eduqas
Part of WJEC

Exercise physiology, training and performance.

How do I prepare to perform on the international stage?

To answer the big question you will need to be able to complete the following tasks:

1. **Analyse the short term responses to exercise and discuss their impact on performance. (AO3)**

Pages 2 & 16

2. **Assess the long term adaptations that have supported the athletes in finishing this endurance event. (AO3)**

Page 23

3. **Describe the processes involved in the preparation of physical fitness. (AO1)**

Page 31

4. **Analyse the use of specific energy systems in the endurance event and explain how the recovery process can aid preparation for the next event. (AO3, AO2)**

Page 50

5. **Discuss the use of diet and supplementation to improve performance. (AO3)**

Page 50

Exercise physiology, training and performance

1.1.1 Short Term Responses to Exercise on Cardiovascular system

Question
Analyse the short term responses to exercise and discuss their impact on performance. (AO3)

A. Content

- Systemic and pulmonary circulatory systems
- Cardiovascular; cardiac dynamics, cardiac responses, Fran-Starling mechanism and venous return
- Values associated with Stroke volume, heart rate and Cardiac Output at rest and during exercise (intensity dependent)
- The structure of blood vessels, vascular shunt
- Blood pressure; values rest and exercise
- Vasomotor control
- Control and regulation of cardiac control centre; sympathetic and parasympathetic nervous systems

Assess the long term adaptations that have supported the athletes in finishing this endurance event. (AO3)

B. Knowledge and Understanding

Introduction

Primary purposes of the cardiovascular and respiratory systems are to deliver adequate amounts of oxygen and remove waste from working muscles. During exercise, the reason for cardiovascular/respiratory regulation is to maintain adequate blood flow in order to carry oxygen and nutrients to working muscles and remove waste produces, lactic acid and carbon dioxide as well as regulated body temperature.

The Systemic and pulmonary circulatory systems

The heart is a four-chambered dual action pump. The right side of the heart receives deoxygenated blood from the muscles and other tissues and pumps it to the lungs for oxygenation (**pulmonary circulation**). The left side of the heart receives oxygenated blood from the lungs and pumps it to the muscles and other tissues of the body (**systemic circulation**). Each heartbeat results in the simultaneous pumping of both sides of the heart, making the heart a very efficient pump (**cardiac cycle**).

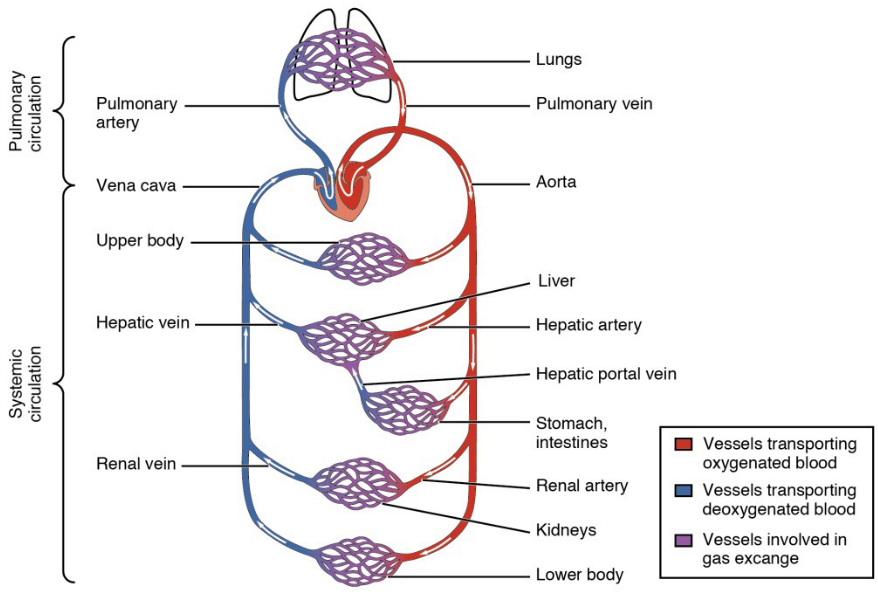
The pulmonary and the systemic systems:

Pulmonary Circulation

- Pulmonary circulation is between the heart and the lungs. It transports deoxygenated blood from the heart (via the pulmonary artery) and onto to the lungs to be re-oxygenated through gaseous exchange. At the lungs CO_2 is removed from the blood and O_2 enters. The blood then returns to the left side of the heart via the pulmonary vein. The chambers of the heart that support the pulmonary circulation loop are the right atrium and right ventricle.

Systemic circulation

- Systemic circulation carries oxygenated blood from the left side of the heart (via the aorta) to the muscles and the other tissues of the body. After the oxygen rich blood has been used in the muscles to produce energy (ATP), CO_2 rich, deoxygenated blood is transported to the right side of the heart. The left atrium and left ventricle of the heart are the pumping chambers for the systemic circulation loop.



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Cardiac cycle is the transport of blood to the lungs and the working muscles. It has two phases the relaxation phase (**diastole**) and the contraction phase (**systole**).The whole cycle takes about 0.8 seconds.

Diastole - this is where the heart relaxes and fills with blood. This is the longest Part of the cycle (0.5 second)

Systole - this is the process where the heart contracts and blood is ejected from the heart. This is the shortest part of the cycle (0.3 seconds)

During exercise the diastole increases in time due to the increase in volume of blood needing to be pumped out of the body (**venous return**) whereas there is little change to the systolic time.

Venous return is the rate at which the blood returns to the heart. When exercising, there is a greater need for more blood and therefore, as exercise intensity increases, venous return increases.

Starling's Law refers to the increased stroke volume as a result of an increased amount of blood filling the heart. This occurs as a result of the cardiac muscles stretching before contracting. Similarly as venous return decreases so too does stroke volume.

Venous return can be regulated by:

- Veins controlling blood flow by valves regulating direction and smooth muscle squeezing the blood back to the heart.
- Musculo-skeletal pump where the muscles contract against the skeletal system forcing the blood through the venous system.
- Pressure gradient – moving from high pressure to low pressure with the arteries and veins.

Cardiac values and exercise intensity

Cardiac dynamics is the physiological, neurological and hormonal changes to exercise intensity, depending upon the intensity and duration of exercise the type of physiological adaptations will differ.

The relationship between heart rate, stroke volume and cardiac output

- **Cardiac output (Q)** is the volume of blood pumped by the heart per minute (mL/blood/min). Cardiac output is a function of heart rate and stroke volume

- **Heart rate (HR)** is the number of heart beats per minute (BPM)
- **Stroke volume (SV)** is the volume of blood, in millilitres (mL), pumped out of the heart per beat. Increasing either heart rate or stroke volume increases cardiac output.

Cardiac output mL/min = **heart rate** (beats/min) X **stroke volume** (mL)

- Q = HR × SV

An average person has a resting heart rate of 70 beats/minute and a resting stroke volume of 70 mL/beat. The cardiac output for this person at rest is:

Cardiac Output = 72 × 70 = 5040 mL/minute.

Q = 5 Litre/minute

During intense exercise, the cardiac output can increase up to 7 fold (35 litres/minute)

Heart rate and stroke volume increase proportionally with exercise intensity.

Aerobic exercise

Individual	Heart rate(beats/min)	Stroke volume (mL)	Cardiac output (mL/minute)
sedentary	130	70	9,000
athlete	110	150	16,500

This is achieved because the athlete has a thicker myocardium (heart muscle) on the left side of the heart. The heart is therefore able to contract with greater force, increasing the ejection fraction (volume ejected each contraction) of blood out of the left ventricle.

Anaerobic exercise

Individual	Heart rate(beats/min)	Stroke volume (mL)	Cardiac output (mL/minute)
sedentary	150	70	10,000
athlete	180	180	35,000

Stroke volume may increase only up to 40-60% of maximal capacity after which it plateaus. Therefore, stroke volume remains unchanged right up until the point of exhaustion. The reason why we are able to continue increasing the intensity of exercise is because of the continued increase in heart rate.

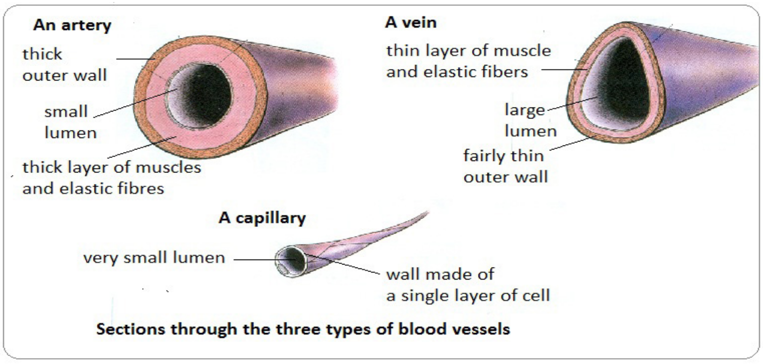
In a sedentary individual it is difficult to increase their heart rate to maximum as they are not used to working at that intensity. If you were able the myocardium is not developed enough to take any more blood into it. Therefore the increase in cardiac output is minimal.

Cardiovascular System

The cardiovascular system consists of the heart, blood vessels and blood. The blood vessels of the body responsible for carrying blood include arteries, arterioles, capillaries, venules and veins. The cardiovascular system is responsible for:

- Transporting oxygen to muscles and other tissues
- Removing carbon dioxide
- Supplying nutrients such as glucose, fats, vitamins and minerals
- Transporting hormones e.g. insulin
- Removing waste products from the body e.g. urea

Structure of Blood Vessels



Arteries carry blood away from the heart via the aorta. Blood carried by arteries is usually highly oxygenated, after leaving the lungs on its way to the body's muscles and other tissues (exception pulmonary artery). Arteries face high levels of blood pressure as they carry blood being pushed from the heart under great force.

Veins carry deoxygenated blood back to the heart and onto the lungs (except pulmonary vein). They usually have low blood pressures. This lack of pressure allows the walls of veins to be much thinner, less elastic, and less muscular than the walls of arteries.

Capillaries are the smallest and thinnest of the blood vessels in the body. They transport the oxygen rich red blood cells through them allowing oxygen to diffuse into the muscles and carbon dioxide out.

To withstand this pressure, the walls of the arteries are thicker, more elastic, and more muscular than those of other vessels such as veins and venules. The largest arteries of the body contain the most elastic tissue that allows them to **vasodilate** and causes **vasoconstriction**; accommodating the high pressure of blood being pumped from the heart.

Vasodilation is the opening up of the blood vessels to accommodate increased blood flow.

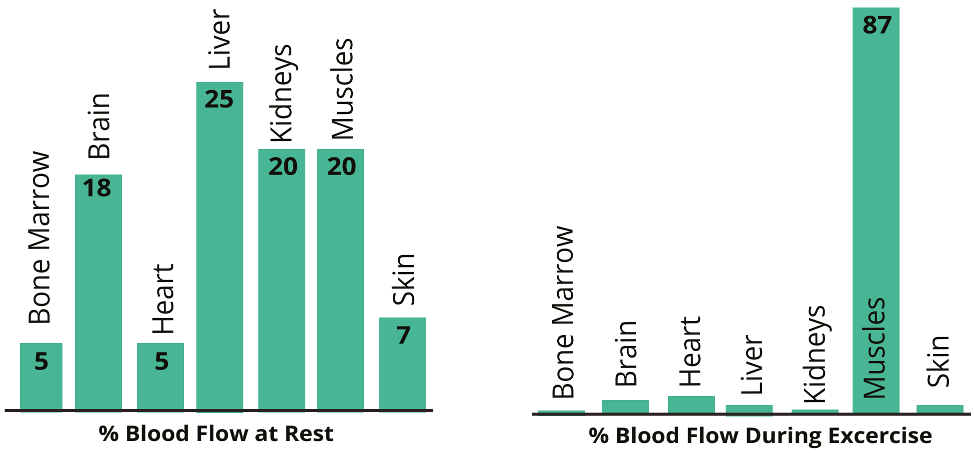
Vasoconstriction is the contraction of the blood vessels, reducing the size of the lumen causing a reduction in blood flow and/or increase in blood pressure.

As exercise intensity increases blood flow is redistricted via vasoconstriction and vasodilation, this is known as the vascular shunt.

Blood pressure responses to exercise

At rest only about 20% of the total volume of blood is distributed to skeletal muscle. However during prolonged exercise up to 87% of the circulating blood can be redistributed to the working muscles. See in diagram below.

Redistribution of blood flow



As mentioned in the cardiac cycle as the systolic blood pressure in the ventricles with increase linearly with the increase in exercise intensity. As more blood is pumped out of the heart the blood pressure in the arteries rises.

In a healthy person the average systolic pressure is 120mmHg and the diastolic pressure is 80mmHg, this is represented as:

120/80mmHg

Aerobic exercise (low/moderate) on blood pressure

Individual	Systolic	Diastolic
Healthy	180	85

Anaerobic exercise (moderate/high) on blood pressure

Individual	Systolic	Diastolic
Healthy	200	110

With most types of exercise there is a minimal change to the diastolic pressure, compared with the systolic pressure.

Anaerobic high intensity strength training

Individual	Systolic	Diastolic
Athlete	240	160

Careful consideration must be given when planning a training programme as cardiovascular aerobic training has the lowest increases on the systolic pressure and therefore is the safest for those with Cardiac risk factors.

Control and regulation of heart rate

Control of heart rate is carried out in the Cardiac Control Centre (CCC) found in the Medulla Oblongata of the brain; this is part of the **Autonomic Nervous System** (ANS). The (ANS) has two sub-divisions:

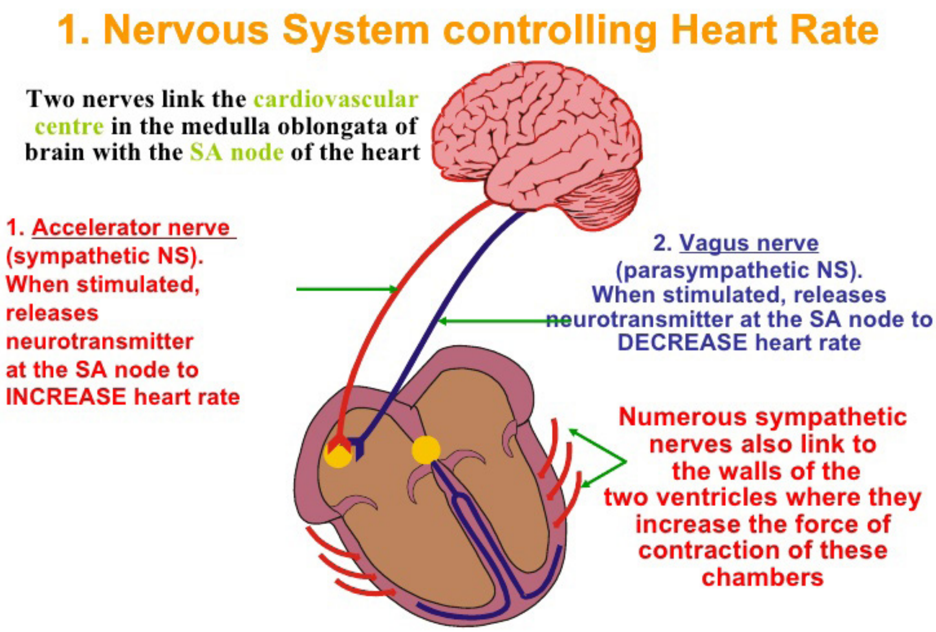
Sympathetic Nervous System (SNS), which speeds up heart rate via the cardiac accelerator nerve.

Parasympathetic Nervous System (PNS), which slows heart rate through the vagus nerve. Both the accelerator nerves and the vagus nerve send messages to the Sino-atrial node (SA), which is responsible for controlling heart rate.

The heart has an electrical conduction system made up of two nodes they are the sino-atrial node (SA) and the atrioventricular node (AV). Unlike voluntary skeletal muscle, the heart produces its own impulses (myogenic) and hence these impulses spread throughout the heart causing the heart muscle (Myocardium) to contract.

During Exercise

When our bodies are at rest the parasympathetic nervous system is in control of heart rate. The (PNS) keeps heart rate down via the vagus nerve, which releases a hormone called Acetylcholine. Exercising for any duration will increase heart rate and will remain elevated for as long as the exercise is continued. At the beginning of exercise, your body removes the parasympathetic stimulation, which enables the heart rate to gradually increase. Subsequently as exercise increases in intensity then the sympathetic nervous system becomes more dominant and takes control of heart rate. The cardiac control centre (CCC) has three ways of regulating or controlling heart rate. This refers to the mechanism that causes the heart rate to increase and decrease.



There are 3 control mechanisms of heart rate (HR):

1. Neural
2. Hormonal
3. Intrinsic

Neural and hormonal control are considered external control mechanisms of (HR), while intrinsic control is the hearts own internal mechanism controlling both rhythm and depth of (HR).

1. Neural control

This involves receptors picking up changes in the body as a result of an increase physical activity. These then send messages to the (CCC) in the medulla oblongata. The (ANS) in the brain in turn sends a message to the SA node to either speed up or slow down the heart rate. The receptors that pick up the changes are:

Proprioceptors (golgi tendon organs) – These pick up movement in joints and muscles. An increase in intensity of exercise generally means increased amounts of movement.

Chemoreceptors (found in muscle tissue, aorta, carotid artery) – These pick up chemical changes such as a lowering of blood pH (blood becomes more acidic), this occurs because as exercise intensity increases there is an increase in carbon dioxide and lactic acid.

Baroreceptors (found in aorta and carotid artery) – Pick up changes in blood pressure as the result of increased exercise intensity.

Thermoreceptors (found in the skin, skeletal muscle and liver) – These pick up changes in body temperature. As exercise intensity increases then there is an increase in body temperature, which is detected by the thermoreceptors.

2. **Hormonal control**

Before and during exercise **adrenaline** and **noradrenaline** is released into the blood stream from the adrenal medulla in the kidneys. These hormones act directly on the **SA node** stimulating an increase in (HR) and (SV). This explains the **anticipatory rise** in HR prior to exercise often associated with being nervous and excited. Furthermore, both adrenaline and noradrenaline aid the redistribution of blood to the muscles through vasodilation and vasoconstriction of arterioles.

When exercise intensity begins to drop and the individuals recover, the hormone acetylcholine then takes over and begins to lower (HR)

3. **Intrinsic control**

This is the heart internally controlling itself. There are two factors to consider:

Temperature – as the temperature of the cardiac muscle increases it speeds up nerve impulses causing an increase in HR.

Starling's Law of the Heart - as venous return increases so does SV.

C. Overview Short term effects of exercise on the cardiovascular system

- There are two circulatory systems; pulmonary and systemic, their functions are transportation and removal of nutrients, oxygen, carbon dioxide and waste products.
- The cardiac cycle consists of two phases diastole (relaxation phase) and systole (contraction phase).
- One cardiac cycle (heart beat) takes on average 0.8seconds.
- Venous return is the volume of blood returning back to the heart. It is supported by valves and smooth muscle in the veins, musculo-skeletal pump and pressure gradients.
- Starling's Law refers to the increased stroke volume, due to increased filling of the heart.
- Cardiac values at rest and at different intensities, the relationship between Cardiac Output, Heart rate and Stroke Volume (Q=HRxSV).
- At rest Q=5 l/min compared with up to 35 l/min when exercising.
- The bodies transport system consists of arteries, veins, and capillaries that vasodilate or constricts to maintain increase or decrease blood pressure.
- Blood pressure at rest 120/80mmHg. It tends to be the systolic pressure that increases significantly compared with the diastolic. Aerobic exercise increases blood pressure to 180/85mmHg whereas strength training can increase both up to 240/160mmHg.
- It is important to note that aerobic exercise causes that lowest increases to blood pressure and are therefore the safest for those with cardiac problems.
- Control of heart rate is carried out in the Cardiac Control Centre (CCC) found in the Medulla Oblongata of the brain; this is part of the Autonomic Nervous System (ANS). The (ANS) has two sub-divisions, the Sympathetic Nervous System (SNS) and the Parasympathetic Nervous System (PNS).
- When our bodies are at **rest** the parasympathetic nervous system is in control of

heart rate compared with the sympathetic nervous system when exercising.

- The cardiac control centre (CCC) has three ways of regulating or controlling heart rate; neural (various receptors), hormonal (adrenaline/noradrenaline), intrinsic (Starling's Law).
- Redistribution of blood to muscles during exercise (blood shunting) is caused by vasomotor control.

Exercise physiology, training and performance

1.1.1 Short Term Responses to Exercise on Cardiorespiratory system

Question

Analyse the short term responses to exercise and discuss their impact on performance. (AO3)

A. Content

- Respiratory response to different exercise intensities.
- Respiratory values form rest to exercise (intensity dependent)
- Tidal volume, breathing frequency and minute ventilation.
- How carbon dioxide and oxygen are carried within the vascular system.
- Role of haemoglobin and myoglobin in the transportation of oxygen to muscles.
- Neuro-muscular; the role of chemoreceptors, proprioceptors, thermoreceptors and baroreceptors; changes in blood pH, stretch, temperature and pressure.
- How these systems work at different intensities; steady state and VO_2 max.

B. Knowledge and Understanding

Introduction

Primary purposes of the cardiovascular and respiratory systems are to deliver adequate amounts of oxygen and remove waste from working muscles.

The pulmonary circulatory system is between the heart and the lungs. It transports deoxygenated blood from the heart to the lungs to be re-oxygenated through gaseous exchange. At the lungs CO_2 is removed from the blood and O_2 enters. The blood then returns to the left side of the heart via the pulmonary vein.

As with the cardiovascular system, as exercise intensity increases, minute ventilation increases proportionally to the intensity.

Ventilation values:

Tidal volume (TV) is the volume of air that is inhaled and exhaled with every breath (similar to stoke volume).

Breathing frequency (Bf) is the number of breathes in a minute (similar to heart rate).

Minute ventilation (ME) is the volume of air breathed in or out every minute (similar to cardiac output).

Minute Ventilation mL/min = **breathing frequency** (beats/min) X **tidal volume** (mL)

- ME = Bf × TV

An average person has a resting breathing frequency of 12 breathes/minute and a resting tidal volume of 500 mL/breathe. The minute ventilation for this person at rest is:

Minute Ventilation = 12 × 500 = 6,000 mL/minute.

ME = 6 Litre/minute

Similar to cardiac output, minute ventilation will increase proportional with exercise intensity.

Aerobic exercise

Individual	Breathing frequency (breathes/min)	Tidal volume (ml)	Minute ventilation (ml/minute)
Rest	12	500	6000
Exercise	25	1,000	25,000

Anaerobic exercise

Individual	Breathing frequency (breathes/min)	Tidal volume (ml)	Minute ventilation (ml/minute)
Exercise	40	2,500	100,000

The most commonly used measure of maximal oxygen consumption during exercise is known as VO_2. VO_2 max refers to the amount of oxygen the body can take up and utilise.

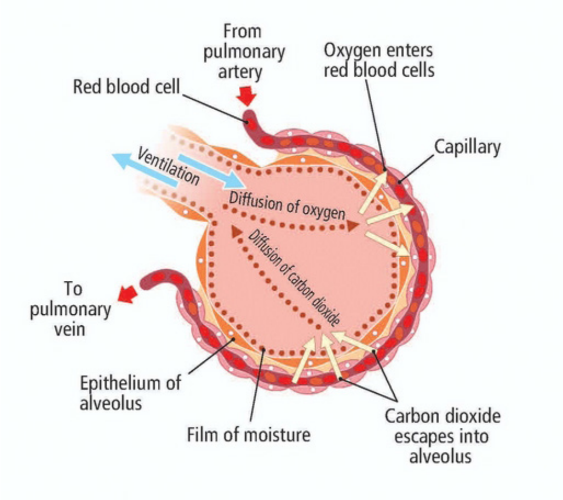
With continuous aerobic exercise VO_2 increases linearly with increases in exercise intensity. This is due to an increasing need of oxygen to help provide energy as exercise continues. There will be a maximum point where the body can no longer utilise anymore oxygen, this is known as VO_2 max.

VO_2max is used as a measure of an individual's aerobic fitness. The multi-stage fitness test estimates an individual's VO_2 max.
At Steady State exercise the need for oxygen is proportional to the consumption of oxygen, therefore ME increases linearly to the need for oxygen.

Gaseous Exchange

The main function of the respiratory system is **gaseous exchange**. This refers to the process of Oxygen and Carbon Dioxide moving between the lungs and blood. This occurs because of the process of diffusion.

Diffusion occurs during gaseous exchange as the air in the alveoli has a higher concentration of O_2 than in the capillaries and therefore diffuses across into the red blood cells. Similarly there is a greater concentration of CO_2 in the capillaries than in the alveoli and therefore the CO_2 diffuses across. There is an increased rate of diffusion during intense exercise due to the increase in concentration gradient.



The role of haemoglobin is to transport oxygen in the blood to the working muscles and then the oxygen diffuses into the muscle cell where myoglobin transports it to the mitochondria.

Control Mechanisms of Breathing

The rate of **inspiration** and **expiration** is controlled by the respiratory control centre (RCC) found within the Medulla Oblongata in the brain.

Inspiration increases due to a firing of inspiratory nerves within the intercostals and diaphragm muscles.

Expiration occurs due to a sudden stop in impulses along the inspiratory nerves

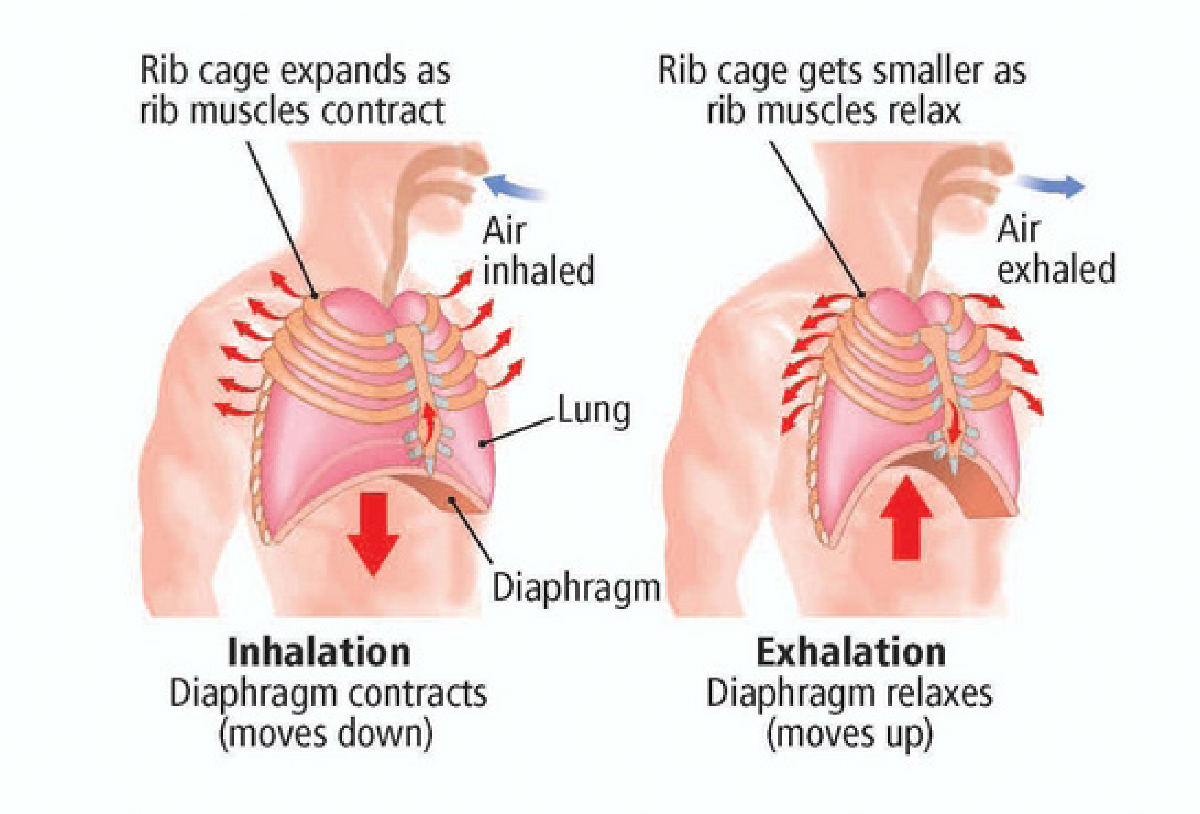
Control of Breathing

As with the control of heart rate, breathing rate is controlled by:

- Proprioceptors (detect movement)
- Chemoreceptors (detect chemical changes),
- Baroceptors (blood pressure)
- Thermoreceptors (detect temperature change).

These receptors detect changes that occur during exercise and adjust breathing rates accordingly.

Mechanics of Breathing –Inspiration (inhalation) and Expiration (exhalation)



C. Overview - short term effects of exercise on the cardiorespiratory system

- Two of the major functions of the respiratory system are to:
    - Provide oxygen (O_2) to the working muscles
    - Remove carbon dioxide (CO_2) from the body

- Mechanics of breathing influenced by the diaphragm and intercostal muscles.

- The main function of the respiratory system is gaseous exchange. This refers to the process of Oxygen and Carbon Dioxide moving between the lungs and blood (between the alveoli and capillaries).

- This occurs because of the process of diffusion. Diffusion occurs when molecules move from an area of high concentration to an area of low concentration until equilibrium is reached.

- The rate of inspiration and expiration is controlled by the respiratory control centre (RCC) found within the Medulla Oblongata in the brain.

- The respiratory values vary depending upon intensity and duration of exercise $ME = TV \times Bf$.

- As with the control of heart rate, breathing rate is controlled by:

    - Chemoreceptors (detect chemical changes)
    - Proprioceptors (detect movement)
    - Thermoreceptors (detect temperature change).

1. Exercise physiology, performance analysis and training

1.1.2 Long-term adaptations to exercise

Quesion
Assess the long term adaptations that have supported the athletes in finishing this endurance event. (AO3)

A. Content

- Musculo-skeletal system; changes to bone density, articular cartilage and ligaments (linked with mobility training), muscular hypertrophy, changes to fibre types, thickening of tendons and increased force of muscular contractions.
- Cardio-respiratory system**;** bradycardia, cardiac hypertrophy and stroke volume (ejection fraction), changes in lung volumes, pulmonary diffusion and the effects on VO_2 max.
- How different methods of training (aerobic and anaerobic) cause long term adaptations to body systems and the physiological changes caused by training and links to improvements in performance.

B. Knowledge and Understanding

Introduction

After we exercise over a period of time, adaptations take place within the body. The main adaptations take place in the:-

- Musculo-skeletal system
- Cardio-respiratory/vascular systems

For the sports performer it is important to understand how the actual physiological adaptations affect sporting performance.

Example 1

Cardiac hypertrophy can help increase stroke volume and maximal cardiac output. This increase in oxygen reaching the muscle will increase the VO_2 max of an individual, which will increase the anaerobic threshold allowing the athlete to work in the aerobic zone for longer, therefore during a hockey match they will be able to work at a higher intensity for longer without fatiguing.

Example 2

Muscular hypertrophy, which can increase the force exerted by a muscle, thus allowing faster contractions allowing greater sprint speed or increasing leg power, therefore a sprinter can get out of the blocks quicker and generate more speed on the track.

Physiological adaptations from Aerobic Training

Following at least a 12 week continuous training programme the following adaptations were observed:

Musculo-skeletal

- Larger numbers of capillaries around muscles increasing diffusion of oxygen into the muscles.
- Larger number of **Mitochondria** (which converts oxygen and food into energy) in the muscle cell.
- Increased amounts of myoglobin (concentrated form of haemoglobin that transports the oxygen into the mitochondria from the blood).
- Increase in the efficiency of Type I muscles fibres and the utilisation of Type IIa

Bones and Joints

- Exercise stimulates deposition of calcium which makes the bones stronger.
- Tendons and ligaments increase in strength and flexibility/mobility of joints.
- Increase in the amount of synovial fluid in the joint capsule, reducing the friction between the bones.

Cardio-respiratory

After training aerobically over a sustained period of weeks their adaptations will include:

- Increased capillarisation of the lungs, where oxygen diffuses from the alveoli into the blood.
- Improved strength of the diaphragm and intercostal muscles.
- Increased utilisation of the alveoli and therefore reducing breathing frequency.
- Increased tidal volume and minute ventilation.

This means that more oxygen can be consumed and transported from the alveoli into the capillaries and into the red blood cells. The remaining systems then transport the oxygen to the working muscles and eventually back out as CO_2.

Cardio-vascular

The adaptation of the cardiovascular system work in tandem with the respiratory system. These adaptations include:

- Increase in myocardium (heart muscle) – cardiac hypertrophy.
- The ventricles can hold a greater volume of blood, increased diastolic phase of cardiac cycle.
- Reduced resting heart rate – bradycardia due to increase the stroke volume.
- Reduced/similar systolic phase.
- Increased blood pressure whilst exercising, a reduced resting blood pressure.

- Increased cardiac output.
- Vasomotor control – more efficient vasoconstriction and dilation. Smooth of blood vessels becomes stronger.
- Increased number of red blood cells and therefore more haemoglobin.
- Improved cardiovascular system has real health benefit by reducing the potential impact of hypertension (high blood pressure), CHD and arthrosclerosis.
- Overall the athlete is able to work for longer in the aerobic zone (taking longer to reach anaerobic threshold) as the exercise intensity increases. This reduces the effects of fatigue and the build-up of waste products.

Improvements to sporting performance

All of the above adaptations mean more oxygenated blood can be transported to the working muscles allowing the performer to:-

- Have a higher **VO_2 Max** (the unit of measurement of aerobic fitness).
- Work aerobically for longer raising the **Anaerobic Threshold,** reducing the onset of blood lactate (OBLA) and conserving glycogen and CP stores.
- Reduced recovery times after intense exercise will be shorter due to the transportation system that removes waste produces as well as delivering oxygen and fuel.
- Faster recovery means the body can replenish **CP stores** and **glycogen** at a faster rate and removal of lactic acid.
- **Lactic acid** will be removed faster.
- **Myoglobin stores** will be re-saturated at a faster rate because of increased oxygen uptake.

Adaptations to the Body after Anaerobic Exercise

Anaerobic exercise includes such activities as sprinting, weight training, plyometrics and anything where a sportsperson is working close to their maximum. Even though there are specific adaptations from anaerobic exercise research suggesting that there is a significant contribution to the adaptations from aerobic exercise.

Training at a high intensity for short duration using predominantly the ATP-PC system, power and strength training may achieve the following adaptations:

- Muscle hypertrophy (increase in size of the muscles).
- Increased Creatine Phosphate stores in the muscles.
- Increased bone density and tendon thickening and strengthening.
- Development of Type IIb muscle fibres and utilisation of Type IIa.
- Neural system improves i.e. the firing patterns speed up, reducing response time.

Training at a high intensity for a slightly longer duration whilst predominantly using the anaerobic system, training which includes interval sprints could produce the following adaptations:

- Greater tolerance to **lactic acid** (also known as **buffering** capacity of the muscles)
- Increase in muscle glycogen stores.

Improvements to sporting performance

All of the above adaptations mean:

- The performer will be able to increase the amount of force, power output, speed and strength within the sporting context.
- The performer can tolerate more lactic acid and therefore be able to remain in the anaerobic zone for longer.
- When using high intensity activity over a longer duration then similar improvements in performance will occur. E.g. Increased VO_2 max, higher anaerobic threshold.

C. Overview - long term adaptations of exercise on the cardiovascular system

After a period of prolonged aerobic training (up to 18 weeks) adaptations to the bodies system include: -

- **Musculo-skeletal;** mobility at joints, increased bone density, muscular hypertrophy, efficiency of muscle fibre types, increased force and length of contractions and capillarisation, increases in myoglobin and mitochondria in the muscle cell.

- **Cardiorespiratory;** changes to resting values of Bf, TV, diffusion rates, capillarisation and haemoglobin content. Values of ME and diffusion when exercising.

- **Cardiovascular;** changes to resting values of SV, HR, BP, (bradycardia, hypertrophy) compared with the changes when exercising.

- Increased **elasticity (Vasomotor control) of arteries and arterioles** (allows greater volume of oxygenated blood to pass through the vessels).

- Increased **CP** and **glycogen** stores and increased **tolerance to lactic acid.**

- Increased capacity of the training zones and energy systems.

- Higher VO_2 max and an increase in anaerobic threshold.

1. Exercise physiology, training and performance

2. Preparation and training methods

Question
Describe the processes involved in the preparation of physical fitness. (AO1)

A. Content

- Field based fitness testing and protocols including: Components of fitness; the benefits of fitness testing, validity and reliability.
- Laboratory tests including: VO_2 max treadmill or cycle ergometer test, 30 seconds Wingate Power test.
- Components of fitness, methods and principles of training
- Periodisation.

B. Knowledge and Understanding

To support the development of physical fitness, athletes need to understand the importance of fitness testing. The ability to follow the correct procedures and how to interpret the results is vital to both the athlete and the coach.

Testing is vital to the coach and the athlete, it allows them to:

- Identify strengths and weaknesses - comparing results, using normative tables.
- Monitor progress - baseline fitness, especially at new training phase.
- Compare with other athletes, yourself, normative data.
- Set goals - incentive to improve, motivation and achievement.
- Identify talent – potential athletes.

Reliability

A test is considered reliable if the results are consistent and repeated over different occasions. You should be able to obtain the same or similar result on two separate trials. This is important as you are often looking for small changes in scores.

Validity

Validity is whether the tests actually measure what it set out to. Tests can be reliable but not valid (e.g. Even though the hand grip dynamometer will produce reliable results it is not a valid test of leg strength because it only measures grip).

Field based Testing

Field based tests are relatively inexpensive and are able to be administered to a large amount of people at the same time. By following the protocol they can be extremely reliable but as they usually only predict the outcomes they tend to lack validity.

Component	Test	Protocol
Cardiovascular endurance	Multistage Fitness test	20 m course. Stay in time with the bleeps on each line. Run until total exhaustion prevents completion three shuttles.
Muscular endurance	1 minute press/sit up test	Perform as many as you can in 60 seconds. Elbows moving from the locked, straight position to 90 degrees of flexion. Straight body positon Or Sit ups from floor to 90 degrees (arms across chest).
Muscular strength	Handgrip dynamometer	Grip with dominant hand. Apply maximum force while arm is straight in front of the body. Repeat three times while non-participant records the maximum force reading.
Flexibility	Sit and reach	Remove shoes and position box against the wall. Keep knees completely locked and reach forward with one hand on top of the other. Stretch and hold position for two seconds while non-participant records score.
Agility	Illinois agility run	Mark out the course with the exact measurements required. Starts in a face-down, lying position at the start line. Must follow same pattern/direction through cones.
Speed	30m sprint	Sprint 30 m distance on an even, firm surface. Rolling start so that they are running at full speed as they hit the start line. For accurate timing, use two timers.
Power	Vertical Jump	Stand sideways near a wall and measure their height with an upstretched arm. Jump as high as possible and mark the wall at the peak of the jump on three occasions. Record the highest jump.
Coordination	Alternative hand throw	Stand exactly two metres from a smooth-surfaced wall. Throw the ball with one hand, catches it with the other hand and repeats the action. Count the number of successful catches in 30 seconds.
Balance	Standing Stork test	Place hands on their hips and one foot on the inside knee of the opposite leg. Raise heel and hold balance for as long as possible. The score is taken as the total time the balance is held.
Reaction time	Ruler drop test	Hold a 30 cm ruler above the open hand. The 0 cm mark must be directly between the thumb and index finger. Drop the ruler with no warning as they try to catch it. The score is taken from where the top of the thumb hits the ruler.

Laboratory Testing

The most valid and reliable tests are carried out in a laboratory. The advantage of these sorts of tests is that they actually measure the component. However they are relatively expensive and time consuming, usually requiring expensive equipment.

Maximal VO_2 Test

The VO_2max test is the criterion measure of aerobic power in athletes. Described here is the method to measure VO_2max directly. Many other aerobic fitness tests estimate VO_2max score from their results. (see AS PE for methodology)

The test is performed on an appropriate ergometer (treadmill or cycle) with workloads selected to gradually progress in increments from moderate to maximal intensity.

The results are presented as either l/min (litres per minute) or ml/kg/min (ml of oxygen per kilogram of body weight per minute). The athlete is considered to have reached their VO_2 max if several of the following occurred: a plateau or 'peaking over' in oxygen uptake and maximal heart rate was reached.

Advantages: Accuracy of measurement - This test actually measures body oxygen consumption, which other tests try to estimate. You can also get measurement of maximum heart rate by recording heart rate during the test.

Disadvantages: Relatively large time and costs required

This test is a maximal test, which requires a level of fitness. It is not recommended for sedentary, or people with health problems.

The Wingate Test

The Wingate test, also known as the Wingate Anaerobic Test. This test measures anaerobic power and capacity.

Anaerobic power: The highest power output in any 3-5 second interval of the test.

Anaerobic capacity: The total amount of work through the 30-second test.

The Wingate test requires the performer to pedal a cycle ergometer for 30 seconds, maximally against a predetermined resistance.

Advantages: Accuracy of measurement - This test actually measures anaerobic power and capacity, which other tests try to estimate.

Disadvantages: Relatively expensive equipment, time and specialist knowledge to interpret the data and administer the test.

Components of fitness

Aerobic capacity (CV endurance) is the ability to exercise for a sustained period of time e.g. playing hockey at the same level of intensity for the duration of the match.

Muscular endurance is exercising a specific muscle group over a period of time e.g. a rower pedalling using just their legs and arms over the course of the race.

Muscular strength is the maximum force a muscle can generate against a resistance e.g. pushing in a rugby scrum as soon as the ball is put in.

Flexibility is the elasticity of muscles and the range of motion at a joint e.g. a dancer increasing the range of motion in a split leap.

Body composition is the proportions of body weight which are fat, muscle bone and visceral e.g. a long jumper would require a larger muscle mass than a 200m swimmer. Both would not require much fat as it would be detrimental to their performance.

Agility is the ability to change direction quickly e.g. a tennis player moving side to side at high speed to return the ball.

Speed is moving the body or body parts as quickly as possible from A to B e.g. a netball wing attack moving forward up the court from an interception to support the goal attack.

Power is a combination of strength and speed e.g. a hammer thrower applies great force to the hammer while moving rapidly in the rotations.

Coordination is the ability to move two or more body parts at the same time e.g. a badminton player moving quickly across the court and performing a drop shot return.

Balance is the stability of the body's centre of mass above the base of support e.g. a 100m sprinter holding the sprint start position.

Reaction time is the time taken to respond to a stimulus e.g. a goalkeeper diving after a free kick has been taken.

Methods of training

It is important that an athlete trains as specifically as possible in order to prepare for competition. This means selecting the most appropriate methods of training to suit the components of fitness being used in the sporting activity.

Training can be divided into two methods:

- Continuous
- Interval

Continuous Training predominantly develops the aerobic system by working **continuously** at the same intensity. Endurance athletes such as marathon runners, road cyclists and tri-athletes predominantly use the continuous method of training. When referencing continuous training always refer to the specific intensity and duration of session, e.g. a cyclist working between 65-75% of max heart rate for 3 hours. This method of training develops the aerobic system and endurance.

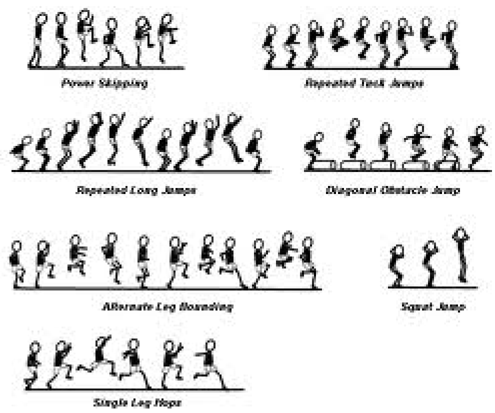
Interval training is any form of training with a set recovery period built into the session. Weight training, circuit training, and plyometrics are all forms of interval training. Interval training tends to be associated with periods of sprinting, running or swimming, with periods of rest between exercises. Interval training can develop any energy system depending on the intensity and duration of the exercise or the length of recovery between sets. Predominantly interval training develops, speed, power, agility and strength.

Fartlek is a Swedish word meaning 'speedplay'. Fartlek is training at varying intensities at different distances often at different gradients. This method of training is used to develop all the energy systems. Fartlek is often used by games players to replicate the varying intensities that occur during matches.

Plyometrics

This method is used to develop power and speed. It is often carried out using hurdles of varying heights, and boxes. It is a maximum intensity activity of relatively short period of time, usually no more than 10 seconds with a rest period allowing near full recovery between repetitions and sets. The focus is on rebound and eccentric muscular contractions.

Examples of plyometric exercises



Perform Better; http://bit.ly/2h6ztli

Weight training can develop different components of fitness depending upon the number of sets reps and weight used. Most commonly it is strength, power and speed that tend to be developed as a result of weight training. This is because all of these components of fitness use fast twitch type IIb fibres.

In order to train for strength, power and muscular endurance, sets, reps, weight and recovery must all be applied differently. It is also vital that an athlete has knowledge of their '1 rep max' for any weight training exercise undertaken.

Weight training for strength is carried close to the maximum (1rep max)

Exercise	Sets	Reps	Weight (% of 1 rep max)	Recovery time between sets
Shoulder press	3	3	95%	3-4 mins

The weight is close to the 1 rep max; hence the number of repetitions is low. Also a 4-minute recovery allows almost full recovery of the creatine phosphate (CP) system.

Weight training for power is again close to maximum effort. However, because it is a combination of speed and strength the actual weight lifted is slightly less than is often used at strength. This reduction in weight allows the movement/exercise to be carried out with greater speed.

Exercise	Sets	Reps	Weight (% of 1 rep max)	Recovery time between sets
Power clean	3	6	80%	3-4 mins

Working at 80% of the athletes 1 rep max allows the movement to be carried out highly explosively which maximises power development. As with strength the recovery period 3-4 minutes to allow full replenishment of the CP system.

Weight training for muscular endurance improves muscle tone, when training for muscular endurance both fast twitch and slow twitch fibres are recruited and hence the predominant energy systems used are both the anaerobic glycolysis system and the aerobic system.

Exercise	Sets	Reps	Weight (% of 1 rep max)	Recovery time between sets
Shoulder press	4	16	50-60%	1mins

Both the sets and reps are higher than would be used when strength training, only lifting far less weight in order to complete the high number of repetitions.

By altering the intensity, duration and rest periods Interval training can be used for aerobic fitness.

Middle distance runners, commonly use this type of interval training. Because the development of aerobic system is the main aim of this type of interval session then working at an intensity close to the anaerobic threshold is essential.

A typical session for a middle distance runner:-

Exercise	Sets	Reps	(% of maximum HR)	Recovery time between reps
800m intervals	1	6	80-85%	2 mins

Interval training for speed requires maximum effort, it is important to train as close to maximum effort as possible. A typical session for a 100m sprinter would be: -

Exercise	Sets	Reps	(% of maximum HR)	Recovery time between reps
40m intervals from starting blocks	1	5	100%	4 mins

The effort has to be 100% to replicate what is happening in a race with long recovery periods for almost full replenishment of CP.

Circuit Training

Circuit training can include a variety of exercises that can be either sport specific or fitness related. It is important that whatever the type of circuit is being carried out then the time on each station meets the needs of the sport or activity. Below are two examples of how circuit training can be applied very differently depending on what the sporting needs of the individual are.

Principles of Training

When developing your sporting performance, training is inevitably a key consideration if progress is to be made. Training can be beneficial to you whether it is burning calories when trying to lose body fat or trying to increase speed for your particular sport. However, in order to make steady continual training improvements the **Principles of**

Training are essential if progress is to be made.

It is important to point out that there are a variety of principals of training and definitions, but our concern is their application.

Specificity

With any sportsperson, before any form of training is undertaken there must be a clear understanding of the specific components of fitness and the specific skills requirements that are essential in that particular sport. E.g. A shot putter will require a great deal of strength, power and a reasonable degree of flexibility. Training programmes must be designed around the specific needs of the athlete and focus on the methods of training that will develop the components of fitness. These will be developed by altering the intensity, duration and frequency of training.

Progressive overload or Progression and Overload

Progression and overload are closely linked, and terms tend to be used interchangeably and together – progressive overload. Progression is the building of the programme and this is achieved by overloading the energy systems/components of fitness. Progressive overload is achieved by applying effective principles of strength training.

Frequency – how often a component or method is developed in the programme.

Intensity – increasing the intensity as the physiological changes take place – being able to work at higher intensities for longer.

Duration – working at the same/higher intensities for longer by either tolerating or off setting fatigue (lactic acid).

For example

Session 1

Exercise	Weight	Sets	Reps	Recovery (mins)
Half squat	140kg (90% of 1 rep max)	4	4	4

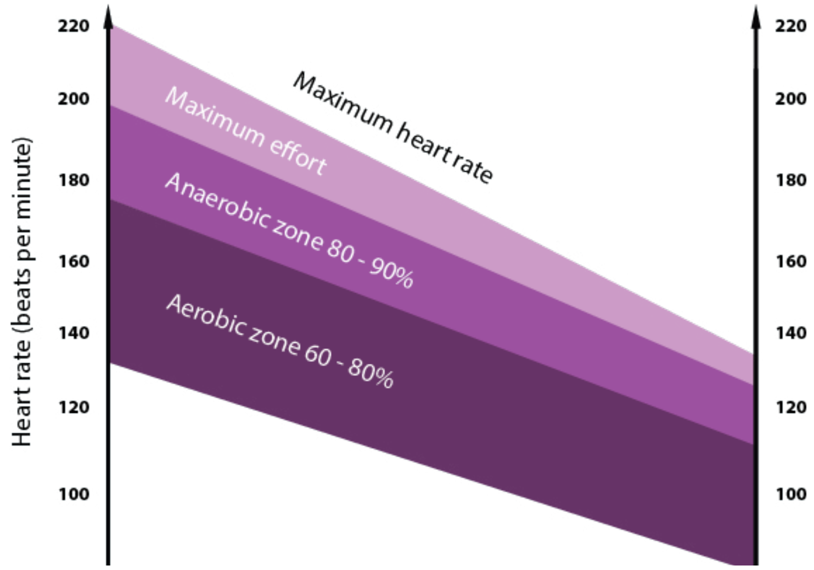
Session 2

Exercise	Weight	Sets	Reps	Recovery (mins)
Half squat	**145kg** (90% of 1 rep max)	4	4	4

The athlete is increasing the intensity of the session by increasing the weight by 5kg. This would be the most appropriate and effective way of developing strength.

Overload can also be achieved by increasing the frequency of training from 3 times a week to 4. But it is also important not to stress the same muscle groups by doing the same exercises on two consecutive days. By doing so would not allow sufficient recovery time for growth and repair of the muscle fibres.

It is also vital that an athlete has knowledge and understanding of intensity of exercise and the subsequent heart rate training zones.



Intensity is usually defined as a percentage of maximal heart rate.

Maximal Heart rate = 220 – Age

The anaerobic threshold is the point at which the body begins to use more anaerobic rather than aerobic energy to sustain exercise intensity. Training very close to the anaerobic threshold will result in an increase in your anaerobic threshold thus improving aerobic fitness. This is approximately 80% of maximal heart rate.

Reversibility will not occur if the above principles are applied correctly.

Variance is the altering of the programme, perhaps a type of activity or component, changing exercises but usually not the intensity and duration. Variance is used to combat plateauing and tedium.

Any good training programme must apply the principles of training. All programmes must have:

- Specificity – recognises the fact that the body adapts in a way that is specific to the type of training carried out. For example, to run faster, you need to carry out speed and power types of training e.g. Interval training.

- Progressive overload – the need to regularly increase in the frequency, intensity and time of training.

Training has to be carefully structured and periodised for progression and in preparation for the event or performance.

Periodisation

The training year was split into pre-season, in season and off season and the methods and types of training reflected the sport and the particular time of year. A traditional linear periodisation is a widely accepted method of structuring training programmes to produce maximum performance at the right time, also known as peaking.

The aim of periodisation is to peak for a specific competition and develop a specific component of fitness.

Preparation Period (general) - this can often be associated with pre-season training, this is a period of training that lays the foundations for the main competitions. Towards the end of pre-season, more general skills become more sports specific.

Competitive Period – associated with in season, almost all of the training is related to sport-specific movements.

Transition Period – associated with the off season is characterised by non-competitive activities. This phase is important because it allows full physiological recovery where neural central nervous system fatigue can remain for a long period of time. The transition phase incorporates rehabilitation, which allows the athlete to recover from any injuries and psychological relaxation.

The training plan is usually divided into microcycles. The microcycles are grouped in mesocycles and the mesocycles grouped in macrocycles.

These are then assembled into phases to complete the training plan.

Duration of each cycle

The duration of the cycles is very much dependent on the sport, and the competition the athlete is training for. The following timescales reflect this.

- A microcycle is usually between 1 to 14 days
- A mesocycle is usually between 2 weeks to 6 months
- A macrocycle is usually between 1 to 4 years

Microcycles have planned recovery times between each session, this allows the body parts to recover and physiologically adapt. The pre-season/preparation phase for a triple jumper may look like this:

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Interval training Sprinting with full recovery 30m × 10	Technique Skill, training; looking at phases of triple jump	Plyometrics Working on eccentric muscular contractions for power	Flexibility training PNF stretching	Rest,	Skill, Speed, 10m x15 with full recovery and linking to phases of TJ	Weight training Power in upper body

Mesocycles group 2-4 microcycles together this allows recovery to be planned over a longer period of time. Similar the tracking of progression overload is clearer and planned. Within this phase you should be able to identify the reduced intensity of the recover weeks.

A macrocycle is a group of mesocycles. It is the all of the training that is carried out for that full cycle e.g. 1 year.

The Training Plan (Macrocycle) is seen in the graph below:

	OCT NOV DEC		JAN FEB MAR		APR MAY JUN JUL AUG	SEP OCT
Mesocycle (Period)	Off-season phase		Pre-season phase		In-season phase	Transition phase
Resistance Training Emphasis (phase)	GP*	Hypertrophy	Strength	Power	Strength and Power Maintenance	Reset
Fitness Conditioning Emphasis	Aerobic and Anaerobic		Aerobic and Anaerobic		Fitness maintenance	Reset

T = Transition period, R = Reset, GP = General preparation

An example of a yearly plan (Macrocycle) including all Mesocycles and Microcycles.

	The Annual Plan				
Phases of training	Prepatory		Competative		Transition
Sub-phases	General Preparations	Specific Preparations	Pre-Com-petative	Competitive	Transition
Macro-cycles					
Micro-cycles					

Considerations of periodisation

Periodisation was initially designed for Olympic weight lifting which is a sport that only uses two principle components of fitness i.e. strength and power. It has also been widely used in athletics and swimming where the goal is to peak for a particular event or competition.

Team games provide the problem of a relatively short preparatory phase (pre-season) with a long competitive stage (season). With the length of the season so long it is impossible to peak for every week or match of the season. Therefore, the in-season or competitive period is focused towards the maintenance of fitness with the possibility of small gains. A further problem then arises as to when a team should aim to peak in a season e.g. major competitions.

An example of a general periodised training programme for a rugby union player:

A gerneralised Macrocycle Rugby Union

Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Peroid	Off-season	Pre-season			In-season or competition period							
Aerobic work	Develop		Maintain									
Anaerobic work	No specific		Develop			maintain - attempt to develop if periods of inactivity are present						
Strength	Non-specific	Strength endurance	Max-strength	Rate of force development	Max-power	Speed strength	Max-strength	Rate of force development	Max-power	Speed strength	Maintain	
Speed	No specific work	Emphasis on technique		Top end speed	Acceleration	Agility	Game specific					
Volume	Low	Trend high start lowering towards season			Volume will be lower tahn pre-season but may increase during periods of downtime/injury or non-competition games intensity need to remain high will decrease if volume increases							
Intensity	Medium	Trend med increasing towards season										

An example of a Mircocycle in Preseason with anaerobic developement as the goal.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	Speed and acceleration	Anaerobic small intervals	Whole body strength	Recovery day	Anaerobic long intervals	Skills	Recovery day
PM	Whole body strength		Aerobic training		Upper body strength	Anaerobic games	

K. Overview of Preparation and training

- Fitness tests; monitor our progress, often after a period of training; identify strengths and weaknesses; set goals; comparisons; normative tables; elite athletes.
- Select appropriate tests that are reliable and valid for specific components of fitness.
- Standardise all the testing procedures, in order to produce the most accurate results possible.
- Differences between Field and Lab tests.
- Understanding VO_2Max testing.
- Continuous - Submaximal aerobic method of training med intensity and long duration.
- Interval – Maximal effort high intensity, short duration reps sets and recovery time.
- Fartlek - Usually used for games players because of the varying speeds, distances.
- Plyometrics – develops power and uses eccentric muscular contractions
- Weight - used to develop strength, power or muscular endurance. To develop strength high weight (80-100% 1 rep max) should be used with 1-6 repetitions with 3-4 min recovery. To develop power high weight (70-90% 1 rep max) should be used with 2 - 8 repetitions carried out as fast as possible with 3-4 min recovery. To develop muscular endurance a medium to low weight should be used (40-60% of 1 rep max) with 10-20 repetitions with only a 1-2 minute recovery.
- Circuit - Circuit training can be adapted to meet the needs and the goals of the individual.
- The main principles of training that develop sporting performance are specificity, progressive overload (progression and overload) and variance.
- Progressive overload uses frequency, intensity and duration.

- Periodisation split into Preparatory phase (pre-season), Competitive phase (in season), Transition phase (off season)
- Within the training year (Macrocycle) there is mesocycles and microcycles. A microcycle is usually between 1 to 14 days. A mesocycle is usually between 2 weeks to 6 months. A macrocycle is usually between 1 to 4 years.
- The aim of periodisation is to peak for a specific competition and develop a specific component of fitness. As the macrocycles progresses then volume of training is reduced with greater emphasis on intensity specific to the event or components of fitness.
- Periodisation is more problematic for team games where there is such a long competitive season and with so many components of fitness and skills to develop.

1. Exercise physiology, training and performance

1.3 Energy systems and their application to training principles

Quesion
Analyse the use of specific energy systems in the endurance event and explain how the recovery process can aid preparation for the next event. (AO3, AO2)

Quesion
Discuss the use of diet and supplementation to improve performance? (AO3)

A. Content

- Energy systems and the energy continuum.
- Recovery process.
- Diet, nutrition and performance.

Question

Analyse the use of specific energy systems in the endurance event and explain how the recovery process can aid preparation for the next event. (AO3, AO2)

Discuss the use of diet and supplementation to improve performance? (AO3)

B. Knowledge and Understanding

Energy systems

Exercise physiology is underpinned by the energy systems. The way energy is made available to muscles changes depending on the specific intensity and duration of exercise.

Adenosine tri-phosphate (ATP) is the only energy source for all bodily functions and activities (movements). When ATP is used for energy production it must be replenished, the body can replenish (recreate) ATP aerobically or anaerobically.

The 3 energy systems

ATP-PC System or Alactic System – ATP and creatine phosphate (CP) are present in very small amounts in the muscle cells. This system can supply energy very quickly because oxygen is not needed for the process. This system can last up 10seconds and not produce any waste products.

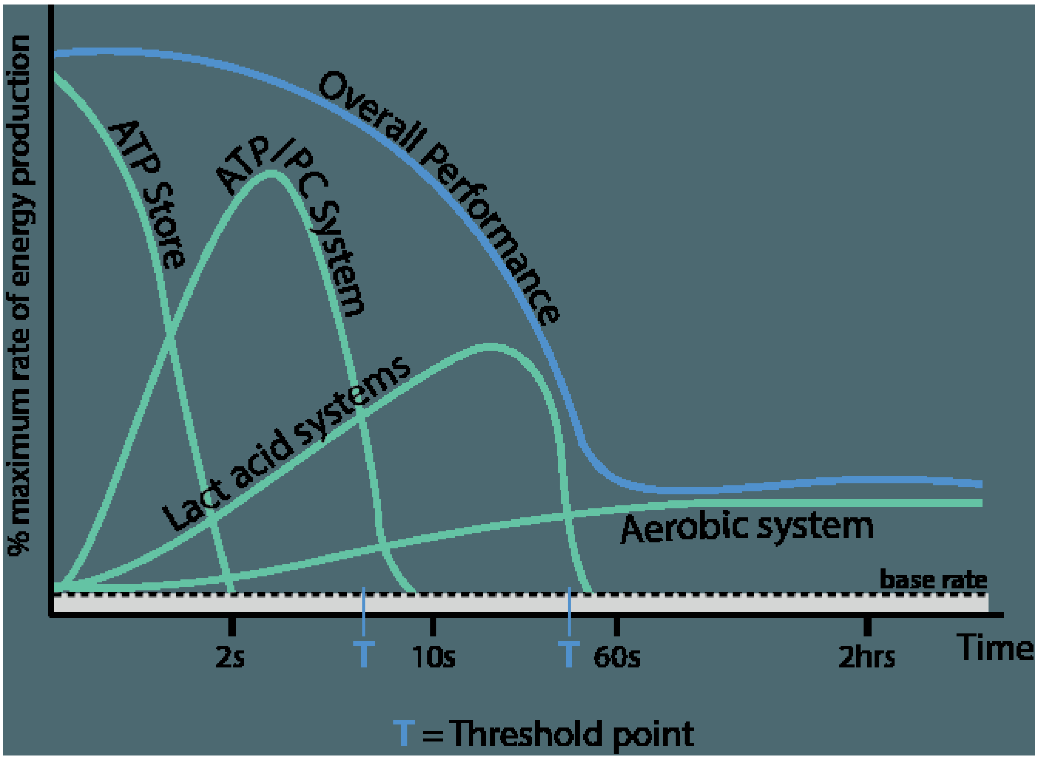
Anaerobic Glycolysis or Lactic Acid System uses carbohydrates (glucose) stored in the muscles as glycogen. Because no oxygen is required to re-synthesise ATP, energy is produced quickly. Also because no oxygen is used in the process lactic acid is produced as a waste product.

Aerobic System also uses carbohydrates (glucose/glycogen) to replenish or resynthesise ATP. Because oxygen is required for the process, energy production takes a little longer but can continue for a much longer duration. Water and carbon dioxide are the waste products of this system.

The three energy systems contribute to energy product simultaneously (see energy continuum). However the predominant Energy System used to is dependent on 3 factors:-

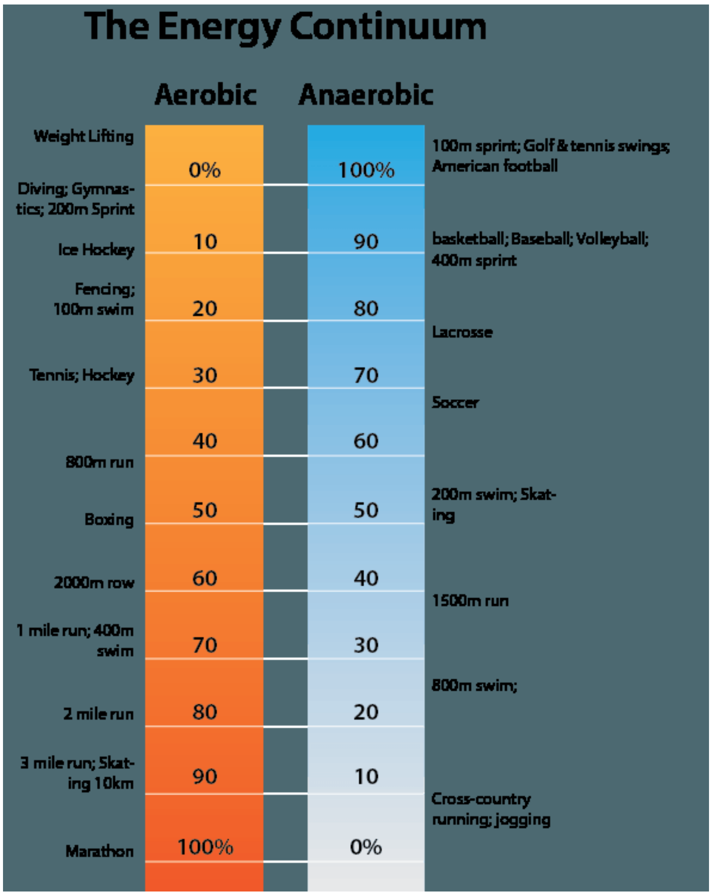
- INTENSITY
- DURATION
- FITNESS LEVEL

A higher level of aerobic fitness will mean it will take a performer longer to reach the Anaerobic Threshold (The point at which the performer gets more energy from the anaerobic systems rather than aerobic). This is beneficial because when a performer begins to work anaerobically there is only a limited supply of energy available (PC and muscle glycogen - up to 2 minutes max)



The energy continuum in graphical form.

In practice, all these factors work together to determine which are the predominant energy systems being used during the activity.



Fatigue and the recovery process

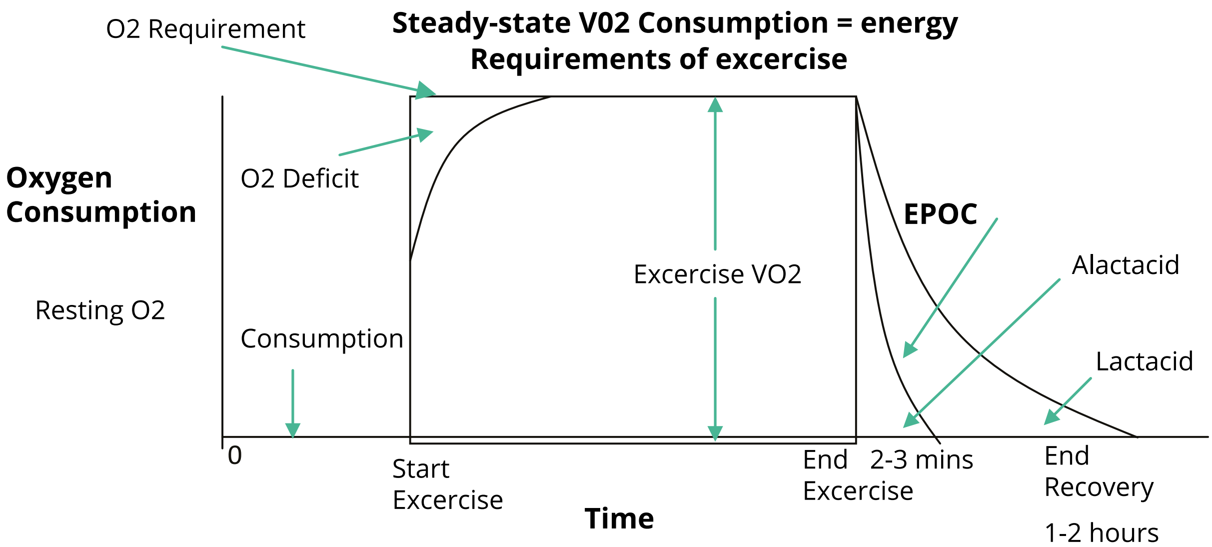
After a strenuous exercise the athlete needs to develop an effective recovery process to; replenishment of ATP, removal of lactic acid, replenishment of myoglobin with oxygen and replenishment of glycogen. This may take 24 hours depending upon the intensity and duration of the activity undertaken.

Recovery Process main aim is to restore the body to its pre-exercise state, this involves the removal of waste products produced during exercise and replenish the fuels used up during exercise.

Excess Post-exercise Oxygen Consumption (EPOC – formerly known as Oxygen Debt); is the excess consumption of oxygen during recovery to restore the bodies levels back to the pre exercise state. This is the reason for elevated breathing and heart rates.

The graph below show EPOC with the stages of recovery

1. Alactic Debt – initial recovery stage
2. Lactic Debt – the slower phase of recovery



OXYGEN DEFICIT can be thought of as the extra amount of oxygen that would be needed to complete the entire activity aerobically.

Alactacid Debt (Rapid Recovery Stage)

Resynthesise store of ATP and PC in the muscles as well as helping replenish the muscle stores of **MYOGLOBIN** and haemoglobin.

MYOGLOBIN is similar to haemoglobin (helping to transport oxygen) and is found in the muscle sarcoplasm (cell).

During recovery, with elevated heart and ventilation rates, there is a surplus of O_2 available for myoglobin to be replenished with oxygen.

ATP/PC stores take 3 minutes for fully recover (30 seconds for 50% recovery; 75% recovery in 60 seconds).

Recovery Time (seconds)	CP recovery (%)
15	60
30	70
45	80
1 min	85
2 min	90
4 min	97

Lact acid Debt (Slow Recovery Stage)

This is primarily responsible for the removal of lactic acid. It is converted back to pyruvic acid and then put through the krebs cycle. The removal of lactic acid can take between 1 and 24 hours after exercise, depending on the exercise intensity and the levels of lactic acid that have to be removed. This also repays the MUSCLE GLYCOGEN in the anaerobic glycolysis energy system.

The oxygen also re-saturates the myoglobin stores.

OXYGEN DEFICIT also has to be re-paid, oxygen deficit occurs as we begin to exercise.

Summary

EPOC will always be present at any exercise intensity when using aerobic exercise at steady state (oxygen supply (VO_2) meets the requirements of the exercise) there is a smaller EPOC.

There is an increased concentration of CO2 (waste product) produced as a waste product of aerobic exercise.

After exercise, glycogen stores in the liver and muscles will be depleted, which is a major factor in muscle fatigue. A complete recovery can take up to two days in prolonged endurance exercise.

Glycogen can be completely recovered if a high carbohydrate diet is consumed, within the first two hours of recovery. This could take the form of hypotonic or hypertonic drinks.

Recovery

Warm up thoroughly before training. This will help reduce Oxygen Deficit by increasing O_2 supply to the working muscles and ensure myoglobin stores are full. Also use an active cool down during recovery from anaerobic work where lactic acid is accumulated. This speeds up the removal of Lactic Acid. Moderate intensity seems optimal for the active recovery to be effective.

During steady state aerobic exercise where little lactic acid is produced, a more passive recovery has been shown to speed up recovery more than an active recovery. Active recovery elevates metabolism and will delay recovery in this instance.

High intensity training will help with increasing ATP and PC muscle stores and improve lactate tolerance.

Other methods to aid recovery:

Supplements - often contain a mix of carbohydrate (to re-supply the glycogen stores), protein and amino acids, (for growth and repair of the muscle) and creatine (Help restore CP stores).

Ice baths reduce the swelling around the muscle micro-tears and reduce the pain that they cause, this means that the performer is able to train at a higher level the next day, these micro-tears that cause Delayed Onset of Muscle Soreness (DOMS)

Massage can serve two purposes; psychological benefits e.g. relaxing feeling of the massage; physically by returning de-oxygenated blood from the muscle tissue to the heart to be re-oxygenated.

Compression Clothing can help recovery by maximising the pumping action of the muscles in returning blood to the heart and help with subsequent removal of lactic acid and blood lactate.

Fatigue is caused by:

Lack of energy i.e. insufficient CP and glycogen store.
Lactic acid preventing the enzyme ATPase from effectively breaking down ATP to release energy.

Dehydration and the reduction of plasma volume in the blood that will slow the delivery of blood and therefore oxygen to the muscles.

Diet and Nutrition

Nutrition for sport is built upon an understanding of how nutrients such as carbohydrate, fat, and protein contribute to the fuel supply needed by the body to perform exercise.

A Balanced Diet

Sportspeople must have carbohydrate, protein, fat, vitamins, minerals and fibre in the correct proportions within your diet (see tables below). If there is not enough protein, you will not be able to grow properly and you will not be able to repair yourself i.e. muscle repair after intense exercise. If you do not have enough energy containing foods (carbohydrate and fats) you will feel very tired and lethargic and there will be a severe drop in performance in any sport or exercise related activity. However, if you have too much energy containing foods you will become overweight, which can lead to obesity.

Recommended daily allowances (RDA's) are: -

Carbohydrate 50-65%

Fats 20-30%

Proteins – 10-20%

The main functions of these nutrients

Carbohydrates - our main source of energy.

Fats - one source of energy and important in relation to fat soluble vitamins.

Proteins - essential to growth and repair of muscle and other body tissues.

Vitamins - water and fat soluble vitamins play important roles in many chemical processes in the body e.g. Vitamin A - maintenance of skin, mucous membranes, bones, teeth, hair; and vision.

Minerals - those inorganic elements occurring in the body and which are critical to its normal functions e.g. Calcium - needed for bone and tooth formation; heart function and blood coagulation; muscle contraction.

Fibre - the fibrous indigestible portion of our diet essential to health of the digestive system.

Water - essential to normal body function, 60% of the human body is water - as is used as a vehicle for carrying other nutrients e.g. glucose in the blood and is also used to control body temperature by carrying heat to the skin surface before being released as sweat.

As with nutrition and health it is vital for a sportsperson to have a sufficient balance diet to meet the needs of their sport, event or activity. E.g. a marathon runner would have a different diet to that of a sprinter because of the differing energy demands. Nevertheless the primary source of energy for their training and competing regimes would come from carbohydrate. As previously stated, it takes approximately 15% less oxygen to break down carbohydrate (glucose) than it does a fat molecule. As well as proteins being an essential element of recovery after exercise, knowledge of the type of carbohydrate to consume and when to consume it is essential for any sportsperson.

Carbohydrates and fats get converted to ATP based upon the intensity and duration of activity, or the aerobic/anaerobic fitness level of the performer. Carbohydrate are generally the main source of energy fuelling exercise of a moderate to high intensity, with fat providing energy during exercise that occurs at a lower intensity. Fat is a good fuel for high endurance activities such as hiking, but it is not adequate for high intensity exercise such as sprinting or exercising close to the Anaerobic Threshold because it requires approximately 15% more oxygen than carbohydrate to be metabolised.

As exercise intensity increases, carbohydrate metabolism takes over. It is more efficient than fat metabolism, but has limited energy stores. This stored carbohydrate (glycogen) can fuel about 2 hours of moderate to high level exercise depending on an individual's level of fitness. After that, glycogen depletion occurs (stored carbohydrates are used up) and if that fuel isn't replaced athletes may hit the wall.

Carbohydrates are the main source of fuel during moderate to high intensity exercise and require approximately 15% less oxygen to be metabolised. During rest and low intensity exercise, fats are the main source of energy. As exercise intensity increases then more carbohydrates are used as fat usage decreases.

During anaerobic exercise CP and glycogen (carbohydrate) are the main source of energy. The higher the individual's aerobic fitness (VO_2 max) then the longer the fats will be metabolised, sparing important carbohydrate stores. The higher degree of anaerobic fitness means greater CP and glycogen stores which allows an individual to exercise at a high intensity for a longer period of time.

The Glycaemic Index

The glycaemic index is the rate at which carbohydrate releases energy (glucose) into the bloodstream. Carbohydrates vary greatly with regard to how quickly they increase blood sugar levels. Some types of carbohydrate release energy quickly and increase blood glucose levels very quickly ('high GI' foods) while others release glucose at a slower rate, ('low GI' foods). To make this easy to understand carbohydrates have been ranked on a scale of 1 to 100. Glucose has a ranking of 100 on this scale and is used as a reference against which the other foods are placed. Generally foods are categorised into low, medium and high GI foods.

In general high GI carbohydrates should be avoided when attempting to lose weight because they release energy/glucose quickly into the bloodstream. If this energy is not used then it gets stored as fat in the adipose tissue. DIABETES can occur with continued consumption of high GI foods, when high GI foods are consumed it causes the pancreas to secrete INSULIN also known as an insulin spike, to control the blood sugar levels, the more high GI food consumed the greater the amount of insulin secreted.

Low GI foods are the opposite of high GI because they release energy at a far slower more gradual rate, which makes it far easier for the body to use/burn the energy. Low GI carbohydrate also leaves the individual less hungry after a period time thus reducing the likelihood of consuming more food. They also do not cause the same spike/secretion in insulin as high GI foods.

The best strategy for athletes is to consume low GI carbohydrates in a pre-exercise meal to allow for sustained energy (3-4 hours before to allow full digestion).

How the Glycaemic Index (GI) is used in sport

An athlete participating in an endurance event should consume a low GI meal between 3-4 hours prior to exercise consisting of foods such as brown bread, fruit, vegetables, porridge (see other items on the index below). During the event high GI foods such as isotonic drinks and gels, jelly babies, jaffa cakes are often consumed. Post exercise a mixture of both high and low GI foods should be consumed with 30 minutes of ceasing exercise; this is the optimum time for glycogen uptake for the muscles. Specific recovery drinks/shakes that include a mix of low/medium and high GI carbohydrate and protein are often consumed immediately after exercise. After the athlete has showered and changed, glycogen and protein stores are further restored with a balanced meal containing a high proportion of low GI carbohydrate and protein. This helps to continue to restore glycogen stores as metabolic rate remain elevated up to 4 to 5 hours after exercise has ceased. Protein helps repair the muscle tissue. Replacement of fluids is also essential to re-hydrate the body.

Nutrition and Performance

As with nutrition and health it is vital for a sportsperson to have a sufficient diet to meet the needs of their sport, event or activity. E.g. a marathon runner would have a different diet to that of a sprinter because of the differing energy demands. Nevertheless the primary source of energy for their training and competing regimes would come from carbohydrate.

Fuelling the Energy Systems

Carbohydrate are generally the main source of energy fuelling exercise of a moderate to high intensity, with fat providing energy during exercise that occurs at a lower intensity.

As exercise intensity increases, carbohydrate metabolism takes over. It is more efficient than fat metabolism, but has limited energy stores. This stored carbohydrate (glycogen) can fuel about 2 hours of moderate to high level exercise depending on an individual's level of fitness. At this stage all glycogen stores will be depleted and if the fuel isn't replaced they will 'hit the wall' and have to reduce the intensity of exercise to use fat as the fuel. High GI carbohydrates through isotonic drinks can replace stores to allow intensity to continue.

The Glycaemic Index and Exercise

The glycaemic index is the rate at which carbohydrate releases energy (glucose) into the bloodstream. Carbohydrates vary greatly with regard to how quickly they increase blood sugar levels. Some types of carbohydrate release energy quickly and increase blood glucose levels very quickly ('high GI' foods) while others release glucose at a slower rate, ('low GI' foods).

It is important to understand that not all high GI foods are bad e.g. jacket potato is considered in the high category but is healthy, also milk chocolate is considered medium to low GI but because of the high fat content found in the milk then the calorie content is higher. It is important to get a balance of the GI foods in your diet to provide both immediate and long term energy. Too much of any food or over consumption will result in a positive energy balance and subsequent weight gain if sufficient exercise is not carried out. Such unproductive weight gain is not beneficial to sportspeople.

Carbo-loading

Carbo-loading is a diet or process of increasing carbohydrate consumption and storage of glycogen usually prior to an endurance event. There are numerous ways to carbo-load but all follow a similar principle. The Shearman technique has three stages: -

- Depletion
- Tapering
- Loading stage

Depletion stage

This stage involves the reducing muscle glycogen stores. The training intensity continues or in some instances increases but the carbohydrate intake is reduced. The theory is that the body will store more carbohydrate when it's available.

Tapering stage

At this stage the amount of training is reduced with the same amount of carbohydrate consumption. There is a preparation for the event and a replenishment of glycogen stores within this stage.

Loading stage

Finally the intensity has decreased to almost no training and there is an increase in the consumption of carbohydrates. This allows the body to overload the systems with glycogen.

At the end of day three, the body will think that there is a problem with its glycogen stores and that it should store more glycogen than normal. In the last three days, when the athlete consumes carbohydrate, the body will replenish the glycogen stores and top them up with extra glycogen. This process is called super compensation.

For example: A typical week of a marathon runner

Day/s	Diet	Training	Stage
Sunday	Balanced diet	Light	Recovery
Monday/Tuesday	Balanced diet	High intensity	**Depletion**
Wednesday	Balanced diet	Medium intensity	**Tapering**
Thursday	Medium/High Carbohydrate (Low/ medium GI foods)	Light	**Tapering/Loading**
Friday	High Carbohydrate 80% of diet. (Low/medium GI foods)	Light	**Loading**
Saturday	Low-Medium GI meal 3-4hrs prior to competition	Competition	**Loading**

The method of carbo-loading is to deplete glycogen stores on day prior to competition with a short burst of high intensity activity, no more than 15 minutes in duration. The loading phase would begin immediately after exercise consuming 80% carbohydrate.

Supplementation in Sport

Sports supplementation is also called **ergogenic aids**. These are products used to enhance athletic performance that may include vitamins, minerals, proteins (amino acids), or any concentration, extract and are generally available over the counter without a prescription. Sports supplements tend to be dietary supplements; however lots of organisations including the International Olympic Committee (IOC) have developed policies on their usage and guidelines on illegal aids.

The most common supplements of protein, caffeine and creatine all have different effects on the body.

Proteins are required for growth and repair. Proteins are broken down into amino-acids and are used by the muscle to repair any damaged tissue after intense exercise e.g. help repair microfiber tears in the muscle and therefore rebuilding bigger stronger structures – muscular hypertrophy.

Caffeine's main physiological impact is the maintenance of alertness in the brain. There, it blocks adenosine, and slows down other brain signals making us feel less fatigued and more focused. Research suggests there is a positive impact on sports that are; high intensity, strength, multiple sprints, and can aid recovery. Caffeine's main effect is muscular (neuro-muscular). It also suggests that it allows the metabolism of fatty acid rather than glycogen stores.

Creatine is naturally occurring meats and fish can is also produced in the body. There is also a manufactured product that is available over the counter.

Sports people who take creatine do so to improve strength however there are no long term studies to look at the physiological impact of the supplementation. Similarly the improvements in strength and power may also be placebo (psychological rather than physiological). Some research that creatine is most effective for athletes doing intermittent high-intensity exercise with short recovery intervals, such as sprinting and power lifting.

The most common side effect of creatine supplementation is weight gain. It is also suggested that people with kidney problems should not use creatine because it may affect kidney function.

Illegal aids

Doping means athletes taking illegal substances to improve their performances. There are five classes of banned drugs, the most common of which are stimulants and hormones. There are health risks involved in taking them and they are banned by sports' governing bodies.

According to the UK Anti-Doping Agency, substances and methods are banned when they meet at least two of the three following criteria:

Enhance performance,

Threat to athlete health, or

Violate the spirit of sport.

The most commonly used substances are androgenic agents such as anabolic steroids. These allow athletes to train harder, recover more quickly and build more muscle, but they can lead to kidney damage and increased aggression. Other side effects include baldness and low sperm count for men, and increased facial hair and deepened voices for women.

Anabolic steroids are usually taken either in tablet form or injected into muscles. Some are applied to the skin in creams or gels.

Then there are stimulants, which make athletes more alert and can overcome the effects of fatigue by increasing heart-rate and blood flow. But they are addictive and, in extreme cases, can lead to heart failure.

Diuretics and masking agents are used to remove fluid from the body, which can hide other drug use or, in sports such as boxing and horse racing, help competitors "make the weight".
Human Growth Hormone (HGH) is a natural testosterone booster that's produced on its own in the pituitary gland and plays a vital role in cell regeneration, growth and maintaining healthy human tissue, including that of the brain and various vital organs.

Human growth hormone can be injected in larger doses to promote weight loss and increase muscle size while a small doses can be used for general recovery, health and ignite the anti-aging process. Two main impacts are:

1. Increased Muscle Strength
2. Increased the risk for cardiovascular disease.

Blood doping is the misuse of certain techniques and/or substances to increase one's red blood cell mass, which allows the body to transport more oxygen to muscles and therefore increase stamina and performance. Erythropoietin (EPO) is the most common synthetic oxygen carrier.

EPO is released from the kidneys and acts on the bone marrow to stimulate red blood cell production, which increases bulk, strength and red blood cell count and gives athletes more energy.

An increase in red blood cells improves the amount of oxygen that the blood can carry to the body's muscles. It may also increase the body's capacity to buffer lactic acid.

EPO causes the blood to thicken, leading to an increased risk of several deadly diseases, such as heart disease, stroke, and cerebral or pulmonary embolism.

Beta blockers, meanwhile, which may be prescribed for heart attack prevention and high blood pressure, are banned in sports such as archery and shooting because they keep the heart-rate low and reduce trembling in the hands.

B. Overview of diet nutrition and supplementation

- The primary source of energy for their training and competing regimes would come from carbohydrate.
- Carbohydrate are generally the main source of energy fuelling moderate to high intensity exercise, with fat providing energy during exercise that occurs at a lower intensity.
- The glycaemic index is the rate at which carbohydrate releases energy (glucose) into the bloodstream.
- Carbo-loading is a diet or process of increasing carbohydrate consumption and storage of glycogen usually prior to an endurance event.
- There tends to be three stages to carbo-loading; depletion, tapering and loading.
- Sports supplementation is also called **ergogenic aids**.
- The most common supplements of protein, caffeine and creatine all have different effects on the body.
- Proteins are required for growth and repair.
- Caffeine main physiological impact is the maintenance of alertness in the brain.

- Sports people who take creatine do so to improve strength, however there are no long term studies to look at the physiological impact of the supplementation.
- Doping means athletes taking illegal substances to improve their performances.
- The most commonly used substances are androgenic agents such as anabolic steroids.
- Human growth hormone can promote weight loss and increase muscle size.
- Blood doping is the misuse of certain techniques and/or substances to increase one's red blood cell mass, therefore increase stamina and performance.
- Erythropoietin (EPO) is the most common synthetic oxygen carrier.

Overview Exercise physiology, training and performance

A. Overview Short term effects of exercise on the cardiovascular system

- There are two circulatory systems; pulmonary and systemic, their functions are transportation and removal of nutrients, oxygen, carbon dioxide and waste products.
- The cardiac cycle consists of two phases, diastole (relaxation phase) and systole (contraction phase).
- One cardiac cycle (heart beat) takes on average 0.8seconds
- Venous return is the volume of blood returning back to the heart, it is supported by valves and smooth muscle in the veins, musculo-skeletal pump and pressure gradients.
- Starling's Law refers to the increased stroke volume, due to increased filling of the heart.
- Cardiac values at rest and at different intensities, the relationship between Cardiac Output, Heart rate and Stroke Volume (Q=HR×SV).
- At rest Q=5 l/min compared with up to 35 l/min when exercising.
- The bodies transport system consists of arteries, veins, and capillaries that vasodilate or constricts to maintain increase or decrease blood pressure.
- Blood pressure at rest 120/80mmHg. It tends to be the systolic pressure that increases significantly compared with the diastolic. Aerobic exercise increases blood pressure to 180/85mmHg whereas strength training can increase both up to 240/160mmHg.
- It is important to note that aerobic exercise causes the lowest increases to blood pressure and are therefore the safest for those with cardiac problems.
- Control of heart rate is carried out in the Cardiac Control Centre (CCC) found in the Medulla Oblongata of the brain; this is part of the Autonomic Nervous System (ANS). The (ANS) has two sub-divisions, the Sympathetic Nervous System (SNS) and the Parasympathetic Nervous System (PNS).

- When our bodies are at **rest** the parasympathetic nervous system is in control of the heart rate compared with the sympathetic nervous system when exercising.
- The cardiac control centre (CCC) has three ways of regulating or controlling heart rate; neural (various receptors), hormonal (adrenaline/noradrenaline), intrinsic l (Starling's Law).
- Redistribution of blood to muscles during exercise (blood shunting) is caused by vasomotor control.

B. Overview Short term effects of exercise on the cardiorespiratory system

- Two of the major functions of the respiratory system are to:
  - Provide oxygen (O_2) to the working muscles
  - Remove carbon dioxide (CO_2) from the body
- Mechanics of breathing influenced by the diaphragm and intercostal muscles.
- The main function of the respiratory system is gaseous exchange. This refers to the process of Oxygen and Carbon Dioxide moving between the lungs and blood (between the alveoli and capillaries).
- This occurs because of the process of diffusion. Diffusion occurs when molecules move from an area of high concentration to an area of low concentration until equilibrium is reached.
- The rate of inspiration and expiration is controlled by the respiratory control centre (RCC) found within the medulla oblongata in the brain.
- The respiratory values vary depending upon intensity and duration of exercise.
- $ME=TV\times Bf$
- As with the control of heart rate, breathing rate is controlled by:
  - Chemoreceptors (detect chemical changes)
  - Proprioceptors (detect movement)
  - Thermoreceptors (detect temperature change)

C. Overview long term adaptations of exercise on the cardiovascular system

After a period of prolonged aerobic training (up to 18 weeks) adaptations to the bodies system include: -

- **Musculo-skeletal;** mobility at joints, increased bone density, muscular hypertrophy, efficiency of muscle fibre types, increased force and length of contractions and capillarisation, increases in myoglobin and mitochondria in the muscle cell.
- **Cardiorespiratory;** changes to resting values of Bf, TV, diffusion rates, capillarisation. and haemoglobin content. Values of ME and diffusion when exercising.
- **Cardiovascular;** changes to resting values of SV, HR, BP, (bradycardia, hypertrophy) compared with the changes when exercising,
- Increased **elasticity (vasomotor control) of arteries and arterioles** (allows greater volume of oxygenated blood to pass through the vessels).
- Increased **CP** and **glycogen** stores and increased **tolerance to lactic acid.**
- Increased capacity of the training zones and energy systems.
- Higher VO_2 max and an increase in anaerobic threshold.

D. Overview of Preparation and training

- Fitness tests; monitor our progress, often after a period of training; identify strengths and weaknesses; set goals; comparisons; normative tables; elite athletes.
- Select appropriate tests that are reliable and valid for specific components of fitness.
- Standardise all the testing procedures, in order to produce the most accurate results possible.

- Differences between Field and Lab tests.
- Understanding VO_2Max testing.
- Continuous - Submaximal aerobic method of training med intensity and long duration.
- Interval – Maximal effort high intensity, short duration reps sets and recovery time.
- Fartlek - Usually used for games players because of the varying speeds, distances.
- Plyometrics – develops power and uses eccentric muscular contractions.
- Weight - used to develop strength, power or muscular endurance. To develop strength high weight (80-100% 1 rep max) should be used with1-6 repetitions with 3-4 min recovery. To develop power high weight (70-90% 1 rep max) should be used with 2 - 8 repetitions carried out as fast as possible with 3-4 min recovery. To develop muscular endurance a medium to low weight should be used (40-60% of 1 rep max) with 10-20 repetitions with only a 1-2 minute recovery.
- Circuit - Circuit training can be adapted to meet the needs and the goals of the individual.
- The main principles of training that develop sporting performance are specificity, progressive overload (progression and overload) and variance.
- Progressive overload uses Frequency, intensity and duration.
- Periodisation split into Preparatory phase (pre-season), Competitive phase (in season), Transition phase (off season).
- Within the training year (Macrocycle) there is mesocycles and microcycles. A microcycle is usually between 1 to 14 days. A mesocycle is usually between 2 weeks to 6 months. A macrocycle is usually between 1 to 4 years.
- The aim of periodisation is to peak for a specific competition and develop a specific component of fitness. As the macrocycles progresses then volume of training is reduced with greater emphasis on intensity specific to the event or components of fitness.

- Periodisation is more problematic for team games where there is such a long competitive season and with so many components of fitness and skills to develop.

E. Overview of energy systems, diet and recovery

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- The glycaemic index is the rate at which carbohydrate releases energy (glucose) into the bloodstream.
- Carbo-loading is a diet or process of increasing carbohydrate consumption and storage of glycogen usually prior to an endurance event.
- EPOC is the repaying of energy after anaerobic exercise.
- There are two components of oxygen debt. Alactic and Lactacid. Alactic replenishes the CP stores (takes approx 4 mins to replenish 97% of the CP). Lactacid primarily replenishes the stored glycogen and removes lactic acid.
- Higher levels of aerobic fitness can result in quicker repayment of oxygen debt.
- There are a number of methods to speed up the recovery process including: - cool down, ice baths, correct nutrition and hydration, compression clothing and massage.
- Carbohydrates are the main source of fuel during moderate to high intensity exercise.
- Carbohydrates require approximately 15% less oxygen to be metabolised.
- During rest and low intensity exercise fats are the main source of energy.
- As exercise intensity increases then more carbohydrates are used as fat usage decreases.

- During anaerobic exercise CP and glycogen (carbohydrate) are the main source of energy.
- A higher the individual's aerobic fitness (VO_2 max) then the longer the fats will be metabolised, sparing important carbohydrate stores.
- The higher degree of anaerobic fitness means greater CP and glycogen stores which allows an individual to exercise at a high intensity for a longer period of time.
- The glycaemic index is the rate at which carbohydrates releases energy (glucose) into the bloodstream.
- High GI carbohydrates such as sugars release energy the fastest, which is beneficial during exercise and just after exercise.
- Low GI carbohydrates release their energy slowly which is beneficial 3 hours prior to exercise and within 30 minutes after intense exercise.
- A mixture of low, medium and high GI foods, are consumed after intense exercise to refuel the bodies depleted glycogen stores.
- Protein and fluids are also essential for growth and repair and re-hydration during recovery.
- There tend to be three stages to carbo-loading; depletion, tapering, loading.
- Sports supplementation is also called **ergogenic aids**.
- The most common supplements of protein, caffeine and creatine all have different effects on the body.
- Proteins are required for growth and repair.
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