits of information can be processed in the STM at a time).

Chunking

Because the short-term memory can only hold 7±2 bits of information, if a coach can group (chunk) bits of information together, there will be less 'bits' to process, and the athlete can process more information.

For example: In high jump, instead of remembering every individual part (subroutine) of the take-off:

- drive the lead knee upwards, across the body and away from the bar
- fully extend the take-off ankle, etc.

The athlete instead chunks all the individual subroutines together into the 'take off'. The whole high jump movement can then be broken down into four 'chunks' of information:

- Run up
- Take off
- Over the bar
- Landing.

Numerous factors can reduce or improve the efficiency of the **short-term memory** and knowledge of these factors can aid a coach or athlete to improve performance.

Table 3.6.2: Factors that can aid an athlete to improve working memory.

Irrelevant Stimuli (Distractions)	Distractions that are irrelevant to the skill being performed (such as crowd noise), add extra information taken in from the environment. This can distract the athlete from attending to the relevant stimuli or bits of information, so the wrong information can be sent into the short-term memory. A coach can minimise these distractions by using a closed environment for practice.
Practice or Rehearsal	As soon as information comes into the short-term memory, it should be acted on if it is to be retained and move to the long-term memory for retrieval. After giving feedback, the coach should give the athlete time to practice or rehearse this new information.
Relevance	How meaningful or relevant the information is to a learner, will affect their ability to transfer it into their short-term memory. Learners will quickly be turned off learning if all the feedback or information is irrelevant, not meaningful or of no interest to them (refer to Focus Are 1.5: Giving and receiving feedback).

Long term memory

Information moving from the STM into the long-term memory (LTM) is the final step in the processing and retention of information. The long-term memory has an unlimited capacity, and information is stored in there indefinitely. Information moves into the long-term memory from the short-term memory only if the information was acted upon while in the short-term memory. Information moving into the long-term memory is coded and stored as an executive motor programme for future retrieval back into the short-term memory.

Figure 3.6.6: Information must be 'acted upon' in the STM before it moves to the LTM for coding.

No skill is learned or improved without practice. Practicing a skill enables a player to take in information and process it back and forth between the STM and LTM to slowly embed the executive motor program into the player's LTM for 'instant' recall when required during competition. The model below is a representation of the memory process.

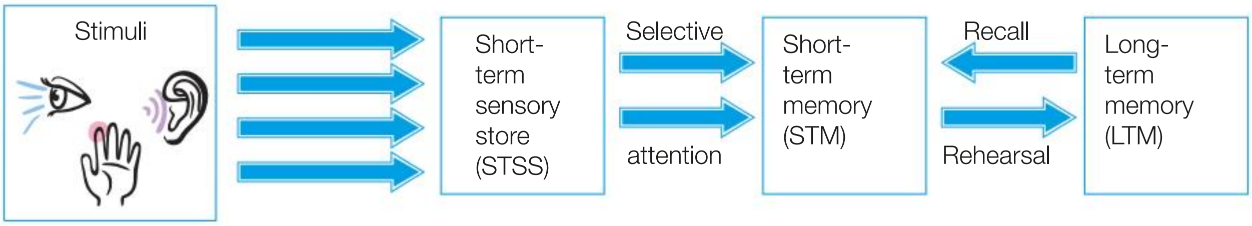


Figure 3.6.7: A model of memory process.

Table 3.6.3: An executive motor programme

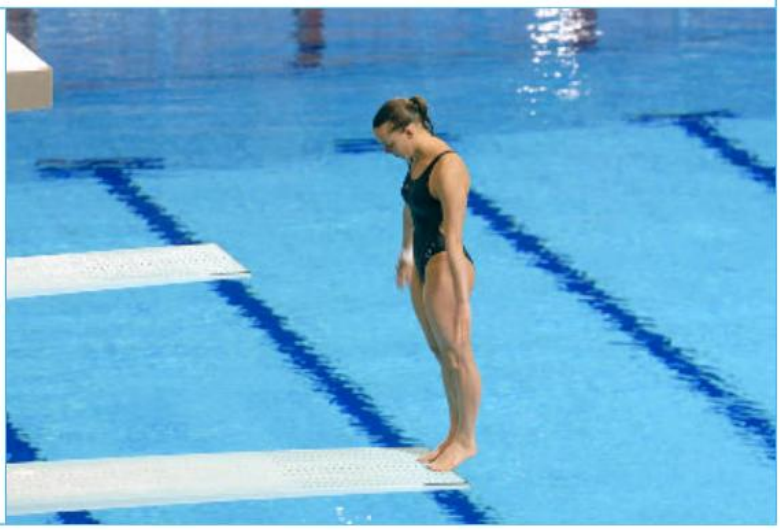
Executive Motor Programme - Long-term memory (LTM)	
The executive motor program is: • A whole skill • Composed of a series of movements: called subroutines • Stored in the long-term memory (LTM) • Retrieved from the LTM and back into the STM for 'action' by the effector muscles that are recruited to complete the skill.	

Figure 3.6.8: Diver 'mentally rehearsing' their executive motor plan prior to the dive.

Focus Questions

2. Identify two things a coach can do to improve the chances of a piece of information going into the short-term memory.

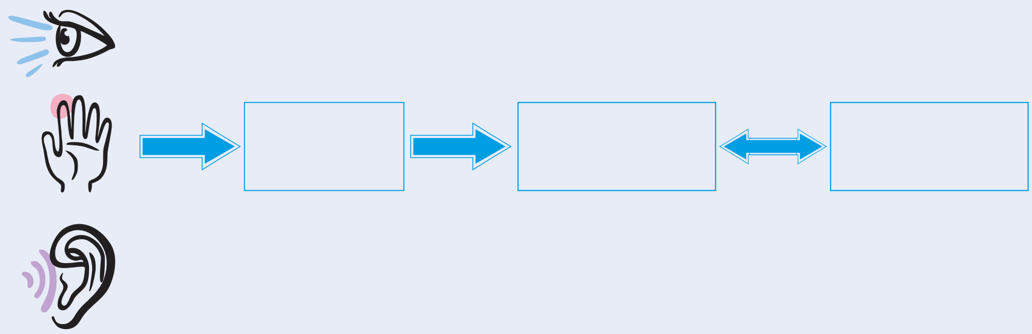
3. Complete the following sentence: Information enters the short-term memory via

4. Information enters the long-term memory via four possible processes, identify what these four processes are.

5. Given the capacity of the short-term memory, explain how much feedback should be given to a beginner learner.

6. In the sport of your choice, describe an example of distraction and explain how this distraction could impact on a player's ability to successfully execute a skill.

7. Reconstruct the entire memory cycle (below) using information from the previous diagrams.



8. Identify how you can improve your ability to remember the following 12 individual letters:

URCATEIGHTIT

Focus Questions

9. As coach of a ten-year-old beginner in badminton, explain how relevant the feedback of "pronate the forearm as you swing through to contact the shuttle" would be when teaching the overhead clear to this young child.

Signal Detection

Ultimately, a player's 'signal detection' depends on the following factors:

- Stimulus intensity or 'strength of the cue'
- Speed of the cue
- Noise level
- Functioning of the sensory organs
- Arousal level.

Stimulus Intensity (Strength of the Cue)

The more intense the stimulus, the quicker the cue is likely to be accurately detected. This means the reaction time can be reduced, allowing more time to process the stimuli. The information transferred to the decision-making mechanism is also more likely to be accurate if it is easier to detect.

The three basketballs below (A, B and C) illustrate this idea of 'stimulus intensity'. Clearly the middle ball (B) represents a stimulus (cue) of low intensity. You can test this by standing your book upright and then walking 10m away (or across the classroom). Looking across the room, how much of the detail in Ball B can you still see?


Ball A


Ball B


Ball C

Figure 3.6.9: The contrast of different coloured balls (equipment) will affect a player's signal detection.

The problems encountered with trying to see a white basketball against a white background in Figure 3.6.9 is the same principle behind the sight screen in cricket. In cricket the white ball in a night game is bowled with a black sightscreen behind the bowler. This strengthens the cue for the batsman, resulting in recognition of the correct cue earlier and allowing more time to carry out the proposed motor plan.

Figure 3.6.10: Note the white ball is easier to see with a black background.

In the example below, if Batter 1 detects the cue (ball) earlier, it will allow them more time to process the information. Therefore, Batter 1 is more likely to make a correct decision, an accurate response and have time to get into position to make the response (play the shot).

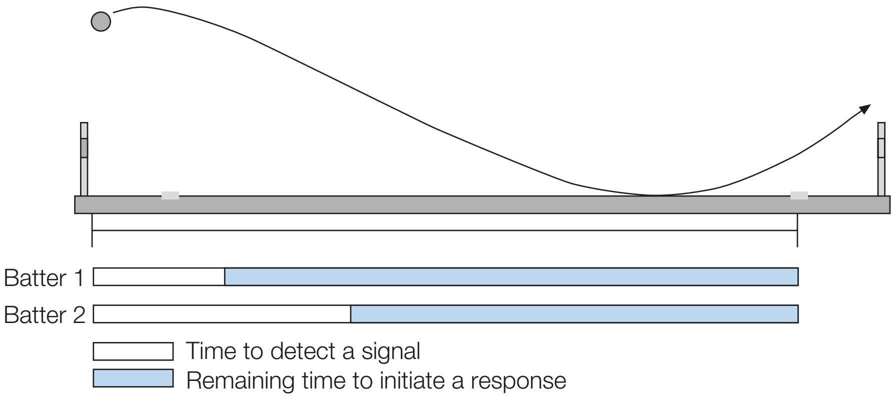


Figure 3.6.11: Better signal detection (Batter 1) gives a player more time to initiate a response (play the shot).

Focus Questions

10. Explain how earlier detection of a cue impacts on the technique of the person during the execution of the skill or movement?

Figure 3.6.12: A pitched baseball takes approximately takes 0.4 seconds to reach the batter.

In Figure 3.6.12, it takes approximately 0.4 seconds for a pitched baseball (travelling at about 150 km/hr) to reach the batter. The average processing time for the batter is approximately 0.2 seconds. (In addition, the batter's response-time to swing the bat is around 0.2 seconds). That doesn't leave much time to pick up what type of ball is being delivered.

How much does anticipation play in the batter's success?

Considering the speed the ball is travelling, by starting the swing a thousandth of a second too late or early will mean that the ball is not struck correctly; hence a strike or foul ball results.

Signal detection is thus very important; therefore, the areas directly behind the pitcher, the fence and stadium are all one colour in order to contrast the white of the ball.

Focus Questions

11. Using two sports of your choice, explain two other examples where administrators of sports have tried to increase the 'strength of the cue'.

12. In table tennis, there is a serving rule which states that prior to serving, the ball must be visible at all times. Explain how this ruling helps the receiver make a more accurate return.

Speed of the Cue

The faster an object is moving towards you (e.g. baseball pitch), the quicker you must react and respond. This results in less time available for detection and processing of relevant cues and so a rushed muscular response may result.

Coaches teaching beginners new skills, will purposely slow the speed of the cue down to ensure the beginners have time to process all the cues and respond correctly.

Examples:

- tee used in softball to hold the ball still for the batter
- driving the ball off a cone in 'Milo' or 'Kanga' Cricket (modified versions of cricket).

Slowing the speed of the ball in this way allows the beginner to develop a basic technique first. This may be gradually modified and 'fine-tuned' as the demands are increased to a faster, more unpredictable ball that is thrown or bowled.

Figure 3.6.13: There are many distractions that an athlete needs to block out through selective attention.

Noise level

'Noise' is any background information in the sporting environment that is not directly relevant to the athlete completing the required skill, but it is still present and can enter a player's sensory system. Noise can obviously be auditory (sound), but 'noise' is a term used to describe anything that will affect signal detection through distraction.

Noise adds another stimulus that an athlete must filter out of the equation. They must learn to ignore the extra stimuli, otherwise they will waste time processing these irrelevant cues. This is process is called **selective attention**, but the greater the noise contained within the sporting environment, the harder it is to do. In turn, this may negatively affect the athlete's signal detection.

Functioning of the Sensory Organs

An athlete's perception of information (cues and stimuli) from the sporting environment relies on the sensory systems that enable humans to see, hear, feel, smell and taste. The primary senses used by athletes in a sporting environment are sight, sound and touch. Problems with any of the sense organs will result in an athlete's signal detection being impaired.

Examples:

- Being colour-blind may affect the ability of a racing driver to see the colour of the different warning flags
- Hearing loss affects the ability of a player to pick a call from teammates
- Sun glare in a softballer's eyes prior to taking a catch, may result in late signal detection.

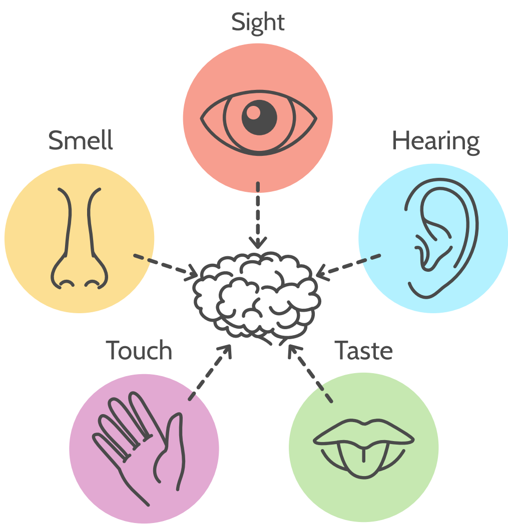


Figure 3.6.14: The sensory system is made up of the receptors that receive stimuli from the environment - tactile (skin), eyes (visual), and ears (auditory) are the main senses used in a sporting environment.

Arousal Level

Arousal levels refer to 'your readiness to participate and/or train.' The inverted U theory is commonly used to explain the relationship between arousal and performance. This topic is also addressed in Focus Area 2.2.

For each sport and individual, there is an optimum arousal level for maximum performance.

- If the arousal level is too low, then the performer lacks concentration and is likely to miss relevant cues (they aren't 'pumped up' enough!)
- If the arousal level is too high then the performer's anxiety and stress levels increase and they are likely to react to the wrong cues, cues that aren't there or misinterpret the cues.

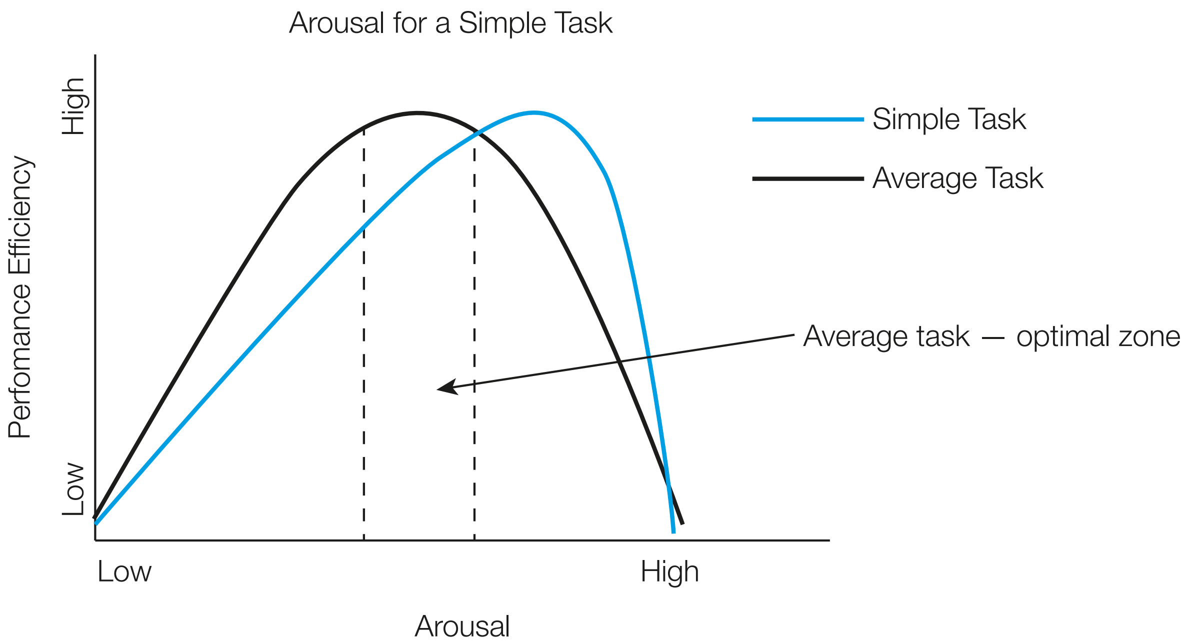


Figure 3.6.15: Optimal arousal levels (performance efficiency - high) for a simple versus average task.

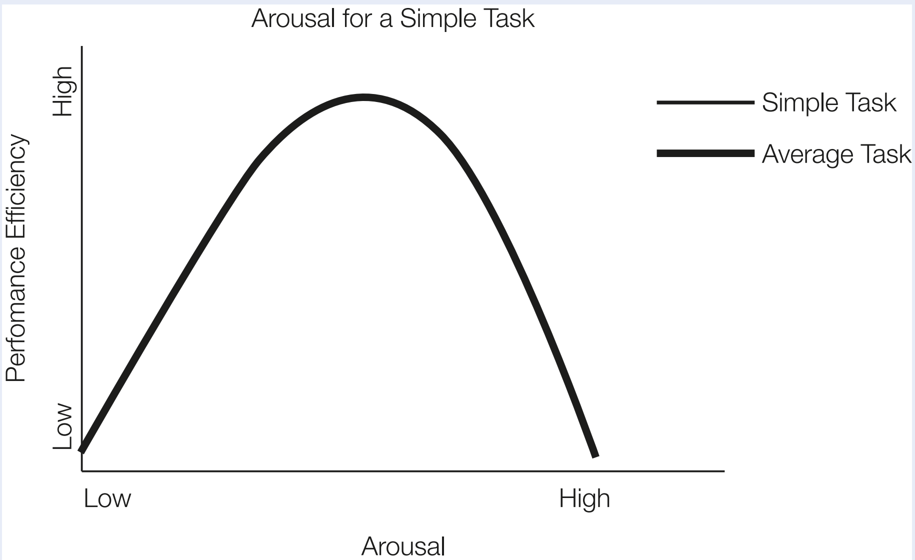
Between these two levels there is an optimal level of arousal to maximise performance.

Optimum arousal levels for each sport depend on the individual athlete. But, generally, for a simple task, the arousal level can be higher before performance efficiency is affected as seen in Figure 3.6.16.

Figure 3.6.16: Higher levels of arousal are beneficial for a 100m sprint race.

Focus Questions

13. The graph below shows the arousal curve for an 'average task' (such as a netball pass). On the same graph, draw the likely arousal curve for a complex task (such as a golf putt).



Archery and rhythmic gymnastics (apparatus) are examples of complex tasks where high arousal isn't desired, as the task requires extreme concentration.

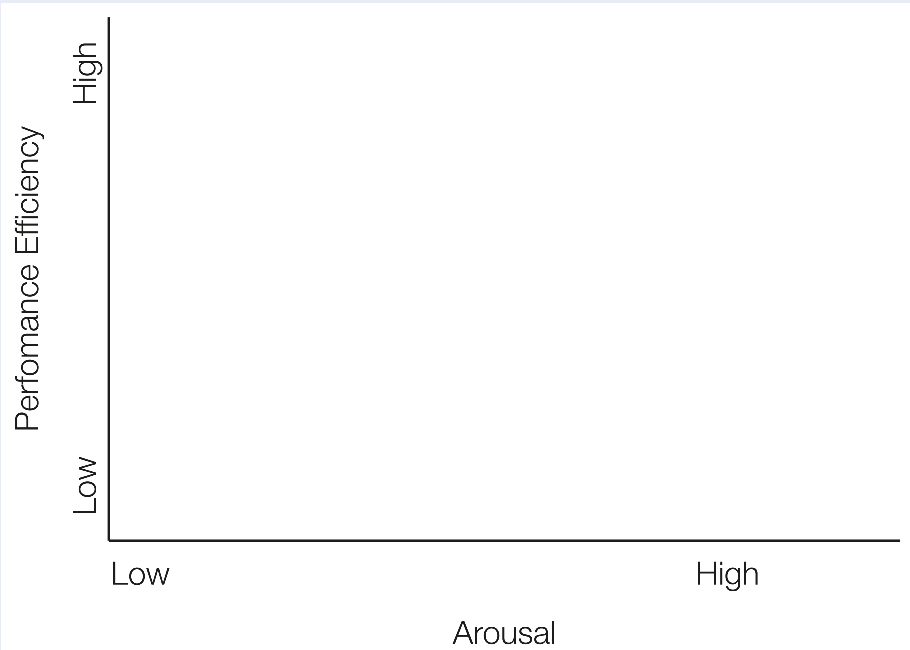
Figure 3.6.17: Archery.

Figure 3.6.18: Rhythmic gymnastics.

Figure 3.6.17 and 3.6.18: Complex tasks require lower levels of arousal for optimal performance.

Focus Questions

14. Using a sport or sporting skill of your choice, draw an arousal curve on the graph and explain why you have drawn it this way.



Again, there are many other 'theories' that are designed to explain the effects of an athlete's arousal level on performance. Briefly though, one further theory to briefly outline may act as a starting point to begin some further research if this interests you.

Catastrophe theory

This theory implies that there are dramatic (catastrophic) declines in performance above a certain arousal level.

This may be caused by game stress or anxiety and muscle tension etc.
For example, a missed penalty in a Cup Final may result in a further and marked deterioration in performance. Perhaps even a 'catastrophic' drop in performance.

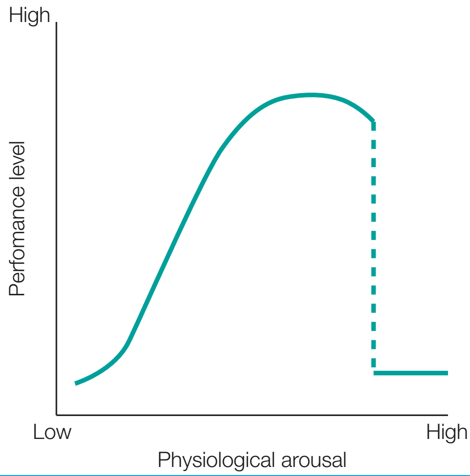


Figure 3.6.19: Catastrophe theory.

Reaction Time, Movement Time and Response Time

How well a player reacts or responds to a stimulus from the sporting environment is very important in many sports (such as a goalkeeper in soccer) and can be the difference between a good performance and not.

The time it takes to complete a movement skill after the detection of a stimulus is called the **response time**. It is comprised of an athlete's **reaction time** and **movement time**.

Response Time = Reaction Time + Movement Time

Reaction time = the time it takes to initiate a response to a stimulus.

Movement time = the time it takes to initiate and complete (finish) a response to a stimulus.

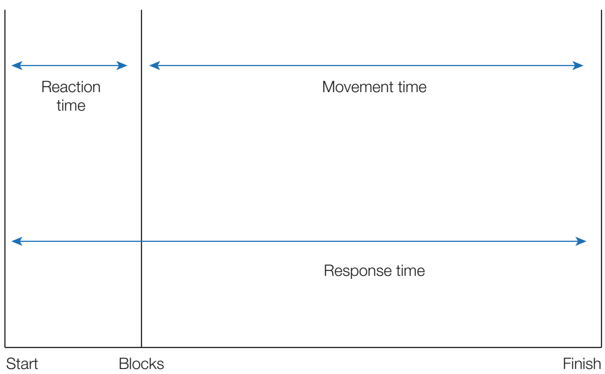


Figure 3.6.20: Components of response time in a 100m sprint.

Figure 3.6.21: A soccer goalkeeper needs a good response time to save a penalty kick.

An athlete with a faster 'response' time has the ability to make 'faster' decisions, which can provide many sporting advantages over their opponents. For example, a quicker response time provides for a faster 100m sprint time, and the quicker a tennis player can respond to ball that deflects off a net-touch, the more likely they can reach the ball and keep the point alive.

Research suggests there are numerous factors which may affect or influence reaction time, including individual and also stimulus characteristics.

Table 3.6.3: Reaction time - Individual characteristics.

Reaction Time - Individual constraints	
Age	Reaction time is likely to be quickest in people in their 20s, with a gradual slowing over time thereafter.
Gender	Research suggests that males generally have faster reaction times than females. However, it is also believed that women will retain their reaction time abilities for much longer than males as they age.
Arousal Levels	Arousal levels will impact on reaction time.
Personality	Extroverts may have faster reaction times than introverts. Personality may also influence a person's default 'arousal levels' which in turn affect reaction time.

Table 3.6.4: Reaction time - Stimulus characteristics.

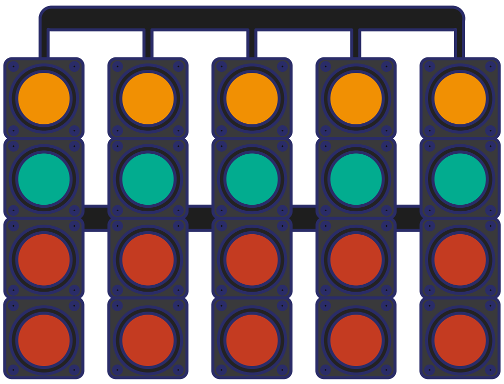


Figure 3.6.22: The lights above signify the impending start of the car race as they cycle through 'red', 'yellow', then 'green' (start) for a faster reaction time.

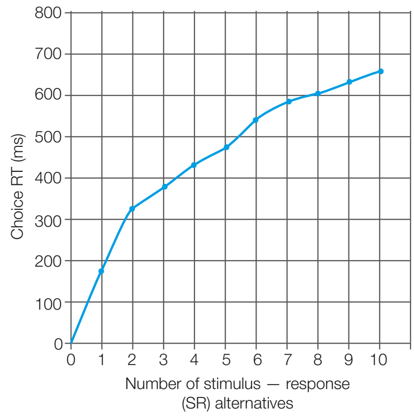


Figure 3.6.23: Hick's Law state the more options available to a player, the more stimulus-response choices so the slower we react.

Figure 3.6.24: Psychological Refractory Period.

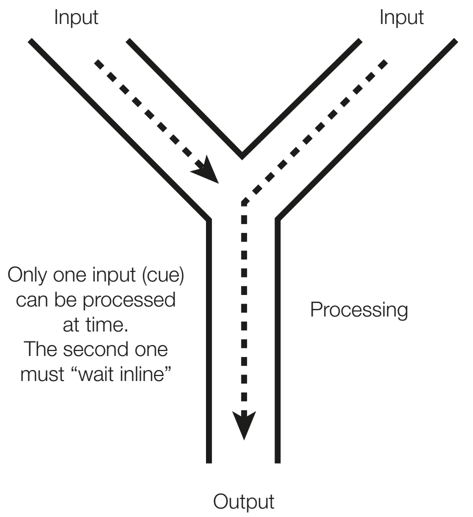
In Figure 3.6.24, the netball player (X) leads one way for the ball, but then very quickly doubles back, making a lead in the opposite direction, so that she will remove player Y from the play and receive a pass to shoot.

Why?

Because player Y is still processing the first cue and must process this cue before she can process the second cue (called the **single channel hypothesis**).

By then it is too late and player X has received the ball behind her. The delay in the correct response being processed is called the **psychological refractory period**.

Table 3.6.5: Reaction time - Stimulus characteristics.

Reaction time - Stimulus Characteristics	
Strength of stimulus	The stronger the stimulus (larger, brighter etc.), the faster the reaction time will be (refer to Focus Area 3.6: Signal detection).
Type of stimulus	The type of stimuli presented to an athlete will influence the time it takes to react, with the following stimuli ranked in order from fastest reaction to slowest reaction speeds: 1. Kinaesthetic (fastest) 2. Audio 3. Touch 4. Visual 5. Smell (slowest).
Likelihood of stimulus occurring	A player can react faster if they know a certain stimulus is likely to happen. For example, a batter in softball standing more front-on to the pitcher than usual, or holding one hand further down the bat, indicates the likelihood of a bunt. The pitcher may therefore demonstrate a quick reaction to field a ball hit toward them after the pitch.
Warning signals	If there is some sort of sign or signal which indicates a stimulus is coming, then reaction time is faster. For example, the start of a car race is often conducted via a series of lights, and on the last light the cars can begin. Therefore, the second to last light is an indicator of when the 'start' light will appear (Figure 3.6.22).
Number of choices	When there is only one possible response to a stimulus (**simple reaction time**), the reaction time is much faster than when there is more than one possible response (**choice reaction time**). This concept is often referred to as Hick's Law (Figure 3.6.23). For example, when two different teammates make a lead for the ball, who do you throw the ball to? It takes a little longer to process information when confronted with more than one choice and, hence, response time is slowed.
Psychological refractory period	When presented with two cues or stimuli very close together, the first stimuli must be processed before the second stimuli can be acted on. This is referred to as the **single channel hypothesis**, which states that only one cue can be fed into the processing mechanism and processed at a time (Figure 3.6.25).  *Figure 3.6.25: Single channel hypothesis.* *The* **psychological refractory period** *(Figure 3.6.24), describes the unavoidable 'delay' in information processing that occurs because the second (correct) stimulus must wait until the first (incorrect) stimulus is processed.*
Familiarity of stimulus	The response to stimuli is quicker when the required response matches the cue or stimuli. For example, a starter in a 400m race giving the commands of "on your marks, set…. BANG!" would create a faster reaction time than runner's simply reacting to the BANG!

Focus Questions

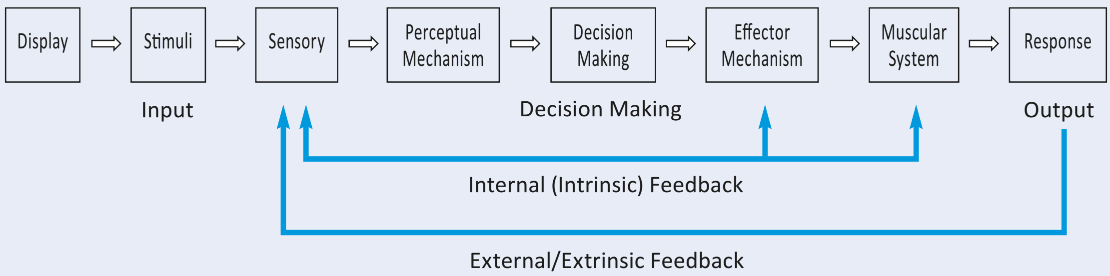
15. In a sport of your choice, explain a situation where the response by an opponent is reasonably predictable.

Example A: A team sport player (hockey).

Example B: An individual sport athlete (shot putter).

16. Refer to examples A and B above to explain why a team player (Example A) with the ball, generally has a greater number of cues (stimuli) that they must respond to (or ignore) than in an individual sport (Example B).

17. Choose a skill in a sport of your choice and use the model of skill or information processing model to analyse how this skill is executed.



Anticipation

Anticipation is an educated guess on what is going to happen next in a game. Through experience, an athlete develops an understanding for what cues are relevant in a given situation. Eventually, this allows an athlete to anticipate the play or an opponent's next move with a degree of accuracy. This allows the athlete more time to move into position, more time to prepare for the execution of the response and more time to think about the correct response. Anticipation is an educated guess, based on relevant cues or stimuli.

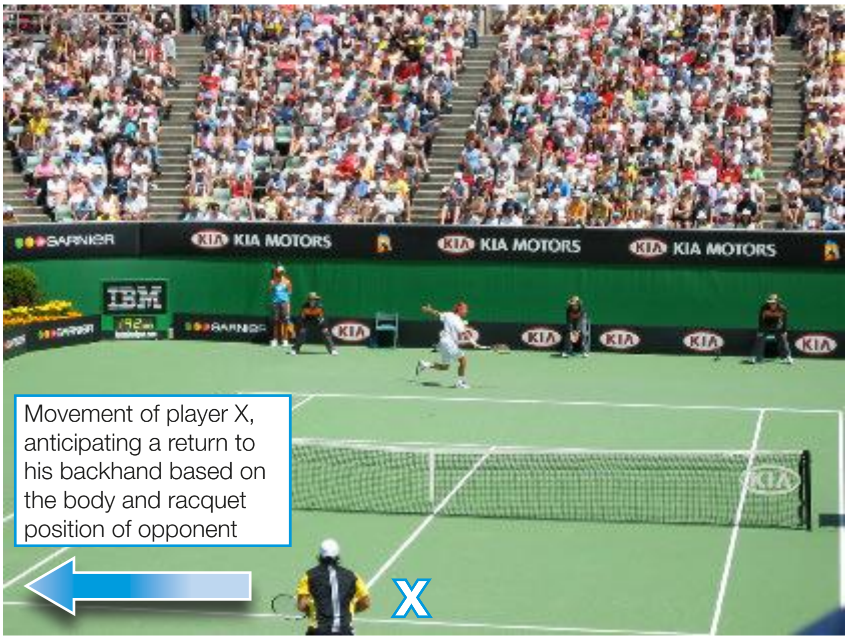


Figure 3.6.26: The early detection of cues enables a player to 'anticipate' and move early to begin the appropriate response.

Focus Questions

18. Explain whether you believe a fielder in softball or cricket needs to wait until the batter has contacted the ball before they can begin moving.

Attentional focus

In sport, the ability to focus and maintain attention during competition is often required to maximise performances. Specifically, attentional focus refers to the process where an athlete allocates mental resources (attention and concentration) to cues, stimuli, or states within a sporting environment.

Attentional focus is commonly classified along dimensions and one particular model (Nideffer, 1976) proposed two dimensions of **direction** (internal or external) and **width** (broad or narrow).

Table 3.6.6: Attentional Focus in cricket batting.

Broad External The batter quickly checks the fielding placements as the bowler runs in for their delivery.	**Broad Internal** The batter makes tactical decisions and a game plan based on the run rate required.	Internal focus - Concentration on thoughts and feelings e.g. muscle fatigue, breathing, anxiety, daydreams etc. External focus - Concentration on the environment e.g. scenery, crowd, other players etc.
Narrow External The batter carefully watches the bowled ball onto their bat.	**Narrow Internal** The batter undertakes mental rehearsal techniques to control their anxiety and emotional state.	Broad focus - Concentration on the 'big-picture' of what is happening in the sporting environment e.g. players changing positions etc. Narrow focus - Concentration only on a few of the immediate and important points of what is required e.g. personal skill execution etc.

In general, the attentional focus model advocates that closed skills require a narrow focus and open skills a broad focus. In a game environment, most activities require a broad focus but may switch to a narrow focus when executing a complex skill.

Errors in performance are often the result of lapses in both concentration and attention, when an athlete focuses on not the most important information relevant to performance at that moment in the game - refer to Focus Area 3.6: Signal detection/selective attention and Focus Area 2.2: Psychology of sporting performance.

Although Nideffer's model (1976) states that individuals will tend to have a preferred attentional style - either broad-external, broad-internal, narrow-internal or narrow-external - it is generally accepted that attentional focus can be practiced and developed to assist performance by allowing an athlete to:

- Concentrate on the relevant stimuli and cues from the sporting environment
- 'Block out' irrelevant 'noise' i.e. assist with selective attention focus
- Avoid 'information overload'
- Quickly shift between narrow and broad / internal and external focus when required in a game.

Focus Questions

19. Using a specific example, explain how a lapse in concentration and/or attention may cause an error for an athlete in the sport of your choice.

20. With reference to Nideffer's model of attentional focus, explain how an athlete could shift their focus from broad-narrow and internal-external to avoid the described lapse in concentration (above) and avoid the subsequent error.

Perceptual-motor workplace

The **perceptual-motor workplace** is a concept that relates to skill learning within the **ecological (dynamical systems) theory perspective**. Essentially, it is a term used to describe the practice context for a learner.

Figure 3.6.27: Dynamic system theory perspective - the perceptual-motor workspace

Constraints-led game-practice provides opportunities for players to search for movement solutions through their perceptual-motor workspace.

The perceptual-motor workspace represents all of the possible movement solutions available to a learner to explore during a practice task. As discussed previously, practice in a dynamical learning system theory perspective must be game based and constraints-led at either the task, individual or environmental levels (refer to Focus Area 1.4 and 3.5). This will allow players to fully explore their 'perceptual-motor workspace' in order to detect opportunities for action in the practice - these are called affordances.

As an example, we will look at a soccer player training within a modified soccer game context.

During the game, an attacking player receives the ball and looks up to scan the soccer field to perceive the sporting environment - this is their **perception**. As they search the playing environment, they begin to focus on the most useful information at hand, and they see a defender moving across the field which creates an open 'space' and an 'unmarked' team mate - this is the player's **attunements**. The player now sees that this has created possibilities for action to either pass the ball or dribble into the space - this is their **affordances**. As they watch the space open-up a bit more, they recognise that they have the ability (speed, fitness and ball control) to dribble quickly through the space and create a scoring opportunity - this is the player's **constraints**. The player executes their response and dribbles the ball into the 'space' and shoots and scores a goal - this is the player's **action**. Their successful response was a function of the attended information from the game (their perception) and the subsequent action(s) they took to successfully solve the problem - so this response will strengthen their **perception-action coupling**.

In this scenario, the soccer player has searched through their **perceptual-motor workspace** through attunement to the information they perceived and solved the sporting problem with a creative and unique solution - the player demonstrated high **degrees of freedom**.

Figure 3.6.28: Practice sessions must provide all the information that would be present in a game situation, to strengthen a player's perception-action loop.

In the dynamical systems theory perspective, **perception** and **action** have a strong circular relationship with each other.

Figure 3.6.29: Perception (of the game) helps a player's action (movement) and a player's movement also aids their perception.

This means that perception affords a player opportunity to move, but a player must also move in order to perceive more game information as well.

Focus Area 3: About Movement

3.7 The learning journey

- Stages of learning - cognitive and ecological

Stages of learning - cognitive theory perspective

A commonly used model to describe the skill learning process within the **cognitive theory perspective** was proposed by the psychologists Fitts and Posner (1967). This model of learning describes a gradual process of skill acquisition from a beginner player right through to an advanced or 'elite' player as they move in a linear fashion through a 'three-stage model' that classifies learning into 'phases' along a continuum.

The three stages range from the **cognitive** stage, where a beginner is learning 'what needs to be done', through to an advanced **autonomous** stage, where skills are 'automatic' and there is a focus on higher level tactical and strategic applications in a game environment.

The three stages of skill learning are viewed as a learning continuum. An individual player will not necessarily pass from one stage to another in all aspects of the sport. For example, in basketball, a player may be in the **associative** stage for dribbling the ball down the court and taking a 'jump shot' but they are in the autonomous stage for taking a foul shot because they have many, many hours of practicing shots from the foul-line in closed practice sessions.

Table 3.7.1: The 'cognitive stage' of learning a motor skill.

Cognitive Phase	
 *Figure 3.7.1: A beginner learner.*	• Beginner learner - trying to understand 'what needs to be done' • Uncoordinated movements • Many errors and the errors are very large • Rely on external feedback from a coach - focus on simple instructions, positive reinforcement & knowledge of performance • Coach may use demonstrations and 'manual guidance' and 'closed' training sessions to maximise learning • Usually a short stage of learning with rapid improvements.

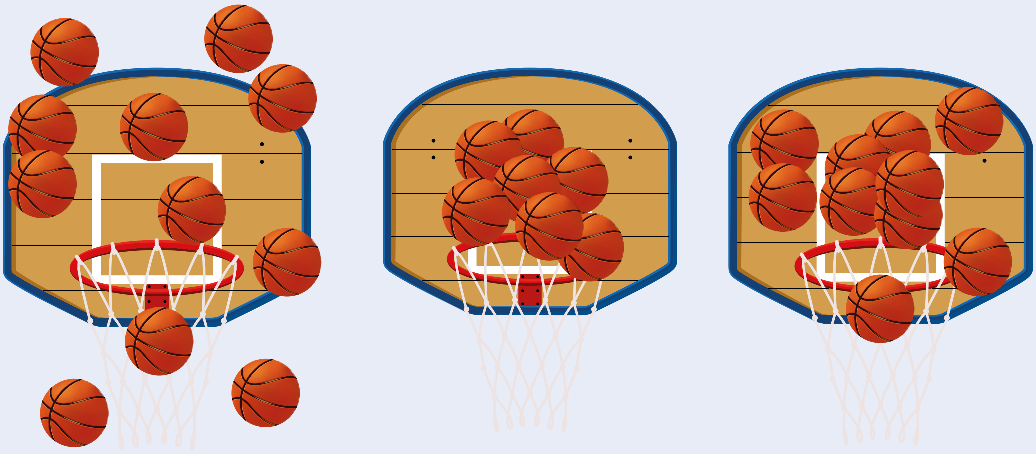
Table 3.7.2: The 'associative stage' of learning a motor skill.

Associative Phase	
 *Figure 3.7.2: The practice stage.*	• Refining the skills - the 'practice stage' of learning • Improvements through 'trial and error' will see skills become smoother • Begin to be able to self-correct their skills • Building an executive motor program into their long-term memory • Lowered cognitive process to execute the skills - growing focus on tactical applications in a game • As the skills are learnt, improvements slow down - many players do not progress past this stage of learning.

Table 3.7.3: The 'autonomous stage' of learning a motor skill.

Autonomous Phase	
 *Figure 3.7.3: Movement skills are 'automatic'.*	• Movements are 'automatic' and almost perfect • Motor programs are stored within the long-term memory for quick and instant recall • Player can focus on the decision-making elements of the game - tactics and strategy • Regular practice is required to stay in this stage of learning • Rely on 'intrinsic' feedback (kinaesthetic feel) to make small adjustment to skills if required.

Focus Questions



A B C

1. Identify and explain which example in the diagram are more likely to represent learner in the associative stage?

The practice of sports skills

A player's ability to learn motor skills is enhanced if the coach or teacher is able to take into consideration factors that may affect the learning of skills. Some of these factors include the nature of the task and the characteristics of the learner:

The Nature of the Task - Prior to coaching or teaching a new skill to a beginner, assessment of the 'nature of the task' to be learnt may ascertain factors such as whether the task:

- occurs in an open or closed situation
- is complex or simple - if complex, the skill or task may need breaking down into smaller components
- involves fine or gross motor skills
- involves major muscles groups
- uses predominantly one energy system in relation to others.

Figure 3.7.4: Tennis coaching in a 'closed' drill situation where the coach 'feeds' a ball to the player.

The previous factors can be reviewed in Focus Area 1.4: Practical application of learning theories.

Focus Questions

2. (a) Analyse the skill of batting in softball and identify where this skill sits in relation to each of the following continuums?

Once you have assessed the complexity of the skill, you can then think about how to teach it.

(b) Now you have analysed the skill of batting in softball, explain whether the skill would be easy or difficult for a beginner to learn.

(c) Explain how understanding the nature of the task may influence how a coach presents this skill to a beginner.

Introducing the tee takes the skill of hitting a pitched ball in softball from a very **open skill** to a **closed skill**.

The beginner is now more in control of the movement and dictates when it will be initiated. The speed and unpredictability of the pitch has been removed.

This allows the beginner the chance to practice the same basic technique over and over again, correcting errors in a controlled environment. Once a basic motor programme has been developed, the skill can begin to be opened up again. As more demands are placed on the learner, they must adapt and adjust their motor plan of this particular skill until they can hit in a game situation.

Figure 3.7.5: A tee is used to 'slow' down the cue and improve signal detection.

Focus Questions

3. Using the above example of a softball hit, complete the skill progression a coach might take to move from a closed environment to a more open one:
   (a) Tee ball stand
   (b) Slow predictable feed over a short distance
   (c) Slow predictable feed over a larger distance
   (d) Predictable feed over a large distance, yet with increasing speed
   (e) ....
   (f) ....

The planning of a coaching or practice session is important for effective learning to take place. The main types of practice that a coach can choose to implement are:

Massed Practice

This type of practice involves continuously practicing the same skill over a long period of time. To ensure improvement, there needs to be a level of consistency. Fatigue generally affects the ability of the athlete to continue to correctly do the skills, and so monitoring of performance is necessary in most learners. For this reason, massed practice is good for simple and discrete skills that don't fatigue the athlete. The repetitive nature of this practice makes it more suited to highly skilled athletes, who are motivated to perfect a particular skill. Massed practice can assist with making a skill habitual and storing it into an athlete's long-term memory as an executive motor program for instant retrieval during a game.

Beginners may find the repetition boring, and lose interest in the massed practice - they may also practice a skill incorrectly (because they have not mastered the subroutines) and reinforce the learning of a poor technique and as stated previously in this workbook: "practice makes permanent" (Focus Area 1.4). Another problem with massed practice is the inability for an athlete to receive feedback during the session because there are no rest breaks for opportunities for a coach to provide input.

Example: performing 50 shots of a basketball or setting a volleyball 40 times.

Focus Questions

4. Identify three examples of massed practice in three different sports of your choice.

....

....

....

5. Explain why the repetitive nature of massed practice may not suit beginners learning a skill.

....

....

....

....

Distributed Practice

Distributed practice involves practicing a skill with rest periods in between each practice session, or even practicing another skill or concept between each practice. The rest period between practices helps reduce fatigue when practicing skills with high energy demands. It also breaks up a potentially 'boring' task or a task that is complex.

Example: catching a basketball 20 times, then shooting practice for 5 minutes, and having a 3 minute rest before returning to catching practice.

Focus Questions

6. Identify three examples of distributed practice in a sporting situation.

Fixed vs. Variable Practice

Practice can also be categorised as fixed (constant) practice or variable (distributed) practice:

- Fixed Practice - involves specific movements being practised repeatedly. This type of practice lends itself to closed or habitual skills, if the correct technique is practised it can strengthen the motor plan for that skill. Again, this type of practice can cause problems of poor motivation (boredom) and fatigue if this type of practice is undertaken too much or for too long.
- Variable Practice - involves repeating a skill in different playing conditions, allowing you to experience similar conditions to that used in games. This type of practice lends itself to open skills and helps develop the ability to adapt to various situations. Varied practice is well suited to beginners, to allow them to progress, as more difficult elements of a task can slowly be added to ones they are already familiar with.

Focus Questions

7. The start of each frame is identical in ten-pin bowling. Therefore, professional bowlers can spend hours each day practicing the same shot.

   (a) Explain why a ten-pin bowling coach may decide to use distributed practice for beginners, rather than massed practice like the professional players.

   (b) Explain one advantage of using distributed practice for each of the following scenarios:

   (i) When the skill is physically demanding.

   (ii) When the motivation levels of the learner are low.

   (iii) When a complex skill is involved.

   (c) Explain the advantage of professional bowlers using massed practice for the opening shot they would use on the start of each frame.

Whole Practice

Whole practice involves learning a skill in its complete form. Each component (part) of the skill is learnt as one large skill.

Example: If the pole vault was taught all at once, it would be an example of whole practice. This would mean learning the run-up, pole plant, take off, swing and extension all at once.

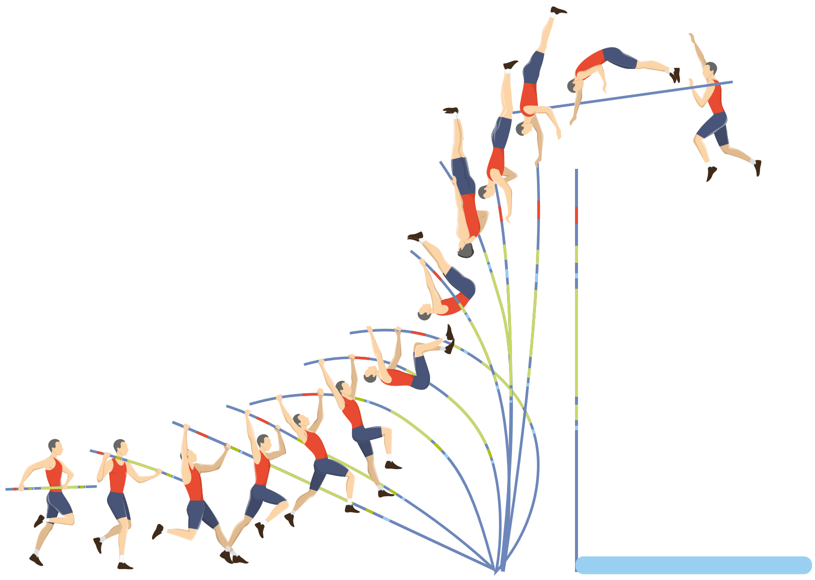


Figure 3.7.6: Pole vault is a complex skill.

Whole practice is especially useful in simple skills which have less parts or components to master (throwing or kicking a ball). Hence, learning pole vault using whole practice could be difficult.

Part Practice

Part practice involves breaking a whole skill down into smaller parts and learning these parts individually or sequentially developing each part until the whole skill can be attempted.

Example: learning pole vault through breaking the skill into parts would be an example of part practice. In this situation, the parts could be learned separately, or by learning one part and then developing this further by adding the next part of the skill (part-progressive practice).

Figure 3.7.7: Running with the pole would be one of the first parts addressed in a part-practice approach.

Part practice of pole vault would involve breaking down the skill into its component parts such as:

- run-up
- pole plant
- take off, etc

Part practice is useful in complex skills.

Whole-part-whole

The whole-part-whole method is simply a combination of the whole and part methods, often used when trying to identify any weaknesses that may exist in the execution of a skill. Firstly, the skill will be performed in its entirety, and areas of weakness are identified. Subsequently, the areas (subroutines) of the performance that need further development, will be isolated and then practiced using the part method, before being reintegrated into the entire skill.

Specific Factors Affecting Skill Learning

Physical Environmental Factors - Learning skills can be influenced by the environment in which a beginner is performing. The following environmental factors may influence skill learning for beginners, and should be acknowledged by the coach:

- Positive environment – an environment where you are encouraged to try new things and not be afraid of failure is conducive to learning.
- Variety – monotonous (always the same) environments and practice activities lead to boredom and a lowering of the arousal level of the learner.
- Environments free of additional stimuli (distractions) – a distracting environment is one in which it is harder for a beginner to concentrate and could lead to reduced signal detection.
- Competitive environment – an environment that is too competitive may reduce learning. The coach needs to set attainable goals which develop the skills to a level where the competitive atmosphere of a game or game-like situation is helpful to the learner's development.
- Role models – people in the community that a learner aspires to be like are powerful motivators for beginners.

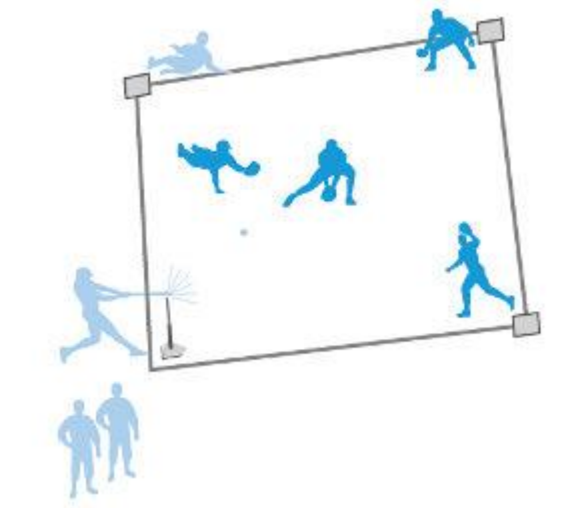
Characteristics of a Skill Learner

The characteristics of the learner may affect the ability for learning to occur.

1. Age/Physical Development - the physical development of the learner is an important factor to consider when coaching:
    - During early childhood, the coordination of the child is developing but is not at a level that allows for fine and controlled movements. This ability develops with age and so the expectations on the learner should match their actual physical ability at that time.
    - Learners of a senior vintage (the elderly), may have reduced movement due to the wear and tear on joints and muscles. So, once again, the expectations should be individualised (suit their actual ability).
2. Due to differing physical development, modification of skills by coaches or educators will vary depending on the level of the learner and their capabilities. Young learners will generally need more modification of the learning environment, compared to adults who are more capable of dealing with an unaltered environment.
    - Some of Australia's most popular sports (netball, cricket and softball) are modified for younger participants in an attempt to provide opportunities for greater success.

Focus Questions

8. (a) Choose a skill within a sport (other than softball/baseball) commonly played by adults and describe how a junior league coach could close that skill down.



(b) With reference to your example above, explain how the modification improves the chance of success for the beginner players.

The cognitive development of the learner

The cognitive development of the learner is, to a large degree, related to the age of the learner and maturity level. For example, a young child may find problem-solving difficult, and so a more direct style of coaching may be beneficial. However, adults or the elderly may appreciate more involvement in training and the option of being able to work in small groups to solve a problem.

The language used to express ideas during feedback also needs to take into consideration the cognitive development of the learner. Large words may not be in the vocabulary of a young child; hence they may miss the main point being put across by the coach. For example, using words like ‘pronate’ to a beginner, when you want them to turn their forearm so the palm faces down, may not be understood.

There may also be sport-specific terminology which beginning players need to learn.

Focus Questions

9. Match the following sports with the terminology common to it.

16 yard line	Basketball
3 point line	Squash
Crease	Swimming
'Hit above the tin'	Softball
Home plate	Netball
Wing attack	Cricket
Lane rope	Hockey

Psychological Development (Maturity Level)

The maturity level of the learner 'should' increase with age.

Focus Questions

10. Explain how a greater level of maturity may affect the way a coach allows learners to practice a new skill.

Gender

Owing to gender role stereotyping, learners may come into a sport with different degrees of exposure to certain movement patterns or skills. The level of the learners in a co-ed environment may therefore be quite varied.

Evidence suggests that males learn more through visual means; hence, coaching mixed groups requires more than one approach to maximise learning.

There is little difference in the physical development (strength, etc) of preadolescent girls and boys. Yet post-adolescence may reveal differences. For example, muscle hypertrophy differences between males and females will affect strength, speed and power, so coaching expectations in regard to running speed, kicking or throwing distances may need to be adjusted accordingly.

Figure 3.7.8: Post-adolescence may reveal differences in muscle hypertrophy between males and females.

Previous Experience

Previous experience in a sport usually means that this person will be at a more advanced level (technically and tactically) compared to others who have never experienced the sport or movements specific to it.

Figure 3.7.9: Previous experience in a sport usually means that this person will be at a more advanced level (physically, technically and tactically).

Focus Questions

11. Explain how a coach could utilise a person with previous experience in a group during the coaching process.

Cultural Considerations

Some cultures demonstrate a preference for certain sports over others. A multicultural group of learners, therefore, comes with different skills, depending on the type of sports they have been exposed to. You may find that some learners already have good hand-eye coordination, while others have good foot-eye coordination.

Stages of learning - ecological (dynamical systems) perspective

The **ecological (dynamical systems) perspective** on skill learning advocates that learning a motor skill is a complex interaction of an individual's capabilities, their environment and the task at hand. Therefore, motor learning is viewed as **self-organized,** with a focus on the performer adjusting their own unique movement patterns to achieve a task from information collected from within the changing environment.

New patterns of skill execution will emerge as a function of the demands arising from the constraints imposed by the organism, the task, and the environment.

Newell (1986).

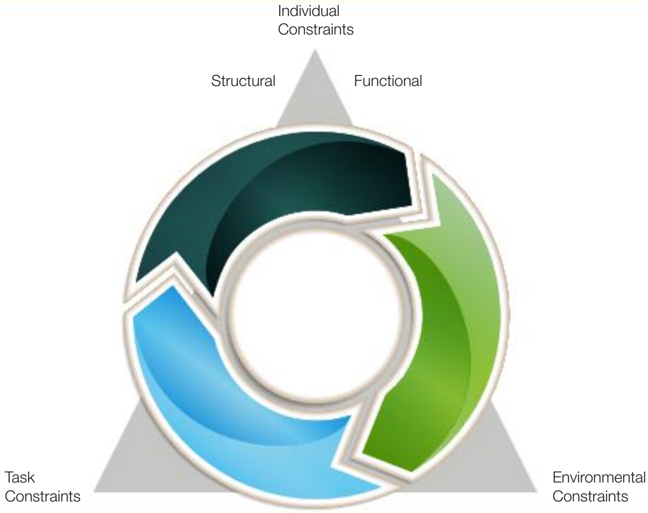


Figure 3.7.10: Newell's model of movement constraints (refer to Focus Area 1.4).

From a dynamic systems perspective, skill learning is not a gradual and consistent (linear) progression, but instead, a dynamic and **nonlinear** series of progressions and (regressions). The dynamic systems approach to learning advocates that learning will move **up and down** through Newell's 3-stage learning model.

The first stage of this model is referred to as the **coordination stage**, where a learner focuses on the task and how to achieve the goal (skill) within the game. There is usually a limited exploration of movement patterns (termed their **degrees of freedom**) to achieve the goal. As a consequence, the learner may not look 'relaxed' and unable to execute the skill in a 'smooth' or 'coordinated' way. Learners generally progress rapidly to the second stage, which is termed the **control stage**. In this stage, learners explore different task solutions characterized by greater degrees of freedom which enable skill adjustments during performance that decrease dysfunctional variability and enable greater task success. Finally, the third stage of learning is referred to as the **skill stage**, where an optimal adaptation in movement is found that feature creative and energy efficient solutions to constraints.

Table 3.7.4: Newell's 3-stage learning model (dynamic systems perspective).

Stage	Characteristics of Stages of Learner (Dynamical Systems Perspective)
1	**Coordination Stage** • Focus on the task • Establishes the movement pattern (skill) • Limited 'degrees of freedom' (low variation in movement solutions) • High outcome variability.
2	**Control Stage** • Exploring task solutions • Greater 'degrees of freedom' (greater variation in movement solutions) • Higher consistency in task success • Greater attunement to environmental demands • Formation of the **perception–action coupling** (refer to Focus Area 1.4).
3	**Skill Stage** • Optimal adaptation of movements • Creative and energy efficient solutions to constraints • High 'degrees of freedom' with functional and effective variation in movement solutions • Effective goal achievement.

Adapted from: Strength and Conditioning. A Biomechanical Approach, Chapter: 10 Skill Acquisition, Publisher: Jones & Bartlett Learning, pp.387-430, January 2015.

Focus Questions

12. (a) Explain what is meant by non-linear teaching pedagogy.

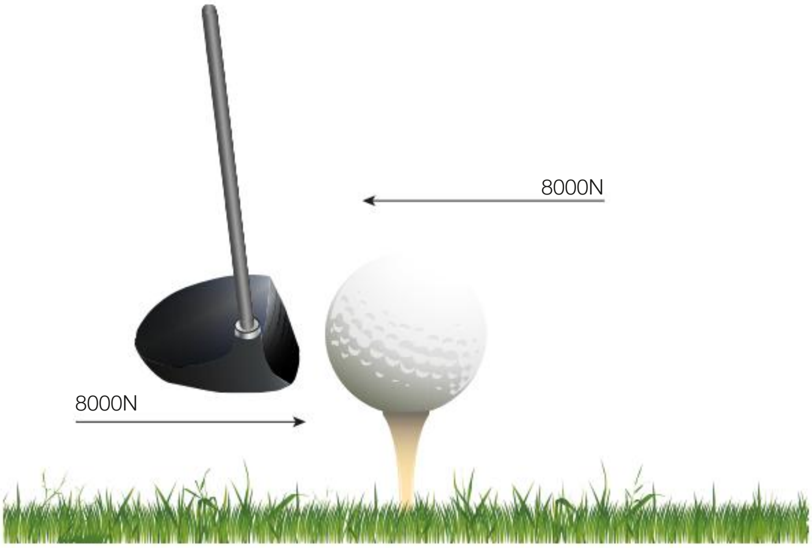
(b) Using examples, explain the term ‘constraints’ in reference to Newell’s model of movement.

(c) Using the table below, contrast the stages of learning by identifying the characteristics of each model.

	Stages of Learning	
	Linear	Non-linear
	Cognitive theory	Dynamic systems perspective
Stage 1	• •	• •
Stage 2	• •	• •
Stage 3	• •	• •

Given that when forces are applied to objects, they apply an equal but opposite force back, why then do objects move at all?

A force (push or a pull) has a direction and a magnitude. With forces being measured in the unit - Newton's (N).



So, in our golf ball example, if the club applied a force of 8000N on the ball, the ball applies an equal but opposite force back (Figure A)

Figure A Forces involved in hitting a golf ball.

When the golf club contacts the ball, the **IMPULSE** will cause the ball to accelerate (increase the speed).

Impulse refers to a change in momentum, so **Impulse = Change in momentum**

Where **IMPULSE = F × Δt** [F = Force and Δt = how long forced is applied] and

CHANGE IN MOMENTUM (Δp) = m × Δv

[Δp= Change in momentum, m = mass of object and Δv = objects change in velocity]

So, in our example the FORCE was equal to 8000N.

The time the club was in contact with the ball we will say is 0.0005 seconds (not very long!!).

The mass of the club we will say in 320g and the ball 40g.

What is unknown is the change in velocity. But that can be calculated:

IMPULSE = CHANGE IN MOMENTUM equation

$$F \times \Delta t = m \times \Delta v \text{ (the change in velocity)}$$

OR

$$\Delta v \text{ (the change in velocity)} = \frac{F \times \Delta t}{m}$$

The golf ball:

$$\Delta v_{\text{Golf Ball}} = \frac{8000\text{N} \times 0.0005 \text{ sec}}{0.04 \text{ kg}} = 100 \text{ ms}^{-1}$$

Change in velocity of 100 ms^{-1} after the impact with the club head.

The club head:

$$\Delta v_{\text{Golf Ball}} = \frac{8000\text{N} \times 0.0005 \text{ sec}}{0.32 \text{ kg}} = 12.5 \text{ ms}^{-1}$$

Change in velocity of 12.5 ms^{-1} after the impact with the ball

In the example, the impulse is the same for the club head and ball but, the mass of the two objects (club head vs ball) is not. As the club has more mass than the ball, the change in velocity is not as much in the club head. The ball however has a much larger change in velocity and moves forward.

Figure 1.3.18 A struck golf ball gains momentum.

In our golf example, the momentum of the club head is transferred to the momentum of the golf ball. This transfer of momentum is explained using the LAW OF CONSERVATION OF MOMENTUM.

This law states that '*the total momentum after contact must be equal to the total momentum before contact*.'

This means in our example; the golf ball was gaining momentum because the club head 'pushes' on the ball. While the club head loses momentum due to the ball pushing back. As we saw in this example, the mass of the club and ball determine exactly how much momentum we are talking about.

CHANGE IN MOMENTUM = mass of club (or golf ball) × Change in velocity of club (or golf ball)

CHANGE IN MOMENTUM or **(Δp) = m × Δv**

Using the values from before

Golf ball's change in momentum = 0.04kg × 100 ms^{-1} (the answer is +4kg ms^{-1})

Clubs change in momentum = 0.32kg × 12.5 ms^{-1} (the answer is –4kg ms^{-1})

The ball **GAINS** momentum and the club **LOSES** momentum.

Focus Questions answers

Focus Area 1.1

1. The intensity must be maximal, duration is subsequently very short (up to 10 seconds).
2. Alactacid means no lactic acid is produced.
3. (a) Track and field: shot put, discus, javelin, long jump, hammer throw.

   (b) Team sport: Tennis 1st serve (with power), volleyball spike.
4. Sprint 6 seconds ATP – CP dominant; Following the sprint, CP stores depleted; 3 minutes recovery allows for nearly 100% CP recovery, therefore can fuel subsequent sprint. Process may be repeated if 3 minutes recovery allowed.
5. (a) A product of anaerobic glycolysis. Without sufficient oxygen, pyruvic acid converts to lactic acid and contributes to muscle fatigue.

   (b) Lactic acid is produced (lactic acid system).
6. The intensity is high; the duration is short (up to 2.00 minutes).
7. (a) Track and field: 400m sprint (45-60 seconds) maximal work / 800m sprint (1.45-2.00 minutes) maximal work.

   (b) Team sport: Repeated high intensity efforts in volleyball (block/spike combinations in extended rally) which deplete CP
8. Personal time recorded = approx between 50 seconds and 90 seconds.

   (a) After 100m - starting to slow down, feeling some fatigue.

   (b) After 400m - very fatigued, legs feel heavy, shaky, breathing rapidly. Intensity above 85% HRmax (lactate Threshold/OBLA) and CP stores depleted so there will be a large accumulation of lactate and H^+ ions causing the fatigue. After the 400m run there is rapid breathing to deliver oxygen to repay EPOC (lactacid + alactacid components) and return body to resting conditions.
9. Refer to text for explanations.

   (a) Exercise that is below maximal intensity – can be maintained for extended periods of time.

   (b) Where oxygen consumption matches oxygen requirements for a given workload – achieved during ‘submaximal exercise’.
10. The intensity is low (sub-maximal); duration is long (1-2 minutes plus).
11. (a) Track and field: 10,000m, 3000m, marathon.

    (b) Team sport: walking in netball by a GK when ball at the other end of the court, jogging in soccer to follow play, interchange bench for AFL player (body in EPOC).
12. Aerobic glycolysis – requires oxygen, occurs in mitochondria, no fatiguing by-products, 3 potential fuels: carbohydrate, fat, protein.

    Anaerobic glycolysis – no oxygen required, occurs in the cytoplasm of cell, fatiguing by-product lactic acid produced (moves into blood as lactate and hydrogen), one fuel: carbohydrates.
13. Refer to text for explanations.

    (a) The maximal volume of oxygen consumed by the body. May be expressed in litres of oxygen per minute (L/min) or millilitres of oxygen per body weight per minute (ml/kg/min).

    (b) The maximum intensity of steady state exercise (% VO_2 max) that a person can sustain without rapid lactate accumulation.

    (c) A blood lactate concentration of 4 mmol/L indicates the Onset of Blood Lactate Accumulation.
14. (a) See Figure 1.1.17 for example of LT graph

    (b) 18km/hr.

    (c) 20km/hr the blood lactate accumulation has reached 8mmol/L so this is above LT and OBLA, so fatigue will be very soon (up to 2minutes) before the muscles fatigue in an acidic muscle environment.

A

(d) Heart rate of 160 bpm is below LT and OBLA, but still maximising the pace without the accumulation of these by-products during the run.

15. Refer to text for explanations.

(a) The difference between the oxygen required for a given task and the oxygen actually consumed by the body.

(b) The volume of oxygen consumed after exercise (above that normally required at rest) is termed the Excess Post-Exercise Oxygen Consumption (EPOC).

16. (a) It takes 1-2 minutes for the runner to reach steady rate where aerobic system is dominant – this could be achieved in the warm-up. Without a warm-up, the runner would spend the first few minutes in oxygen deficit with the lactic acid system producing lactic acid and causing fatigue.

(b) If the runner spent too much time running at intensity above OBLA, lactate would accumulate and cause the athlete to fatigue and their pace would slow.

(c) An active 'warm down' after race will allow the body to slowly pump blood around the body to prevent 'blood pooling' and speed up the removal of lactate by twofold (90 min down to 45 min). This are part of the EPOC recovery processes - lactacid and alactacid recovery.

17. (a) 500ml/min

(b) 2.0L/min

(c) A = Oxygen deficit, B = E.P.O.C

(d) (i) Minute 6 to 8 the lactic acid system would be dominant as the body has insufficient oxygen being delivered to the body (oxygen deficit).

(ii) Minute 10 to 14 the oxygen system would be dominant, as the athlete has reached 'steady state' where oxygen consumption equals oxygen demand (flat line).

(iii) No. The athlete was working sub-maximally in a steady state - this can be seen in the 'flat' line representing O_2 intake = O_2 demand. VO_2 max is only achieved during maximal exercise intensity with the dominant use of anaerobic glycolysis.

18. (a) See table:

ATP-CP	Lactic Acid System	Oxygen System
ATP-PC, alactacid, phosphagen	Lactacid, anaerobic glycolysis	Aerobic
Anaerobic	Anaerobic	Aerobic
CP	Carbohydrate	Carbohydrate, fat and protein*
Very limited	Limited	Unlimited
Up to 10 secs	20-90 secs	1-3 mins plus
Instant	Quick	Slow
NA	Lactic acid	CO_2, H_2O
CP depleted	Lactic acid accumulation fatigue	Insufficient O_2 supply or fuel (carbohydrate)
50% 30 secs 100% 3 mins	Active – 45 mins Passive – 90 mins	None (although 24-48 hours to replenish carbohydrate, fluid, etc.)

(b) Intensity of the exercise, duration of exercise and fuel availability.

(c) (i) Oxygen (ii) ATP-CP (iii) Lactic acid

Application of Knowledge 1.1 source: Energy Expenditure Estimation During Official Soccer Matches

- Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Monitoring-of-a-Heart-rate-HR-in-beats-per-minute-bpm-of-one-of-the-players-who_fig1_237042434 [accessed 16 Apr, 2024]

Author: Daniel Barbosa Coelho et al Nov 2010

(PDF) ENERGY EXPENDITURE ESTIMATION DURING OFFICIAL SOCCER MATCHES (researchgate.net)

www.brjb.com.br Brazilian Journal of Biomotricity, v. 4, n. 4, p. 246-255, 2010 (ISSN 1981-6324) 247

(d) See table:

Energy System	Explanation
ATP-CP	Duration Less than 10 seconds at Maximal Intensity
ATP-CP/Lactic acid	Initial jumps ATP-CP. Quick succession doesn't allow for CP recovery – lactic acid dominant in later part of rally.
Oxygen	Low intensity, long duration sub maximal exercise.
Oxygen/lactic acid	Predominantly aerobic, but surges in the race take athlete above lactate thresholds for short periods.
Oxygen	Recovery of EPOC – replenish CP, remove lactic acid.

(e) Team sport: AFL is a high intensity, intermittent team sport with a complex interplay of energy systems. All energy systems will be used, but the dominant energy system at any one time will be a function of exercise intensity and duration.

The ATP-PC energy system will be dominant in activities that are maximal for very short periods of time (3-5 seconds), such as a maximal sprint over 20m by a full forward on a lead to receive a mark. High intensity/short duration efforts such as described above are likely to be repeated many times in a game. Without adequate rest breaks (>3-minutes) between efforts, PC stores will become depleted. Subsequent high intensity efforts will see the lactic acid system dominant. As the player works at high intensity above their LT/OBLA throughout the game, they will begin to accumulate lactate and H+, marking the onset of fatigue. During low intensity efforts in the game when the ball is at the other end of play (or at half time etc.) the aerobic energy system will be dominant as it replenishes PC stores and removes lactate during recovery processes in EPOC. The interplay of energy systems may vary when contrasting different playing positions on the field. For example, at times a full forward may not be directly involved in play and get plenty of rest to replenish PC store after maximal exertion, thereby minimising their lactate accumulation and fatigue throughout the match. A midfield player may get very little rest through game play and will be unable to fully replenish PC stores. They will find the lactic acid system more dominant, spending a higher % of time playing above their LT and accumulating lactate. Hence a greater level of fatigue will be experienced.

(f) See table:

	Circle A HR Period	Circle B HR Period	Circle C HR Period	Circle D HR Period
HR Value(s) bpm	Trend: Increasing 106-146 bpm	190 bpm	116 bpm	Intermittent Spikes 165-185 bpm
Exercise Intensity	Increasing Intensity	High / Maximal	Low	High
O_2 Demand	High (O_2 deficit)	High / Maximal	Low	High
Dominant Energy Pathway	Anaerobic	Anaerobic	Aerobic	Anaerobic
Dominant Energy System	Lactic Acid	ATP-CP	Aerobic	Lactic Acid
Likely activity in tennis game	Warm-up hitting Increasing Intensity	95% effort Fast 'serve & volley'	Resting break In-between sets	Long multiple-hit rally/points

A

Focus Area 1.2

1. The soccer midfielder performs many short and explosive efforts of maximal intensity (max. efforts 1.5% of total game time; sprints 4.2% of total game time) where the ATP-CP is dominant. The data also shows that the midfielder regularly works above moderate intensities (stride or above) for over 15% of total game time, so likely CP stores will have insufficient time to recover 100%. Subsequently, there will be a large reliance on the lactic acid system to fuel repetitive high intensity work once CP stores are depleted. Midfield player covers over 13km in the game where the oxygen system would be relied upon. The oxygen system would also be dominant during the 86% of total game time where the athlete is working submaximally (walking or jogging) and recovering from high intensity work by replenishing CP stores or removing lactic acid.

2. (a) See table:

Athlete	Fitness component(s)
A weight trainer in the gym performs a 10 RM Bench Press	Muscular endurance
A marathoner jogging 15km?	Muscular endurance Cardiorespiratory endurance
A basketball slam-dunk?	Power
A diver from the 3m springboard performing a pike?	Flexibility
A soccer player dribbes around two opponents in a cluttered goal box?	Agility
A five-set tennis match at the Australian Open?	Muscular endurance

(b) A recreational game of volleyball will not be performance based, and therefore the skills of spiking or blocking would be minimal; hence, the fitness factor of power and speed will not be as critical to performance. On the other hand, flexibility, cardiorespiratory endurance and agility may be a more appropriate fitness requirement to complete a 'lower intensity' recreational game.

3. (a) Refer to the text for explanations:

- A fitness test must be relevant to the demands of the sport in regard to energy systems, fitness factors and muscle groups used, etc.
- A fitness test must be valid by actually measure what it claims to measure; i.e. 30m sprint does not measure power.
- Reliability of a fitness test ensures that any differences between a pre-test and a post-test are the result of a change in fitness status – not the result of variations in testing technique.

(b) (i) See table:

i	Cardiorespiratory endurance
ii	Strength
iii	Muscular endurance
iv	Power
v	Speed
vi	Flexibility

(ii) Athlete 'A' likely to play midfield because of higher beep test result (11,1 compared to 9,2) indicating a higher level of cardiorespiratory endurance required to cover large distances throughout the game. Also, the greater running agility demonstrated in the Illinois agility run test score (15.8 secs to 16.1 secs) important for a midfielder. Athlete 'B' likely to play goalkeeper because of higher vertical jump (58cm) and a decreased 50m sprint speed (7.0 secs) indicating more power.

4. (a) Speed
   (b) ATP-CP
   (c) Alactacid. ATP-CP system dominant with minimal lactate accumulation.
   (d) Males generally outperform females. This may be the result of their greater size, meaning an increased muscle hypertrophy (and therefore strength and power); and their greater limb length, meaning less strides taken in the 30m.
   (e) Power.
   (f) FT fibres. Exert greater force with each contraction.
   (g) ATP-CP. Maximal exercise intensity for short duration.
   (h) Muscular endurance.
   (i) Maximal work for 2 min period would result in lactic acid system being dominant
   (j) Subsequent blood lactate accumulation associated with fatigue.
   (k) Flexibility.
   (l) Joints: knee and hip; muscles: hamstrings and erector spinae.
   (m) Environmental – previous training and exposure to flexibility-dependant activities. Hormonal – perhaps hormonal release (usually only during pregnancy) may make females more flexible than males. Body structure – female wider Q-angle (quadriceps angle); feet closer to pelvis.
   (n) Body composition.
   (o) Advantage: easy and cheap to conduct with minimal equipment required. Disadvantage: does not distinguish between fat mass and muscle mass; i.e. bodybuilder with very low BF% may be classified as obese with BMI equation due to their high LBM (lean body mass).
   (p) Agility.
   (q) Athlete Y (AFL midfielder) would likely perform better. Test specifically mimics many of the actions performed in an AFL game. 100m sprinter runs in a straight line and requires no change of direction.
   (r) Cardiorespiratory / cardiovascular (aerobic) endurance.
   (s) An athlete who has given a genuine ‘best’ effort on the beep test would move from very easy sub-maximal intensity exercise to a pace that was above their lactate threshold where the lactic acid system would be dominant. Therefore, the accumulation of lactate and H^+ would cause fatigue and prevent the athlete from continuing in the test at the required pace.
   (t) Relevance: conduct test on athletes that require cardiorespiratory endurance and have a substantial running component within the activity. Reliability: conduct the test on flat ground, ideally in similar environmental conditions/time of day etc. as the pre-test. Validity: record the subject’s raw score (i.e. level and shuttle reached) and only compare this result with subsequent tests. Predicting a VO_2 max score is not accurate (and therefore not measuring what the test claims to measure).

5. (a) Refer to the text for explanations.
   - Peak - the process of achieving an optimal performance on a specific occasion.
   - Taper - a less intense training session(s) precedes competition day, so that the player can be fully rested for ‘peak’ performance on the day.
   - Periodisation - a training program is broken down into different sections or phases. During each phase of training, different physical demands from the event or game are emphasised.

   (b) Preseason phase: The preseason phase is to develop a general fitness base or platform from which the competitive season’s fitness can be built upon. Competitive phase: where the regular competition is held, must maintain fitness and ensure adequate recovery between training and competition. Off-season phase: a working holiday away from the chosen sport (‘transition’ phase). The athlete must prevent a loss of their fitness while taking a ‘break’ from the stress of regular training and competition.
   (c) Warm up: to prevent injury by thoroughly preparing the working muscles and joints for more intense activity to follow. Includes easy aerobic activities (to increase blood flow to the muscles, and therefore muscle temperature). Conditioning phase: the intensity increases as the specific fitness factors are trained. Training principles must be adhered to during this phase to ensure training benefits. Cool down: easy aerobic exercise to remove lactate that may have accumulated by pumping blood around the body to move pooling venous blood back to the heart for oxygenation. Finish with some static stretching.

A

6. (a) Refer to the text for explanations.

   Progressive overload - the gradual increase of training stress over a period of time, so the body can progressively make physiological changes to cope with the training demands placed upon the body. If the training load remained at a constant level for extended periods, no further improvements in fitness would occur.

   Recovery - in order for the body to adapt to training stress, there must be an appropriate recovery period (24-48 hours) following training. Without recovery the body will quickly enter a detraining state – adequate recovery will allow an athlete to recover from the cumulative effects of training or competition.

   (b) An athlete must replicate the characteristics of physical activity in training to match that of the event: specificity. However, the athlete must also periodically alter their program: variation. An athlete should not alter their program without thought to specificity. For example, an athlete may change their bench press exercise to an incline press – it still works the pectoral muscles (specificity), but a different exercise means the body is stimulated in a new way and fitness will continue to improve (variation).

   (c) If the principle of reversibility is ignored, an athlete will quickly 'lose it' (fitness) if they don't 'use it' (training ceases). So that an athlete does not lose all the fitness they worked hard to achieve throughout the season, they should do some low intensity aerobic work and/or strength training 2-4 times per week to maintain base fitness levels.

7. (a) (i) X- ATP-CP. Very short duration (5 seconds) @ 100% effort, 1:5 W:R allows CP recovery. Y – lactic acid. 1 min. duration @ 90% effort, 1:3 W:R allows for only partial lactate removal. Z – oxygen. Duration moderately long (3 min), fewer repetitions.

   (ii) To allow for CP recovery to minimise blood lactate accumulation designed to target the ATP-PC energy system. The work:rest ratio is 1:5 (with 5 seconds work), therefore 25 seconds rest.

   (iii) Program Y – accumulation of lactate and H^+ as repetitions continue - causing fatigue (above LT / OBLA).

   (b) The 30 YO should start slowly, medical clearance etc. then use FITT principle: Frequency: 3 × week, Intensity: 60-75% MHR, Time: 20 mins plus, Type: aerobic (elevate HR for an extended period of time).

8. A gymnast completes many isometric contractions (static) where the muscle is under tension but does not alter in its length e.g. balances / handstands etc. Therefore, it would be useful for a gymnast to use the training principle of specificity' to duplicate the isometric training into their program too.

9. (a) Refer to the text for explanations. Examples include:

   (i) Increase total running time; increase intensity (% MHR).

   (ii) Increase repetitions, work intensity or sets. Decrease rest interval (recovery time).

   (iii) Increase difficulty of terrain (uphill), total running time, running intensity, decrease recovery time.

   (iv) Increase the number of repetitions performed at a station in the given time frame.

   (v) Increase the number of repetitions, height or depth of jump.

   (vi) Increase the weight (mass) lifted, sets performed, repetitions. Decrease the recovery time.

   (vii) Increase the time contraction is held.

   (b) Endurance: many repetitions/low weight (50% 1RM)/shorter recovery time between sets. Strength: heavy weight (100% 1RM)/low repetitions/long recovery time between sets. Power: moderate weights (60% + 1RM)/fast repetitions.

   (c) Static: Lying down supine, straight single leg raise, hold for approx. 30 secs. PNF: same as static stretch, hold for 30 seconds, then contract hamstrings (push back) against an immovable object (partner/towel). Repeat process as a 'static-isometric-static' cycle. Ballistic: standing up bouncing toe touch.

Focus Area 1.3

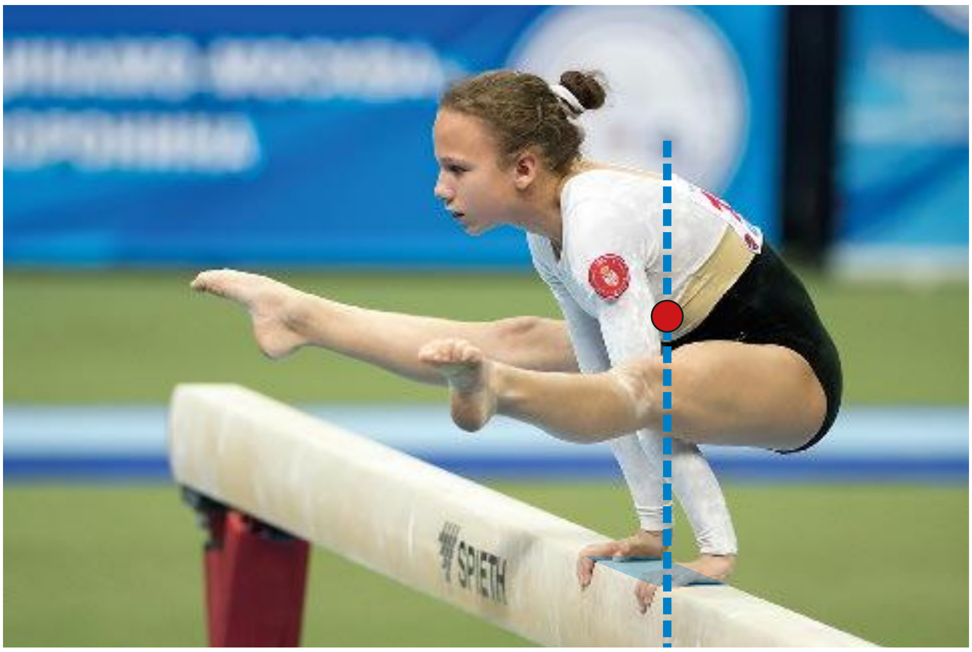
1. The greater the mass, the more inertia or resistance to a change in motion. So, a wrestler with more mass is harder to stop when in motion and harder to begin moving when stationary. This is an advantage in wrestling, as you are less likely to be pushed out of the ring, or you are harder to stop once you begin pushing someone else.
2. Gravity and air resistance.
3. The skull hits the ground and stops almost immediately. However, the brain (floating around in fluid) is already moving, so it will be resistant to any change in motion (inertia). This means it will continue moving backwards straight into the skull (Cranium), creating a 'bruise'.
4. If travelling at 100 km/h the driver's inertia means he/she wants to keep moving. If the car suddenly stops, it means an unrestrained person will continue to move forward as before (inertia – resistance to a change in motion). They will slam into the car's dashboard, steering wheel or windscreen.
5. The gymnast needs to reduce the rotational inertia. They must tuck the limbs in closer to the body. The law of conservation of angular momentum states angular momentum remains constant unless acted on by an unbalanced force. So, if angular momentum equals rotational inertia × angular velocity, reducing rotational inertia means the gymnasts angular velocity must increase. They spin quicker to maintain the same angular momentum. Spinning quicker means they are more likely to land on their feet.
6. Newton's 3rd law states each action has an equal but opposite reaction. So, if you increase the force from the paddle on the water, the reaction force in return will increase (force pushing the canoe forward).
7. The runner pushes in a downward direction on the block. The block pushes upward (reaction force) onto the runner.
8. Average speed:

   $$\text{Speed} = \frac{\text{distance}}{\text{time}} = \frac{100\text{m}}{58\text{ sec}} = 1.72\text{ ms}^{-1}$$

   Velocity:

   $$\text{Velocity} = \frac{\text{displacement}}{\text{time}} = \frac{0\text{m}}{58\text{ sec}} = 0$$

   There is no change in position as the start and finish is in the same location (the wall of the swimming pool).
9. Rope that stretches a little will 'give' with the climber when they fall. This means the force exerted on the climber from the rope when it 'catches' them, will be spread out over a greater time period. This reduces the magnitude of the force the climber experiences when the rope arrests the fall. So less likely to damage internal organs, etc.
10. As the gymnast is balanced and not moving, the centre of gravity must be positioned somewhere within the base of support. So first, you must locate the base of support. In this case, it is the area between (and including) the hands. The centre of gravity is then directly above this area.



A

Focus Area 1.4

1. The tennis serve is discrete, with a definite beginning and end. However, kayaking 1000m race doesn't have a definite end, so is considered continuous. A gymnastics routine is the collection of discrete skills where order is important i.e. handstand forward roll to a balance etc, so it is serial.

2. The jump shot is during game play where opponents etc make the skill externally paced so it is an open skill. The tip-off is also an open skill for the same reasons but may not be at the extremely open on the continuum because it is only a contest between two players, so there are less variables and external pressures/timing to consider. The foul shot is internally paced with no direct opposition to interfere with the shot, so it is largely closed.

3. As above. During game play basketball is a very open environment where opponents etc make the skill executions required to be externally paced i.e. pressure from defenders etc. Therefore, the game is an open environment. A foul shot, however, is a 'free' shot awarded with no direct opposition to challenge the shot, so it is internally paced in a more closed environment - not totally closed due to the crowd noise, spectator movements, flags etc.

4. See table:

Skill	Fine	Gross	Open	Externally Paced	Closed	Internally Paced	Discrete	Continuous	Serial
Handball in football		✓	✓	✓			✓		
Tennis serve		✓			✓	✓	✓		
Receiving a volleyball serve		✓	✓	✓			✓		

5. From one end of the tennis court to the other it is approximately 24 metres. Factor in the fact that the ball must bounce in the service box first, makes it approximately 26 metres that the ball travels. At 200 km/h or 55 m/s that equates to just under 0.5 seconds to react to the ball and play a shot. Now if your processing time is 0.2 seconds, this only leaves 0.25-0.3 seconds to play the shot. Good anticipation can speed up the processing component of the shot, leaving more time to get into position to play the shot. More time to set yourself for the correct shot, means the shot is more likely to be successful.

6. Early detection of the cue means the processing time needed is reduced, allowing more time to get into position to execute the skill or movement. This means the technique is less likely to be rushed or compromised in anyway. In tennis, the opponent may angle their body and wrist and racket slightly to play a backspin backhand. The player picks up these small movements (cues or stimuli) and recognises the likely shot will be a backspin drop shot and 'anticipates' the shot by moving forward into the court earlier to play the shot.

7. (a) Constraints could be placed upon the Task e.g. Rule change to allow the defensive volleyball team 1x catch of the volleyball per rally. This would allow a player who has caught the ball an opportunity to 'self-set' the ball to another player (setter or attacker) with greater consistency and an attacking shot would be 'afforded' to the attacking player, as it would be in 'the right spot'. Constraints could be placed upon the Environment e.g. lower net height to allow a more attacking shot to hit over and an attacking shot would be 'afforded' to the attacking player.

   (b) Constraints could be placed upon the Task e.g. Rule change to allow the players only '3 touches' per player possession. In this way, each player only has 1 × touch to control the ball and 1 × touch to pass the ball and 1 × spare touch (if it is a difficult ball to control for example). This would place the 'constraint' of being unable to dribble. Passing opportunities will be 'afforded' as teammates will need to move quickly to get into early position to receive a pass. Players will look to pass the ball more often knowing the dribble is no longer an option.

   (c) Constraints could be placed upon the Task e.g. Rule change to reward the front segment of the court with a double point bonus - to encourage the player to send their opponent deep (using their game strength) but then try to drop shot for double point bonus. This will also encourage them to 'cover' their own front court to prevent such a point loss from occurring.

8. The direct linear approach is considered effective to develop movement skills in the early stages of learning. This can be attributed to its emphasis on initially teaching simple skills in a progressive way in a relatively 'predictable' and closed environment. Practices that are coach/teacher organised can also keep the players 'on task' and ensure the maximum use of practice time. In this way, prescribed learning goals are achieved through structure practice in a short time span. The main benefits of the nonlinear / game-based teaching approaches include the development of 'thinking players' because the performers are provided with opportunities to think and reflect for themselves in 'open' competitive games that are unpredictable environments because greater variability in practice. Also, problem solving and 'self-discovery' promotes independent learners with a 'growth mindset'.

Focus Area 1.5

1. (a) Intrinsic, continuous and negative

   (b) Extrinsic, knowledge of results

   (c) Terminal, extrinsic, knowledge of results

2. Proprioceptors give the diver continual feedback of where parts of their body are in space while they are spinning or flipping through the air. This information can then be used by the diver to determine when to open up for the water 'entry'.

3. Although kinaesthetic feedback is important to divers, it is not as effective in beginners, as they are not yet at a stage where they fully understand what the correct technique feels like. Therefore, visual or auditory feedback is very important at this early stage. A coach to explain information to the diver based on knowledge of performance such as "bring your knees to chest quicker" to assist with athlete's rotation speed.

4. Knowledge of performance is feedback on the athlete's quality and pattern of the movement (technique) whilst completing the skill. This information can then reinforce technique or provide opportunities to modify motor plans if required. Verbalising knowledge of results is usually feedback that the performer has already received from the environment anyway, so it is simply duplicated feedback and potentially detrimental to a player's motivation. Feedback should focus on the fundamental movement patterns (knowledge of performance) before giving outcome feedback (knowledge of results).

5. The "Feedback Sandwich" allows for a positive comment first, then a constructive criticism followed by a final positive comment — as a way to make the delivery of negative feedback more palatable to maintain motivation and optimal arousal levels.

6. (a) Cognitive learner - small 'chunks' of feedback to not overload the STM (only hold a limited amount of information).

   (b) Associative learner - opportunities to 'play the game' to receive internal feedback (knowledge of performance) as they are able to self-correct and begin to understand the movement patterns involved.

   (c) Autonomous learner - advanced video analysis and biomechanical based feedback for high level analysis and performance measured in knowledge of results.

7. In the Game sense teaching approach, there is a strong focus on open ended questioning to stimulate players to think about the game instead of a coach directly telling the player what they should do. It is hoped that learners will be more motivated in discovery-based instruction because they take ownership of the learning process.

   (a) Time: When should you keep possession of the ball?

   (b) Space: Where is the best 'space' to move to once you have passed the ball?

   (c) Risk: Which option creates more space to pass the ball?

   (d) Execution: How should you kick the ball to keep possession?

A

Focus Area 2.1

1. Technically yes. As there are ‘two or more’ individuals that are connected by their love for a football team.
3. As follows:

Characteristic	Fixed	Growth
‘Loves challenges’		✓
Mistakes are valuable learning tools		✓
A successful image is important	✓	
The success of others is problematic	✓	
Very persistent with tasks		✓
Criticism not appreciated	✓	

Focus Area 2.2

1. A cyclist might drop off the pace in the last kilometre if the pace increases. One explanation could be that the cyclist perceives the effort required to be too hard (perception of effort) and that the level of effort required to keep up is beyond what they are prepared to exert (Potential motivation).
2. Listening to music creates a distraction. The stimuli of the music compete for the limited capacity in the brain. Through distracting the athlete from thinking about the exercise, it increases the potential to lower the perceived effort.
3. Ice vests help the athlete regulate their body temperature while exercising (cools them down). Studies suggest cooling the body during exercise reduces an athlete’s perceived effort.

Focus Area 2.3

1. Adults regular physical activity can drop off due to reasons including:

   Increased family commitments (marriage, children), work commitments (working now on Saturday), Financial commitments (mortgage or car loan means more work to earn money), interest level drops.
2. Females tend to be less physically active as adults (20-40 years) for many of the same reasons in the previous question. Yet, family commitments, raising young children (maternity leave etc) is still largely done by females in the early years of their child’s life. This can impact greatly on a female’s independence (free time) to be physically active.

   Lack of female friendly facilities can also impact on female’s desire to participate. This is currently an issue in female sports like AFLW, where changeroom facilities aren’t available or are inadequate in many clubs.

   Other reasons you might discuss are cultural acceptability, body awareness, self-efficacy, lack of funding or incentive (prize money) to continue playing.
3. Self-efficacy can be influenced by external factors like: coaches comments and actions, comments by spectators, actions of team mates (never being passed the ball can suggest others don’t rate your ability), opponent’s comments or actions (fielders crowding the batter in cricket is often due to them not rating a batter’s skills). A lot of these factors then feed into internal factors, where the individual begins to doubt their own ability etc.
4. Self-efficacy can be improved, as it is a self-belief in your own abilities. Improving this belief through training (skill improvement) or psychological intervention will then lead to greater self-efficacy.
5. Modifications to sports to allow for greater participation. Here are a few suggestions:

   Cricket – junior cricket allows batters a set number of overs to face (regardless of whether they get out or not). Some competitions also make it compulsory for everyone to bowl an over.

   Basketball – lowering the height of the backboard and ring allows for more success in junior basketball. Not all facilities though have this ability to adjust their backboard heights.

   Softball – using a tee when batting, improves the success rate of batters connecting with the ball.

Focus Area 3.1

1. Refer to text for detailed definitions:
   - Carbohydrates - Found in food sources such as bread, pasta and sugar. They are the primary energy source within the body (16kJ energy per gram). Classified as either high GI or low GI according to their effect on blood sugar.
   - Fats - Found in food sources such as dairy, oils and cakes. They are the secondary source of energy in the body - acting as an 'energy reserve' (37kJ energy per gram).
   - Protein - Found in food sources such as meat, eggs and beans. They are the 'building blocks' of the human body and used primarily for growth and repair. Rarely used as a nutrient fuel.
2. (a) Glucose; (b) Muscles; (c) Adipose tissue; (d) Fatty acids; (e) Muscles; (f) Body fat; (g) Amino acids.
3. Protein is generally not used as a macronutrient fuel because it is the 'building blocks' of the human body (i.e. muscles). If protein were used as a nutrient fuel, then the body would be breaking down muscle tissue to fuel energy requirements. This would only occur in extreme circumstances (e.g. starvation - when all carbohydrates and fats have been depleted).
4. Running in a 5km cross country race at 85% maximum HR is likely to be an exercise intensity at an athlete's lactate threshold or OBLA (onset blood lactate accumulation). This means the dominant energy systems that will interplay are the lactic acid energy system and the aerobic energy system. Carbohydrates will be the dominant fuel for both these energy systems. Fats are unlikely to be dominant because the 85% intensity to too high to supply enough O_2 to break down the larger fat molecules.
5. Refer to text for detailed definitions:
   - Adenosine triphosphate is the immediate source of energy for all biological work (ATP → ADP + P + energy).
   - Aerobic lipolysis is a process where fats are broken down to resynthesise ATP in the presence of oxygen.
   - Aerobic glycolysis is a process where carbohydrates are broken down to resynthesise ATP in the presence of oxygen.
   - Anaerobic glycolysis is a process where carbohydrates are broken down to resynthesise ATP without oxygen.
6. Explain the relationship between carbohydrate and fat fuel in and the following conditions:

   (a) As exercise intensity increases there is a progressive increase from fat to carbohydrate as the dominant fuel. This is due to the substantially more O_2 required to break down fat rather than carbohydrate.

   (b) As exercise duration increases there is a progressive increase from carbohydrate to fat as the dominant fuel. This is due to the limited stores of carbohydrates in the body (lasting up to 90 minutes before "Hitting the Wall".
7. Advantage: Fat provides a large energy reserve (approximately 7960g × 37 kJ = 295000 kJ ENERGY) compared to the limited carbohydrate stores (approximately 375g × 16 kJ = 6300 KJ ENERGY).

   Disadvantage: Fats are a larger molecule and require more oxygen to break down, so exercise intensity must be low.
8. Refer to table 3.1.3 for details:

   (a) Assuming total body stores of CHO 375g (6375 kJ), then 6375 kJ / 80 kJ per min = 79 min. (approximately) = 1 hour 19 minutes.
9. (a) "Hitting the Wall"

   (b) Very tired, lethargic, disoriented, exercise intensity would be drastically reduced.

   (c) Fats require greater oxygen to break down; therefore, the same pace could not be sustained.

   (d) Strategies may include:
   - Carbohydrate loading' and an exercise 'taper' in the lead up to the event ensure muscle glycogen stores are maximised.
   - During the event, regularly consume foods/fluids that are high GI for quick absorption of 'sugars' to delay muscle glycogen depletion (Hitting the Wall).
   - Exercise at a low aerobic intensity where the body has O_2 available for the breakdown of fats (referred to as 'glycogen sparing') - but this will probably not maximise performance times or exercise intensity.

A

10. (a) See table:

	g/kg of body weight	Total grams	kilojoules/g	total kilojoules
Carbohydrate	7.0	490g	16	7840
Protein	1.2	84g	17	1228
Fats	1.6	112g	37	4144
Total energy consumption				13212

(b) Carbohydrates - eat foods that are low on the GI; Protein - eat foods that are 'lean' such as lean meat or fish; Fats - eat foods that are 'unsaturated fats' instead of 'saturated animal' fats.

(c) Prior to the event the athlete's diet needs to focus on filling up of muscle glycogen stores. Given there is only 2.5 hours till the next training session and assuming you have eaten well throughout the day it will be a matter of just topping up fuel stores. This should be done with a low bulk/fibre and low-fat source of carbohydrate that is low on the glycaemic index. This will top up glycogen stores and be easily digested prior to training. A liquid meal supplement such as Sustagen may also be appropriate. Also include fluids to ensure you are adequately hydrated. No last-minute food will make up for a poor diet in previous weeks.

(d) (i) The glycaemic index is a system used to describe the rate at which blood sugar increases. White bread is given an arbitrary value of 100. From this, scientists established three categories of glycaemic index: high GI >85, moderate GI 60–85, low GI <60.

(ii) Prior to the event you should focus on foods that are low on the glycaemic index. After the event, carbohydrates that are high on the glycaemic index are best.

(e) 50g of carbohydrate that is high to moderate on the glycaemic index should be consumed every two hours; for example, Jellybeans or similar lollies or other carbohydrates that are high on the GI. Fruit juice, fruit smoothies and other carbohydrate-rich drinks such as 'Sustagen' can provide the required carbohydrate easily and they are also a source of liquid for hydration.

(f) (i) Water is essential for normal functioning of the body; it cools the body as well as being a major component of blood plasma.

(ii) Loss of water reduces blood volume which reduces blood flow to muscles and skin. To maintain blood flow there must be an increase in heart rate, and less blood flow to the skin reduces cooling. Dehydration also changes the balance of electrolytes, thus changing blood chemistry.

(g) (i) Sports drinks provide an easily digestible and balanced source of water, carbohydrates and electrolytes.

(ii) The sports drink is unlikely to be of any real benefit. Plain water is all that would be required to replace the small amount of water lost. It might be useful, depending upon what the athlete has eaten during the day between events. If they have had nothing to eat, it would be helpful, because sports drinks contain 'sugars' or carbohydrates. However, it is unlikely that a sprinter would deplete their muscle glycogen stores - as the primary energy system utilised in a sprint is ATP-PC (where the dominant fuel is CP) and also, the duration of a sprint (10-13 seconds) is very short and there is enough muscle glycogen stores for 90 minutes of exercise - so they are unlikely to become depleted.

Focus Area 3.2

2. Yes, since early 2019, children participating in one of over 100 different sports or recreational activities are now eligible for a $100 sports voucher from the SA government to go towards registration costs.

Focus Area 3.3

1. **Heart Rate**: Number of times the heart beats per minute (bpm.)

   Stroke Volume: Stroke volume is the volume of blood pumped from the left ventricle of the heart per beat.

   Cardiac Output: The volume of blood pumped around the body per minute (HR × SV).

   a-v O_2 difference: The difference between the oxygen concentration of blood in the artery and the oxygen concentration of blood in the vein.

   Blood Pressure: Pressure exerted on the blood vessels when the heart contracts (systolic) or when the heart relaxes (diastolic).

   Tidal Volume: The volume of air breathed in and out per breath.

   Ventilation: The volume of air in an out of the lungs per minute (TV × frequency).

2.

	Response	Why?
Heart rate	Increase	Pump more blood to supply greater O_2 to muscles
Stroke volume	Increase	Pump more blood to supply greater O_2 to muscles
Cardiac output	Increase	Pump more blood to supply greater O_2 to muscles
A-v O_2 diff.	Increase	Muscles extract greater volume of oxygen from the capillaries surrounding the muscles
Redistribution of blood flow	Increase	Blood directed to active areas through vasodilation of capillaries to increase O_2 delivery to muscles. Vasoconstriction of capillaries to inactive organs.
BP (Systolic)	Increase	Greater volume of blood pumped with more force through arteries during exercise.
BP (Diastolic)	Unchanged	Dilation of active blood vessels compensates for increased blood volume.
VO_2	Increase	Greater supply of O_2 delivered to active muscles.
Lactic acid levels	Increase	From resting levels of approx. 1-2mmol/L to around 3-4mmol/L (below LT) or 5mmol/L plus (above LT).
Blood volume	Decreased	Fluid loss through sweating
Ventilation	Increase	Increase supply of O_2 reaching alveoli in lung
Tidal volume	Increase	Increase supply of O_2 reaching alveoli in lung

3. **Motor Unit**: A motor neuron (a nerve that activates muscle fibres) and all of the muscle fibres it attaches to.

   Selective recruitment: In a very weak contraction, the smaller (and weaker) ST motor units will be ‘selectively recruited’ first; larger (and stronger) FT motor units will be ‘selectively recruited’ only during maximal contractions.

   Enzymes: A catalyst to regulate and accelerate chemical reactions.

4.

Increased	Greater force required during muscular contraction, so more motor units recruited. Perhaps the recruitment of FT units in maximal contractions.
Increased	Increased muscle contractions result in a rise in muscular temperature with increased blood flow; also aerobic respiration generates heat.
Decreased	All fuel stores (CP, carbohydrate and fat) may be depleted to release energy to resynthesise ATP.
Increased	To speed up chemical reactions associated with energy release.

5. (a) To increase the supply of blood (and oxygen) to the muscles.

   (b) Increase in heart rate; increase in stroke volume; increase in tidal volume.

6.

	Increase	Decrease	Unchanged
Fast twitch hypertrophy	✓		
Slow twitch hypertrophy			✓
Ability to recruit motor units	✓		
Connective tissue strength	✓		
ATP and CP stores • Concentration (%) within muscle • Total stores in muscle	✓		✓
Glycolytic enzymes	✓		
Glycogen stores	✓		
Lactate threshold / OBLA	✓		
Lactic acid tolerance	✓		

7. **Haemoglobin**: The oxygen-carrying component of red blood cells.

   Myoglobin: Transports oxygen from the blood to the mitochondria in the cells.

   Pulmonary diffusion: The process of oxygen diffusing from the alveoli in the lungs across the pulmonary capillaries into the blood for transport to the active muscles.

   Vital capacity: The maximum volume of air that can be breathed out after a maximal inspiration.

   Residual volume: The volume of air remaining in the lungs after maximal expiration.

8. (a) C, (b) D, (c) C, (d) C, (e) A, (f) B

9. (a) Cardiac output increases with exercise intensity.

   (b) (i) Cardiac output remains largely the same; oxygen requirements for the same sub-maximal workload remain unchanged (may decrease slightly due to increased efficiency of movement).

   (ii) SV increased due to hypertrophy of left ventricle pumping greater volume of blood per beat.

   (iii) HR would be lower. Oxygen requirements remain constant, but with higher SV, the heart pumps the required volume of blood with less bpm.

   (iv) Muscle glycogen use would decrease due to increased efficiency of oxygen system to utilise fats at a lower intensity.

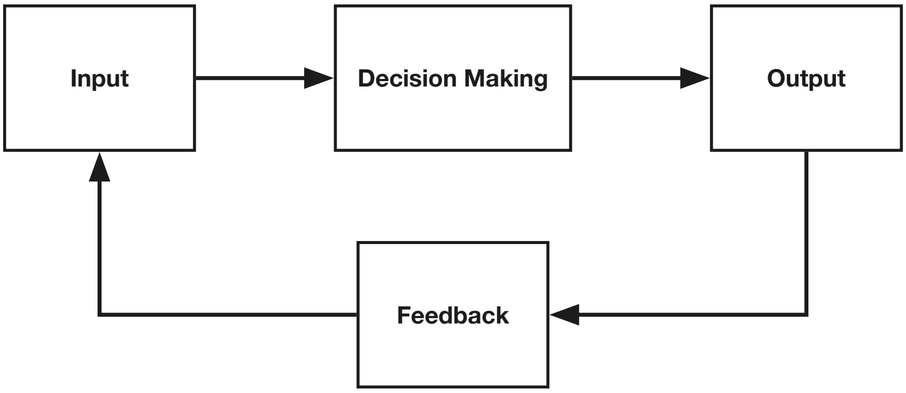
Focus Area 3.5

1. (a) An ‘affordance’ for the acting half may be the ‘gap’ between defenders which opens a ‘space’ through the middle to run into with supporting teammates players able to quickly run in to support them.

   (b) A rate limiter is a ‘constraint’ that acts as a barrier to performance/learning. The acting half may have a lower level of fitness and/or speed and deem that they are likely to be ‘touched’ and a turnover affected so instead they pass and ruck the ball up the field.

Focus Area 3.6

1. See Figure: 3.6.1



2. The STM can only hold information for approximately 60 seconds and approximately 7 ± 2 bits of information. Therefore, a coach can provide small 'bits' of information using techniques like 'chunking' or demonstrations instead of lengthy discussions. In addition, once information is provided to the STM, the coach can allow a player to immediately practice the skill (inside 60 seconds) and 'act' on the feedback to begin the coding process into the LTM.
3. Selective attention from the short-term sensory store (STSS).
4. Short-term sensory store (STSS) - Selective Attention - short-term memory (STM) - rehearsal/encoding - long-term memory (LTM).
5. Feedback to learners should be limited to only a few pieces of information, which is clear, concise and based at a level the learner will understand. This is due to the limited capacity of the short-term memory to process loads of information at one time.
6. The distraction you describe needs to be strong; i.e. the strength of the cue needs to be such that it is noticed. A distraction can affect your ability to execute a skill correctly as it may interfere with your processing of information. For example, in baseball you have less than half a second to react to the pitched ball, so you cannot afford to be processing information that is not relevant to the speed or flight of the ball. Processing extra information can mean you are too slow in deciding on a response, or you react to the wrong information.
7. See workbook Figure 3.6.7: A model of memory process.
8. Break the larger piece of information up into smaller more meaningful pieces. For example: UR (your) CAT (cat) EIGHT (ate) IT (it) [your cat ate it]
9. 'Pronate' is a technical term commonly associated with Year 12 PE, not 10-year-olds. The risk associated with using words like this are that the learner will not understand the full meaning of the feedback and will continue to make errors (decreasing motivation to participate etc.)
10. If an early cue can be detected, then an athlete can reduce the processing time needed and therefore reduce their reaction time. More time to process the stimuli, make correct decisions and also more time to execute the required movement pattern (skill). If a tennis player for example, correctly anticipates a return to their backhand, then they will be into position earlier. The player would have a greater chance to execute the correct technique (movement), resulting in better timing, placement, etc.
11. Some examples could include: Cricket has sight screens behind the bowler and white balls during night games. AFL uses a yellow ball during night games. Tennis courts and surroundings are often green or blue to contrast the yellow ball.
12. This allows the receiver to see the ball make contact with the bat (Paddle) and therefore better able to detect what sort of shot has been played, rather than having to wait until it hits the table.
13. For a complex task the line or curve moves to the left, where higher achievement occurs through lower arousal.
14. Show your teacher - make sure your arousal curve is not favouring the right if a complex skill, and, conversely, not to the left if a simple skill.
15. Any example where the skill is performed in a closed environment is likely to be 'reasonably predictable' - the 'action' itself at least, if not the 'outcome'.

16. Team sports not only have opponents, but they also have teammates. This means that the ball carrier in a team sport has to process the position of opponents coming to get the ball and also the position of teammates to pass the ball onto. Team sports are played in an open and externally paced environment. The Shot putter is performing in a closed and internally paced environment and many less cues to process.

17. See Table 3.6.1 for answer - you must describe a specific sporting example.

18. No, good level players (associative and autonomous) are able to read relevant cues and stimuli (bowler's delivery, batsman's stance, wicketkeeper's movement etc) to predict a likely outcome. This is likely because they have some experience in the sport already and are able to anticipate the batter's shot based on these stimuli (and only need partial cues to act on them appropriately).

19. A golfer is preparing to hit their golf ball off the tee with the driver. Whist they a swinging their club, they are distracted by thoughts of hitting the ball into a water hazard 100m up the green, and they tense their muscles during the swing and hit the ball poorly.

20. In general, the attentional focus model from Nideffer advocates that closed skills (such as a golf drive) require a narrow focus because it is a complex skill. The golfer's error in performance was a result of lapses in both concentration and attention, not focussing on the most important information relevant to performance at that moment in the game - they should shift their focus to Narrow External (watch the club 'contact' the ball) and even Narrow Internal (mental rehearsal to minimise anxiety) just before their shot.

Focus Area 3.7

1. The associative stage of learning is the middle stage, in which the number of errors is reducing, and they aren't as large as they were when first learning the skill. However, they still make some errors, so the right-hand side diagram C, best represents a learner at this stage. [The cognitive learner (beginner) is best represented by the left-hand side diagram A.

2. (a) Softball batting - Simple, gross, open, discrete and externally paced.

   (b) Given the skill is open and externally paced, the unpredictable nature of the skill (speed and height of the ball) would make it difficult for a beginner to learn.

   (c) The information gained from the analysis of a task may influence the way a coach approaches teaching a new skill. For example, hitting the softball is an open skill with a very unpredictable feed or delivery of the ball. Therefore, the coach should look to close the skill down first and remove the unpredictable elements identified in the skill. For softball this would mean introducing a tee to initially hit the ball off.

3. The exact progression may vary depending on the teacher or coach involved, but generally the progressions need to show an increasing level of demand towards that of a game situation. For example, the next progressions may be:

   e. Unpredictable feed over a larger distance

   f. Game-like scenario

   g. Competitive games etc.

4. 30 foul shots in basketball, 30 tennis serves to the forehand, hitting 40 golf balls off a tee

5. The repetitive nature of massed practice may lead to beginners getting bored quickly, especially if they are making frequent errors, or they don't enjoy the sport. Massed practice can also lead to fatigue in the local muscle groups used. Fatigue can reduce the efficiency of the technique, meaning the wrong technique may begin to be practiced over and over again.

6. Your examples should be shorter in duration than massed practice, with breaks in between.

7. (a) Distributed practice allows time for the learner to recover from physical exertion, meaning fatigue is less likely to affect the technique.

   (b) (i) Allows time for the learner to recover from physical exertion, meaning fatigue is less likely to affect the technique.

   (ii) When learner's motivation levels are low, breaking the practice up (either resting between bouts or practicing something else) allows them to shift their attention temporarily to something else.

   (iii) A complex skill involves many components that may be difficult to master in one go. During distributed practice the learner can think about and process the components of the skill during the break. This may lead to a greater understanding of the skill and the part each component plays in the skill when they go to practice it again.

(c) In the opening shot of each frame, the pins are in the same location each time. Therefore, the bowler can utilise the same shot each time. This lends itself to massed practice, where the same technique is repeated. Massed practice allows the professional to concentrate on and fine tune a specific aspect of a skill.

8. (a) To close the skill down remember to reduce the time demands on the players, pressure from opponents, the speed of objects etc.

   (b) Generally, by closing the skill down you should have allowed the beginner to concentrate more on their technique. Allowing them to create a good working technique means they can more readily adapt their technique as you slowly open the skill back up again.

9. Basketball – 3-point line; Squash – “Hit above the tin’; Swimming – Lane rope; Softball – Home plate; Netball – Wing attack; Cricket – Crease; Hockey – 16 yard line.

10. A greater level of maturity allows learners to take more responsibility for their learning; ie. they require less supervision from a management point of view, and so they can practice skills individually or in small groups (keeping in mind they still need feedback). Combined with an increased cognitive development, more mature learners can become more involved in training and problem-solving tasks.

11. An individual with previous experience may have a greater technical or tactical awareness compared to other learners; hence they can be used as demonstrators. The advantage of this is that the learners may relate better to their peers than an adult.

12. (a) Nonlinear teaching pedagogy refers to Skill learning is unpredictable and involves progressions and regressions based on constraints from the learner, tasks and environment.

    (b) Constraints are factors that shape the development of movement skills. In a constraints-based teaching model, the coach deliberately manipulates the interaction of individual, environmental & task constraints to create specific problems in a game to be solved by the players adapting their skills and tactical thinking. Individual Constraints (Body size & shape, Motivation, Attention); Environmental constraints (Size and shape of playing surface, Weather conditions, Society expectations/cultural norms); Task Constraints (Rules, Equipment, Number of players) etc.

    Note: Constraints ‘shape’ the performance of movement skills, they do not necessarily ‘limit’ the movement skills - constraints that do this are specifically referred to as ‘rate limiters’.

13. See workbook for further details: Table 3.7.4 and Tables 3.71, 3.7.2 and 3.7.3.

Stage	Linear / Cognitive Theory	Nonlinear / Dynamical Systems Theory
1	Cognitive Stage • Beginners / lots of errors / short stage	Coordination Stage • Focus on task / high outcome variability / limited degree of freedom
2	Associative Stage • Practice stage / trial and error see improvements/ can self correct	Control Stage • Explore different solutions / developing degrees of freedom / formation of perception/action coupling
3	Autonomous Stage • Automatic movement / almost perfect / focus on tactical play & strategy	Skill stage • Optimal movement patterns / high degree of freedom / creative and energy efficient

A

Review Question Topic 1.2

Multiple Choice

1(C), 2(D), 3(A), 4(B), 5(A), 6(A), 7(B), 8(A), 9(B), 10(D), 11(C), 12(A), 13(A), 14(A), 15(C), 16(C), 17(C), 18(C), 19(B)

Short Answer

1. (a) Game averaged 350+ changes of direction of 90 degrees.

   (b) Power to smash shuttlecock at 280kph or 150 of rallies played involved full arm swings at maximum force. Cardiorespiratory fitness for players to cover up to 6.5km per game/average total game time of 1 hour and 16 minutes. Muscular endurance – as cardiorespiratory endurance/146 rallies with 13.5 shots per rally/56% game time was active. Other fitness components if correctly justified by data in table.

   (c) See Table 1.2.2 and Table 1.2.3 for definitions.

   (d) See text (pages 40 and 41) for appropriate tests and protocols.

   (e) ATP-CP – Smashed shuttlecock of up to 280kph or numerous arm swings at maximum force.

   Lactic acid – the repetitive nature of the rallies (completed 5-10 shots in 20 seconds/ average distance covered per rally was 6.7m/games averaged 146 rallies with 13.5 shots per rally) does not allow for full CP recovery, so lactic acid system dominant.

   Oxygen – average 1 hour and 16 minutes per game with players covering up to 6.5km. Also dominant in recovery of anaerobic systems.

2. (a) (i) Program X – mainly aerobic but has some anaerobic work so athlete can approach and at times exceed lactate threshold as in a race to outrun opponent or maintain speed running up a small incline.

   (ii) Program Z – high intensity anaerobic power dominant (specificity of ATP-CP energy system dominance during the 100m sprint). Small aerobic work with warm up, cool down, recovery, etc.

   (iii) Program W – purely aerobic endurance required. Sedentary person not expected to 'race' so no need to approach or exceed lactate threshold. Just complete race at one sub-maximal pace. It should be noted, that although the program W shows zero anaerobic energy expenditure, the interplay of energy systems states that all systems will in fact be used at some point e.g. O_2 deficit at the start of an 'easy' jog etc.

   (b) (i) The benefits of interval training: allows athletes to train at a higher intensity for longer. By manipulating the variables of work and rest, any energy system may be trained, easy for coaches to monitor an athlete's progress.

   (ii) Repetitions, interval (work) time, work intensity, sets, rest (recovery) interval, work-rest ratio.

   (iii) Short interval training. Repetitions – can be quite high 10-30, interval time – low (5-15s); work intensity must be high (95% +); work-rest interval – manipulated to allow CP recovery (minimal reliance on LA system); sets – 2-3 or more. E.g.: 2x sets [10x 60m (7 secs) @ 100% with W:R ratio 1:5].

3. State level sprinters would display excellent speed and power from their high intensity/short duration event – where the ATP-CP system is dominant. They must now prepare for a low intensity/long duration event – where the oxygen system will be dominant.

   - Specificity – training will need to closely match their new event requirements; i.e. training must shift to predominantly long duration, low intensity endurance training. This may include an emphasis on continuous or fartlek forms of training to enhance their cardiorespiratory fitness.
   - Progressive overload – there should be a slow and gradual increase in the total distance or time ran. Once the athletes adapt to this new level, a small increase (generally 10%) can be made again; i.e. 3.5km walk/jog to 3.5km jog to 4km walk/jog, etc.
   - Individuality – each athlete should only increase their training once they have adapted to the previous load. Some athletes progress faster than others, even though their background may be similar. For example, if one athlete is struggling or injured, they should 'slow' down and manipulate training variables slower.