**A2 Physical Education**

**Applied Physiology to Optimise Performance**

**Revision Guide**

* Energy Systems- sources, supply and recovery of energy in the body
* The physiology of skeletal muscle
* Preparation and training for successful performance
* The nature of injury in sport
* The mechanics of movement



**Energy Systems- Learning Objectives**

* Define energy
* Identify the sources and locations of energy within the body
* Explain the role of ATP in providing energy for movement
* Identify the predominant energy system used related to the type, duration and intensity of exercise for a given activity.
* Compare the effectiveness of the ATP-PC, lactic acid and aerobic systems
* Identify the chemical/ food fuel used, the site of the reaction, the controlling enzymes, the energy yield and any bi products produced for each energy pathways.
* Explain the term’ energy continuum’ in context of a range of activities
* Explain how the body recovers from exercise with reference to the excess post exercise oxygen consumption (EPOC)
* Explain the fast and slow components of the recovery process.
* Define V02 max and its role in limiting performance
* Define and explain the relationship between V02 max and OBLA



**Key Terms:**

**Energy:** the capacity to preform work.

**Adenosine Triphosphate (ATP):** the energy currency of cells. ATP is the only direct source of energy for all energy requiring processes in the body.

**Sources of energy in the body**

**ATP**

P

P

P

***Energy***: 1 calorie = 4.184 joules

**ATPase**- Enzyme that initiates the breakdown of ATP to ADP

**ADP**

Energy

P

P

P

The energy released from the breakdown of ATP- ADP is used to enable the muscles to contract, the heart to beat and electrical impulses to fire.

****There is a limited amount of ATP in the body – enough to fuel a maximal weight lift or a sprint start for 2-3 seconds. ATP needs to be recycles. This is achieved by providing the body with energy in the form of food.

**Key Terms:**

**Exothermic Reaction:** A chemical reaction that releases energy

**Phosphocreatine:** a high energy compound which exists in the muscle cell alongside ATP and provides the energy for ATP resynthesis when the intensity of exercise is very high.

**Anaerobic Metabolism**: Release of energy through the breakdown of food fuels in the absence of oxygen.

**Aerobic Metabolism**: The release of energy though the breakdown of food fuels in the presence of oxygen.

Fuels for ATP resynthesis are derived from the following sources:

**Phosphocreatine:**

* PC is used to resynthesize ATP in the first 10 seconds of intense exercise.
* Stored in the muscle alongside ATP
* Limited supplies
* Dietary sources: red meat and fish

**Glycogen:**

* Stored carbohydrate
* Stored in muscle 350g and liver 100g
* Converted to glucose before being broken down
* **High intensity Ex**: can be used without presence of oxygen- Anaerobic metabolism
* **Lower intensity of Ex**: much more can be energy can be released in presence of oxygen-Aerobic metabolism
* Stores maintain by eating complex carbohydrates

**Triglycerides**:

* Muscular stores of fat
* Rest- 2/3 of our energy requirement is met through breakdown of fatty acids
* Fat provides more energy than glycogen
* 1g fat= 9.1 kcals, 1g glycogen= 4.1 kcal
* Fat needs 15% more oxygen to metabolise
* Fats need lots of oxygen and presence of glycogen to be metabolised.
* Transport of fatty acids in the blood is poor, so they don’t arrive in sufficient quantities to sustain muscle contraction on their own. Glycogen needs to supply the additional energy. Favoured fuel for endurance activities.

**Proteins:**

* Last preferred source of energy. Contributed 5-10% of the total energy yield.
* Used in presence of oxygen when the stores of glycogen are low.
* Primary function is for growth and repair of muscle tissue.
* Diet: fish, meat and dairy products.

**Top Tip!**

When exercising at high intensity levels, the body will rely upon glycogen as a source of fuel.

The conversion of these fuels into energy to then re synthesise ATP occurs through one of three pathways/ energy systems.

**1) Aerobic system**

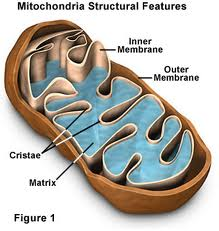
**2) Lactate Acid/ Anaerobic system**

**3) ATP/PC system**

More intense the activity- rely more on ATP/PC and lactic acid. The less intense and longer the duration the more the aerobic system will be used.

**The Aerobic System**

* When oxygen is readily available, the body can release energy from muscle glycogen and fats.
* Most efficient in terms of ATP re synthesis.
* Glucose 6 Phosphate is converted to acetyl- coenzyme-A.
* The site for this reaction is the mitochondria – lots in the muscles especially slow twitch fibres.

Matrix- Krebs cycle

Cristae- Electron Transport Chain

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**Top Tip!**

Aerobic system- low intensity exercise for a long period of time. E.g. marathon runner.

Slow twitch muscles house more mitochondria than fast twitch and are suited to activities such as marathon running.

**Krebs Cycle**

In the matrix part of the mitochondria

**Three significant events occur at this stage.**

Oxidation of Citric Acid: removal of hydrogen atoms from the compound which enters the final stage of the aerobic system: the ETC

Production of Carbon Dioxide: removal of hydrogen means that only carbon and oxygen remain. These combine to form carbon dioxide which is breathed out by lungs.

Re synthesis of ATP: sufficient energy is released at this stage to re synthesis 2 molecules of ATP.

**The Electron Transport Chain**

Final stage of glycogen breakdown occurs in the Cristae of the mitochondria. Hydrogen given off at the Krebs Cycle is carried into the Electron Transport Chain .

**Two main things happen in this stage**:

1. **Water (H20) is formed** when the hydrogen ions (H+) and electrons (e-) combine with oxygen through a series of reactions.
2. **Re synthesis of ATP**: the majority of energy is realised here for the re synthesis of ATP. 34 molecules of ATP can be re synthesised.

**Other fuels used in aerobic energy production**

* Fat can also be metabolised under aerobic conditions to form CO2, H2O and energy for ATP re synthesis.
* Fats stored as triglycerides must first be broken down into glycerol and free fatty acids before they go through the process of Beta oxidation (Fat equivalent to glycolysis)
* Following beta oxidation fatty acids can enter the Krebs cycle and follow the same path as glycogen.
* The main difference is that fat can re synthesis more ATP
* Fatty acids are the preferred fuel as the duration of exercise increases. I.e. after 20 mins of sub max activity. Endurance performers need to use their glycogen sparingly.

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**Key Terms:**

**Mitochondria**: the powerhouse of the cell. Site of ATP production under aerobic conditions.

**Advantages of this system:**

* Significantly more ATP can be re synthesised under aerobic conditions than anaerobic. 36ATP.
* The body has substantial stores of muscle glycogen and triglycerides to enable exercise to last for several hours.
* ****Oxidation of glycogen and fatty acids do not produce any fatiguing by products.

**Drawbacks of this system:**

* When we go from resting state to exercise it takes a while for sufficient oxygen to become available to meet the demands of the exercise and enable the complete breakdown of glycogen and fatty acids. So it can’t provide energy to re synthesis ATP immediately
* Although fatty acids are the preferred fuel during endurance events, the transport of fatty acids to the muscle is slow. It requires about 15% more oxygen than that required to breakdown same amount of glucose.
* Due to the low solubility of fatty acids the endurance athletes will use a mix of both glycogen and fatty acids to provide energy. When glycogen becomes depleted and the body attempts to use fatty acids as the sole source of fuel, and the muscle spasms- hitting the wall.

***Breakdown of one mole of glycogen can be shown as***

***C6 H12 O2 + 6O2 – 6CO2 + 6H2O + energy***

**The Aerobic System and Recovery**

**Recovery process**- returning the body to its pre exercise state. Heart rate, oxygen consumption, blood lactate levels and glycogen stores are the same as before you exercised.

Recovery period involves a period were heart rate and breathing rates are elevated. This is because all recovery is dependent on oxygen consumption, and the elevated respiratory and heart rates ensure enough oxygen is taken to the muscles to allow a quick recovery. It also helps rebuild stores of PC and ATP, as well as removed Lactic Acid.

**Key Terms:**

**Recovery**: the return of the body to its pre exercise state

**Excess post-exercise oxygen consumption (EPOC):** the volume of oxygen consumed during recovery above that which normally would have been consumed at rest during the same period.

**Oxygen Deficit**: the volume of extra oxygen required to complete the entire activity aerobically.

**Excess post-exercise oxygen consumption (EPOC)**

This is the ***extra volume of oxygen consumed following exercise that enables the body to fully recover and return to its pre exercise state.***

Beginning of exercise- both low and high intensity the body will need to work anaerobically at some point as there may be insufficient oxygen available to use the aerobic system straight away. A deficit occurs in the oxygen supply.

The oxygen deficit represents the amount of extra oxygen required to enable the entire activity to be compacted using the aerobic energy system. Since it takes a while for the aerobic system to kick in and provide the muscles with energy at the beginning of activity, a deficit will always develop.

**Two stages**

1. Fast Replenishment stage (Alactacid stage)
2. Slow Replenishment stage (Lactacid debt)

**Top Tip to Remember!**

The term oxygen debt was used to explain the restoration of ATP and PC and removal of lactic acid during recovery. This failed to explain the extra oxygen needed during recovery to restore muscles oxymyoglobin and to keep respiratory and heart rates elevated. EPOC is therefore the preferred term now, and oxygen debt is viewed as one part of this process.

In the graph below the volume of EPOC is greater than the volume of oxygen deficit. This is because the ‘muscles’ of recovery such as the heart and respiratory muscles requires oxygen to keep breathing and heart rate levels elevated.

In figure 10b the two stages of recovery are clearly visible following maximal of high intense exercise. However, following sub maximal or low intensity exercise only the fast stage may be evident. This is due to the majority of the work had been completed aerobically and little lactic acid has accumulated during the exercise.

**Fast Component**

1. Restoration of muscle ATP and PC
2. Re-saturation of myoglobin with oxygen

**Excess**

**Post-exercise**

**Oxygen**

**Consumption**

**Slow component**

1. Removal of lactic acid
2. Maintenance of elevated heart rate and respiratory rate
3. Replenishment of glycogen stores
4. Elevated body temperature

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**Key Terms:**

**Fast Replenishment:** the first component of EPOC. Oxygen consumed is used to re saturate myoglobin and resysnthesise ATP and PC. Takes approx. 2-3 mins.

**Slow Component:** the second component of EPOC. Oxygen consumed during this stage is largely used to remove lactic acid which takes about one hour. In addition oxygen is also used to maintain heart and respiratory rates and normalise body temperature.

**The Fast Replenishment stage:**

First stage and relates to the immediate consumption of oxygen following exercise.

Primary function- re saturate myoglobin with oxygen and provide aerobic energy to re synthesise ATP/PC stores.

2-3 mins, 4 litres of oxygen.

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**Top Tip!**

* **50% of PC stores are restored within the first 30 seconds of recovery.**
* **As a coach how could your knowledge of this help in team games? Think time outs!!!**

**Slow Replenishment Stage**

This stage can take up to 2 hours and uses 5-10 litres of oxygen.

This stage has several functions:

**Removal of Lactic Acid:**

* This must be removed if the boy is to recover from exercise totally.
* Most lactic acid- converted back to pyruvate and then into C02 and H2O. The reminder being converted to muscle glycogen and blood glucose.
* Much of the oxygen consumed in this stage is to aid this removal. Takes about an hour but can be speeded up by a cool down.
* Cool down/ active recovery keeps metabolic activity of the muscles high and capillaries dilated so oxygen can be flushed through the tissues helping to removed lactic acid.

**Maintenance of elevated heart and respiratory rates:**

* Like any other muscles the heart and respiratory system need oxygen to provide energy to help the work continually.
* During recovery extra oxygen is needed to keep heart rate and breathing rate above resting levels.
* This is to allow the lungs to take in more oxygen which can then be pumped round the body to working muscles to re saturate myoglobin, resynthesise ATP/PC and remove lactic acid.

**Replenishment of muscle glycogen stores:**

In all types of exercise some muscle glycogen stores will become depleted. We need to replace theses as soon as possible. The replenishment of glycogen is dependent on two factors:

1. ***Type of exercise that has been performed***
2. ***Amount and timing of carbohydrate consumption following exercise.***
3. **Type of exercise that has been performed:**

**Continuous/ endurance based:** little glycogen is restored straight away. This can take up to 48 hours

**High intensity/ short duration**: a large amount can be restored in 30 mins- 1 hour straight away. (Lactic acid back to glycogen) 24 hour recovery period.

1. **Amount and timing of carbohydrate consumption following exercise.**

Muscle glycogen is replenished quicker if a meal high in carbs is consumed 45-60 mins after exercise. Carbohydrate window. 200-300gs.

**Elevated Body Temperature**

* Increase in body temperature results in an increase in metabolic activity which provides energy to perform work. Every 10 degrees increase metabolic activity doubles. More oxygen is needed to feed this increase even if exercise has stopped until the body has cooled down to normal levels.

***A 400m runner will consume a large volume of oxygen during the slow replenishment stage as a large amount of lactic acid will have accumulated in their muscles.***

**Key Terms:**

**Active Recovery:** recovery time when light exercise if performed.

**Rest Recovery:** recovery period in which the performer has rested passively

**Cori Cycle**: process where lactic acid is take to the liver for conversion into glucose and glycogen .

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**Top Tip!**

The exercise intensity during a cool down that best removes lactic acid is between 30-45% V)2 max for untrained subjects and 50-65% VO2 max for trained subjects.

**Maximal Consumption of Oxygen (VO2Max)**

***The maximal volume of oxygen that can be utilised or consumed by the working muscles per minute.***

High V02 max characterises good endurance.

The ability of muscles to consume the greatest amount of oxygen is dependent on to further key factors:

1. Effective oxygen delivery system that brings oxygen from the atmosphere into the working muscles.
2. Aerobic friendly muscle structure with large volume of mitochondria and myoglobin.

Measuring V02 max

Fitness Tests: multi stage fitness test, Harvard step test, cooper 12 min run.

Only direct gas analysis can measure true V02 max.

Treadmill test……

**Key Terms:**

**Direct Gas analysis:** most valid and reliable method of measuring V02 max. During the test, subjects are measured at progressively increasing intensities on a treadmill. Concentrations of CO2 and O2 inspired and expired are monitored.

**Absolute V02 max:** a V02 max value given in litres/min

**Relative VO2 max:** a V02 max value that take into account of bodyweight and measured in millilitres of oxygen per kg of bodyweight per minute. (ml/kg/min)

**Factors affecting maximal oxygen consumption (V02 max)**

**Physiology**

High % slow twitch muscle fibres

High capillary density

High mitochondria density

High blood volume and haemoglobin content

**Lifestyle**

Smoking, sedentary lifestyle and poor diet can reduce V02 max values



**Genetics**

Accounts for 20-50% of V02 max scores.

**Age**

Decreases with age

After 25 years 1% per year

**Body Composition**

V02 max scores decrease as body fat increases

**Gender**

Untrained male- 3.5 litres/min

Female -21/min

43% difference !

**Training**

Can only be improved by 10-20% by training

Continuous, fartlek and aerobic interval training.

**The Anaerobic systems**

**ATP/PC**

High intensity activity we need to rapidly replenish ATP stores quickly so the body uses stores of Phosphcreatine (PC)

Breakdown of PC takes place in the sarcoplasm

Facilitated by enzyme Creatine kinase

The release of Creatine kinase is stimulated by an increase in ADP and free phosphates.

Endothermic reaction

**The Coupled Reaction**

PC exists alongside ATP in the sarcoplasm of the cell, as quickly as energy is released from the breakdown of ATP during exercise, it is restored by the breakdown of PC. linked reaction- simultaneous.

**Advantages of the system**

* ATP can be re synthesised very quickly
* PC stores can be recovered very quickly 2-3 minutes, so high intensity exercise can be undertaken again.
* Anaerobic process so doesn’t need to wait for the 3 mins for sufficient oxygen to be present.
* No fatiguing by products that could delay recovery
* Some performers seek to extend the time that they can use this system through Creating supplementation.

***ATP/PC system is used by performers such as 100m sprinters and a gymnast performing a vault.***

**Drawbacks of this system**

* Limited amount of PC stores- 10 seconds
* Re synthesis of PC can only occur when there is sufficient oxygen available- usually during resting conditions
* Only one mole of ATP can be re sysnthesised by one mole of PC.

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**Top Tip!**

Don’t forget that for very high intensity lasting less than 3 seconds, the energy here is provided solely by the breakdown of ATP- ATPASE…..

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**Key Terms:**

**Sarcoplasm:** fluid that surrounds the nucleus of a muscle cell that is the site for aerobic and anaerobic pathways.

**Creatine Kinase:** the enzyme used to release energy from Phospho Creatine

**Endothermic Reaction:** A chemical reaction that consumes energy

**Coupled Reaction:** a reaction where the product of one reaction is used in linked (second) reaction. The ATP/PC system is an example of a coupled reaction.

**The Lactic Acid System**

* If the exercise lasts longer than 10 seconds the body switches to glycogen which is stored in liver and muscles.
* Converted to **Glucose 6 phosphate** before it is broken down to form Pyruvate
* This is done by **Phosphofructokinase (PFK) and Glycogen Phosphorylate (GP)**
* This system produces a net gain **of 2 molecules of ATP**.
* In the absence of oxygen pyruvate is converted to **Lactic acid via lactate Dehydrogenase**

**Advantages of this system**

* Few chemical reactions so ATP can be re synthesised quite quickly for bouts of exercise 10 seconds to 3 mins
* Anaerobic so doesn’t have to wait for 3 mins like the aerobic system.
* Any lactic acid produced can be converted back to liver glycogen and fed back into the respiration system.
* In aerobic activities i.e. 10,000 meters the system can be used for an extra bursts of energy during the race or at the end of the race.

**Drawbacks of this system**

* Accumulation of lactic acid which can inhibit the glycotic enzymes.
* Only a small amount of energy can be released from our Glycogen molecule (5%) the remaining 95% can only be released in the presence of oxygen.

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**Top Tip!**

The lactic acid system is on particular use to performers who need to perform high intensity exercises for a period of 1-2 mins. 400m runner.

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**Key Terms:**

**Threshold:** the point at which one energy system is exhausted and another takes over as the predominate energy system

**Glycogen**: form of carbohydrate stored in the muscles and liver

**Glycolysis:** breakdown of glucose to pyruvic acid.

**Onset of Blood Lactate Accumulation (OBLA)**

A large VO2 max sets the ceiling for endurance performance and is an indication of the size of our aerobic engine. But it is the onset of blood lactate accumulation that determines the actual percentage of that engine power that can be utilised.

***The OBLA is the point at which lactic acid starts to accumulate in the muscles***.

***During normal resting conditions thee amount of lactic acid in the blood is 1-2 millimoles/litre.***

This rises dramatically during exercise- the more intense the exercise the more lactic acid is accumulated.

***OBLA occurs at 4 millimoles/litre.***

Just like V02 max , OBLA occurs at different intensities for different people and it is expressed as a percentage of your V02 max.

For the average untrained individual OBLA occurs at around 55-60% of their V02 max whilst trained endurance performers can delay their OBLA until they have utilised 85-90% of their V02max.

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**Top Tip!**

Lactate Threshold and Anaerobic threshold, together with OBLA describe the same phenomenon.

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**Key Terms:**

**Onset of Blood Lactate Accumulation (OBLA):** The point at which lactic acid begins to accumulate in the blood. Usually taken when concentrations of lactic acid reach 4 mmole/litre of blood.

**Lactate Sampling and measurement of OBLA**

* OBLA can only truly be measured in a laboratory.
* The performer will exercise on a bike, treadmill etc.
* The test is 4-6 stages
* 1st stage: 50% of VO2max and gradually gets harder at each stage lasting around 5 mins.
* At the end of each stage heart rate recorded, oxygen consumption measured and blood samples taken.
* The level of exercise is recorded once lactate levels reach 4mmole/litre.

**OBLA and Training**

Improvements in endurance can be observed where lower lactate levels are recorded for any given exercise intensity.

Shows the body has adapted to cope with higher levels of blood lactate and increased the rate of removal by buffering.

Untrained performers usually reach OBLA at 55% of their VO2max this can go up to 70% or higher.

***Remember: OBLA can be in influenced by training- most of VO2max is genetically determined.***

**What happens to Lactic Acid…**

* Lactic acid produced when insufficient oxygen.
* Pyruvate is converted to lactic acid via lactate dehydrogenase.
* Once formed it dissociates into lactate and hydrogen ions.
* The presences of the hydrogen ions makes the muscle acidic and fatigue.
* Acidic environment ceases the breakdown of further glycogen. Irritates nerve endings- heavy legs
* Some lactic is converted to glycogen and can be reused.

|  |  |
| --- | --- |
| **Lactic Acid Fate** | |
| **Conversion into CO2 and H2O** | 65% |
| **Conversion to glycogen** | 20% |
| **Conversion to protein** | 10% |
| **Conversion to glucose** | 5% |
| **Conversion to sweat and urine** | 5% |

**Factors influencing the rate of Lactic Acid accumulation**

1. **Exercise intensity**

Higher intensity- more ATP demand. Pyruvate soon converted to lactate

1. **Respiratory Exchange Ratio**

The closer the value is to 1.0 the more likely the body is using glycogen as fuel and the greater the chance of lactic acid accumulation. If the value is nearer 0.7 then fatty acids are the likely fuel.

VCO2 expired/min

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VO2 uptake/min

1. **Muscle fibre type**

Slow twitch fibres produce less lactic acid at a given workload than fast twitch. Slow twitch have more mitochondria, so pyruvate is more likely to be converted to Acetyl COA.

1. **Rate of Blood Lactate removal**

If the rate of blood lactate removal matches that of the production, the performer will be ok. It is when the rate of lactic acid accumulation is greater than that of removal that OBLA occurs.

1. **The trained status of the working muscles**

If muscles are trained they will reap the benefits of improved capacity for aerobic capacity such as mitochondria and capillary density, improved use of fatty acid as a fuel (no waste products) and increased stored of myoglobin.

**Key Terms:**

**Buffering**: a process which helps in the removal of lactic acid and maintains blood and muscle pH

**Physiology of Skeletal Muscle Learning Objectives:;**

* Distinguish between the different muscle fibre types in the body and explain how each can be of benefit to specific performers.
* Give a definition of a motor unit and explain its role in muscular contraction.
* Explain the term spatial summation in the relation to muscular contraction and apply it to sports performance.
* Explain the contraction of skeletal muscle using the sliding filament hypothesis.
* State the adaptive response expected on the muscle following a period of resistance training.

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**Key Terms:**

**Muscle Belly:** the whole muscle composed of many individual muscle fibres

**Fasciculi:** bundles of muscle fibres that make up the muscle belly.

**Actin:** the thin protein filament found in muscle cells that together with myosin form sarcomeres, the contractile units of skeletal muscle.

**Actin:** the thin protein filament found in muscle cells that together with actin form sarcomeres, the contractile units of skeletal muscle.

**Sarcomere**: the contractile units of skeletal muscle. They are composed of two myofilaments, actin and myosin.

**The Sliding Filament Theory of Muscle Contraction**

* This theory explains the sequence of events leading up to muscle contraction.
* It is the cooperation of two proteins that make up all muscle cells.
* **Actin and Myosin** together form sarcomeres, which are the contractile units of the **myofibril** and are joined end to end along the myofibril.
* During muscular contraction, the **thin actin filament slides inwards over the thicker myosin filaments**, causing a shortening of each sarcomeres along the entire length of the myofibril.
* This causes a shortening of each muscle fibre and therefore the characteristic shortening of the entire muscle during muscular contraction.

**Sequence of events in the Sliding Filament Theory**

**Step 1: Preparation of the binding site**

* Upon receiving an **action potential** (signal to contract)
* The **sarcoplasmic reticulum** release **calcium ions** via the **Transverse Tubules**
* The calcium ions bind to the protein on the Actin filament called **Troponin** which moves **Tropomyosin** out of the way and exposes the active **binding sites** on the Actin filament.

**Step 2: The Power Stroke**

* The myosin filament extends a golf club shaped ‘**cross bridge’** which attaches to the binding site on the Actin filament.
* When it binds the myosin head is in an energised state and pulls on the actin filament pulling it inwards towards the centre of the sarcomere.
* This is called the **power stroke**
* This reaction **uses ATP**

**Step 3: The binding of ATP**

* In order to break the cross bridge and re energise the myosin head, ATP is needed.

**Step 4: The Ratchet mechanism**

* This power stroke action can be continued for as long as there is calcium ions present- in a ratchet like manner
* Coupling and uncoupling of myosin and actin

**Step 5: The return of calcium ions back to sarcoplasmic reticulum.**

* Once the action potential has diminished, all of the calcium ions return to the Sarcoplasmic Reticulum.
* The shape of the Troponin will once again change allowing tropomyosin to return to its protective position of covering the myosin cross bridge site.
* Tropomyosin will remain in this position as long as the muscle is relaxed.

**Sample Exam Question**

***Explain how skeletal muscles contract according to the Sliding Filament Theory…***

**Key Terms:**

**Tropomyosin:** threadlike spirals that wrap around the actin filament which covers the myosin binding site which prevents myosin from attaching during a relaxed state.

**Troponin**: a calcium receptor that sits on top of Troponin. In the presence of calcium ions it pulls tropomyosin away from the myosin binding site and allows myosin to bind to the actin filament and the sliding filament mechanism to commence.

**Myosin Cross Bridge**: the arm and head of the myosin filament which extends to bind onto the actin filament.

**Sarcoplasmic Reticulum:** a system of membranous sacs that surround the myofibrils. The sarcoplasmic reticulum stores calcium and regulates its release during muscular contractions.

**Types of Muscle Structure**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Slow Twitch**  **Type 1** | **Fast Oxidative Glycotic (FOG)Type 2a** | **Fast Twitich Glycotic (FTG) type 2b** |
| Functional Characteristic | | | |
| **Speed of contraction** | Slow | Fast | Fast |
| **Force of contraction** | Low | High | Highest |
| **Resistance to fatigue** | Very high | Moderate | Low |
| **Aerobic capacity** | Very high | Moderate | Low |
| **Anaerobic capacity** | low | High | high |
| Structural characteristic | | | |
| **Fibre size** | small | large | large |
| **Mitochondria density** | high | moderate | low |
| **Capillary density** | high | moderate | low |
| **Myoglobin content** | high | moderate | low |
| **PC store** | low | high | high |
| **Glycogen store** | low | high | high |
| **Triglyceride store** | high | moderate | low |
| **Motor neuron size** | small | large | large |
| **Activity suited** | Marathon | 1500m | Shot putt |

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**Key Terms:**

**Slow Twitch muscle fibre**: Muscle fibre that uses oxygen to produce energy. Associated with endurance activities

**Fast Twitch muscle fibre**: types of muscle fibre that has a high glycotic capacity. Associated with speed and power based activities.

***\*\*\*Performers will have varying distribution of muscles fibre types dependent on their sport. I.e. endurance athlete will have more slow twitch muscle fibres. \*\*\*\****

**Muscle Fibre Recruitment**

* Primary function of skeletal muscle is to contract and facilitate movement
* Contraction involves interaction with the nervous system
* Individual muscles are connected to the nervous system via a group of motor neurons.
* Each muscle fibre within the muscle belly is supplied by just one motor neuron, but this motor neuron can stimulate anything form a few fibres to hundreds!
* Motor neuron plus the fibres it stimulate sis called motor unit.

**The Motor Unit**

* Each muscle is made up of several motor units.
* The number of motor units that are recruited at any one time in the muscles varies with the amount of strength required for a given movement. The more strength needed the greater the number of motor neurons activated.
* The number of fibres within a particular motor unit is dependent upon the control of the movement required in that muscle.
* A small muscle that needs to perform fine motor control such as the eye may only have one fine per motor unit.
* Where as large muscles responsible for gross movements ie quadriceps group when kicking a ball. May be innervated by a motor neuron supplying 500 or more fibres.
* Motor units are made up of the same fibre type i.e. fast or slow twitch. Fast twitch recruited in high intensity activities, slow twitch endurance.

***More motor units will be recruited when performing a bicep curl against a load of 10kg than of 5kg.***

**Innervation of skeletal muscle**

The innervation of skeletal muscle is accomplished by a motor neuron transmitting a nerve impulse or action potential to the muscle fibre. How the muscle fibres responds is governed by the **ALL OR NONE LAW**

**All of None Law**

***States that the individual muscle fibres in a motor unit contracts either fully or not at all.***

* Muscle fibres cannot partially contract!!
* In order to activate these muscle fibres a minimum level of simulation is needed- it needs to reach a threshold.
* If the stimulation exceeds the threshold then all of the muscle fibres within the motor unit will contract at the same time to their maximum possible extent.
* If the stimulation falls short of the threshold then none of the fibres will contract.

**Variations in the strength of the muscle response**

Sporting performances require variations in strength from weak efforts such as a golf putt to maximal efforts like shot putt.

* **Multiple unit summation**
* Strength can be increased by recruiting more motor units. Fast twitch motor units will be recruited over slow twitch for more powerful contractions.
* **Wave summation/Spatial Summation**
* Considers the frequency that the impulse arrives at the motor unit.
* Motor unit responds to an impulse giving it a twitch- short period of contraction by relaxation.

**Wave summation**

* If the second impulse arrives at the motor unit before it has time to completely relax from the first twitch the motor unit will respond with stronger contractions.
* Tetanic contraction…

**Spatial summation**

* Motor neurons are stimulated out of sync to allow one to contract whilst one relaxes.
* This allow the muscle fibre to contract without fatigue.
* Good for endurance events/ performers

**Neuromuscular adaptions to resistance training**

Resistance training will…..

**Recruitment of motor units**

* More motor units may be trained to act synchronously so that greater forces can be generated resulting in bigger strength gains.

**Muscle hypertrophy**

* Size of the muscle belly will increase due to increase in size of individual muscle fibres.

**Hypertrophy of fast twitch fibres**

* As these fibre types are predominantly recruited in strength training these will enlarge.

**Conversion of Type 2b fibres to type 2s fibres**

* This change could account for the delay in muscular fatigue associated with prolonged training.

**Preparation and Training for Successful Performance Learning Objectives:**

* Outline the range and function of sport supplements available to the performer to include: Creatine, protein, herbal supplements, bicarbonate of soda and caffeine.
* Explain the ergogenic effects and associated health implications of the following substances: EPO, anabolic steroids, Human Growth Hormone and Beta Blockers
* Suggest a glycogen loading regime for an endurance performer
* Explain the relationship between water intake and electrolyte balance
* Briefly outline the different methods of training at the dispense of the coach and athlete
* Apply the most appropriate methods of training to particular sporting performers.
* Give a detailed explanation of plyometrics training
* Give a detailed explanation of PNF training
* Give a detailed description of Altitude Training
* Explain the term periodization
* Outline a typical periodization plan for a performer
* Explain the process and physiological reasons behind altitude training
* Explain the mechanism of thermoregulation to maintain body temperature when exercising in different climatic environments



**Sports Supplements and Ergogenic Aids**

****

**Key words:**

**Ergogenic aids:** any substance, method or object used by performers in training or competition that has the sole intention of enhancing athletic performance.

**Creatine Supplementation**: the consumption of Creatine monohydrate in powder, capsule or liquid form which can increase the levels of phosocreatine stored in the muscle cell.

**Caffeine**: a mild stimulant that is naturally found in tea, coffee and cola.

****

**Exam Tip!**

In the exam you will be required to state the intended purpose, the athletes most likely to use them, the perceived benefits and the associated risks for each sport supplement and ergogenic aid.

|  |  |  |  |
| --- | --- | --- | --- |
| **Supplement** | **What is it?** | **Side Effects** | **Who takes it?** |
| **Creatine Supplement** | Extend the threshold of the ATP-PC system by ingesting Creatine monohydrate.  LINK TO ENERGY SYSTEM  Can boost maximal strength and lean muscle mass | Abdominal cramps  Water retention  Bloating | Sprinters  Weight Lifters  High intensity/ short bursts |
| **Protein supplements** | If you have a well balanced diet protein supplementation shouldn’t be needed.  Can be taken if in heavy training or vegetarian  Protein of meal replacement shakes. | Possible kidney and liver damage if taken excessively | Weight lifters |
| **Herbal Remedies** | Range offering to reduce body fat, increase muscle mass, enhance energy and improve stamina.  EG Ginseng and Echinacea  Chinese remedies- issues  May have some mild benefits but largely unproven. | May contain prohibited substances so test positive.  Don’t know what’s in them | Range of athletes |
| **Bicarbonate of soda- Soda Loading** | The pH of the blood increases, making it more alkaline. This enhances the buffering capacity of the blood improving its ability to neutralise the negative effects of lactic acid. Extending the threshold of the lactic acid system- work at higher intensities for longer. | Bloating  Diarrhoea  Tummy cramps  Nausea | Any athletes in events peaking 1min! |
| **Caffeine** | Mild stimulant naturally occurring found in coffee tea and cola. Most widely available and accessible pharmalogical aid. Was listed as prohibited by WADA until 2004. Can reduce the feelings of fatigue, increases use of fat as a fuel | Dehydration  Sleep deprivation  Cramping | Endurance performers  Cyclists  Runners |

**Health Implications of Using Illegal Substances**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **What it is?** | **Side Effects?** | **Who uses it?** |
| **EPO** | Synthetic product that mimics the naturally occurring hormone of EPO produced by the kidneys and stimulates the body to manufacture red blood cells. So enhanced oxygen carrying capacity of the blood. Proven benefits, increased haemoglobin content, increased VO2max | Fatal consequences increased red blood cells increased the viscosity of the blood which can lead to clotting and heart failure  Affects the body’s ability to produce it naturally | Cycling  Endurance based sports |
| **Anabolic Steroids** | Group of synthetics hormones related to testosterone. Taken orally or injected facilitate the growth or lean muscle mass. Performers can train harder and for longer, recover quicker  EG THG and Stanozolol | Liver damage  Heart failure  Increased aggression  Masculine effects e.g. facial hair, deeper voice  Testicular atrophy  Reduced sperm count  Baldness  Brest development in males | Strength and power based performers |
| **Human Growth Hormone** | Synthetic hormone that mimic’s the bodies naturally occurring growth hormone- facilitates protein synthesis and lean muscle mass. So used to get stronger | Enlargement of internal organs i.e. heart  High blood pressure  Acromegaly- abnormal bone development  Cancers | Weightlifting  Rugby |
| **Beta Blockers** | Group of hormones used by performers to lower metabolic activity, lower heart rate and blood pressure. Helps steady nerves and trembling. | Low blood pressure  Chronic fatigue | Archer  Snooker  Shooting |

****

**Key words:**

**Viscosity:** measure of resistance to the flow of blood. An increase in viscosity of the blood suggests the blood becomes excessively think, impeding its flow.

**Specialist Training Regimes**

**Plyometrics**

***Type of training designed to improve power, strength and speed in the trained muscles.***

***Usually bounding, hopping and jumping- can do medicine ball exercises***

**Aim**

To preload muscles by taking it through an eccentric contractions which is then immediately followed by a rapid concentric contraction.

When performing a depth jump the quadriceps perform an eccentric contraction upon landing. This stores elastic energy which is released almost immediately when the quadriceps perform a rapid contraction to drive the performer up to the second platform.

The quicker the transition from eccentric to concentric contraction the more effective the exercise.

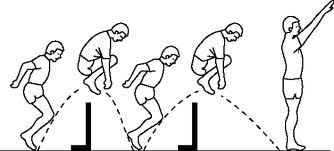
Regular sessions can improve elasticity and contractibility of the muscles fibres which are prerequisite characteristics in the development of speed and power.

**Who benefits?**

Move more quickly, accelerate faster, jump higher and hit a ball further! So just about everyone!!!

**The Theory behind it …..**

* **Muscle spindles**- sensitive proprioceptors lie between skeletal muscle fibres
* When a muscle is stretched during the **eccentric** phase of the contraction, the spindle stretches along with it sending and impulse back to the CNS information it of the extent and speed of muscle lengthening.
* If the CNS thinks that the muscle is lengthening too quickly or too much it initiates a movement called the **stretch reflex** which controls the movement.
* The muscle spindles detect the rapid lengthening and send sensory impulses to the CNS which reciprocates by sending an efferent/motor neuron to the quadriceps muscle initiating a stretch reflex and causing a **powerful concentric contraction.**
* This drives the performer onto the next phase.
* In doing so the muscles spindles have prevented the quadriceps muscles form over stretching and causing injury.



**Proprioceptive Neuromuscular Facilitation (PNF)**

***This is an advanced stretching technique used to improve flexibility***

***Takes full advantage of the muscles safety mechanisms***

* Stretch receptors in the skeletal muscle are called stretch receptors – detect change in length and rate of change of length in muscle fibres.
* When the muscle is stretched so is the muscle spindle
* Information is sent to the CNS to activate the stretch reflex if the muscle is stretched too far.
* Other receptors are sensitive to tension developed within a muscle when it contracts are called Golgi Tendon Organs (GTO’s)
* If the critical tension threshold is exceeded within the muscle, the GTO initiates muscle relaxation known as autogenic inhibition.
* Because the GTO’s override the stretch reflex the window of relaxation is extended, allowing a greater stretch.

|  |  |
| --- | --- |
| **Undertaking PNF** | |
| **Method** | * With the aid of a partner a performer moves a body part to the limit of its range of movement, and stays in position for several seconds. * The performer should now isometrically contract the target muscle for 6-10 seconds- usually pushing against a resistance offered by the partner * The muscle is then relaxed * The target muscle is once again moved to the limit of its ROM by the partner |

**Key Terms:**

**Proprioceptive neuromuscular facilitation (PNF**) :A stretching technique that overrides the stretch reflex to enable a performer to active a greater range of movement in a joint.

**Golgi Tendon Organ (GTO):** proprioceptors found at the attachment of a muscle and tendon fibres that are sensitive to changes in muscle tension.

**Stretch Reflex:** the stretch reflex is initiated when a muscle is stretched too far. It acts to prevent damage to the muscle fibres.

**Attitude Training**

**Why do it?**

Concentration of oxygen in a given volume is reduced at altitude. Partial pressure decreases by 50% at altitude of 5,000m so the body compensates by breathing more quickly and deeply in an attempt to increase blood- oxygen concentrations to normal levels. Heart rate also increases to deliver more oxygen to the tissues. These responses occur immediately where as some take up to 30 days to complete.

Such as production of red blood cells, and an increase in the haemoglobin concentration of blood.

Upon returning to sea level the increased concentrations of red blood cells and haemoglobin remain elevated for about 6-8 weeks and greatly enhance the oxygen carrying capability of the blood.

**Problems with training at altitude**

Can you name perceived benefits and drawbacks of altitude training?

* Training is harder- less oxygen
* Expensive
* Lactate levels increase and V02 max is reduced
* Possible detraining effect

***Best solution is now to live at altitude and train at sea level. Performers can simulate low oxygen environments by hypoxic and altitude tents.***

**Key Terms:**

**Altitude Training:** training above 2,500m above sea level. Reduced pO2 of oxygen causes body to compensate by producing more red blood cells. Hyperbaric chambers can now be used at sea level to mimic the effects of altitude.

**Detraining**: the reversal of positive training effects

**Glycogen Loading:** manipulating the consumption of carbohydrate in the week prior to a competition can increase muscle glycogen storage capacity.

**Glycogen Loading**

***Manipulation of dietary intake of carbohydrate prior to a competition so that muscle glycogen stores are maximised.***

Process favoured by endurance athletes as it elevates stores of glycogen above normal which facilitates the resynthesis of ATP via the aerobic pathway.

**Process**

* Depletion of glycogen stores 7 days before competition
* Three days of low carbohydrate diet- tapering the exercise
* Days up to the competition consume a carb rich diet and little or no exercise

\*Can double the amount of glycogen available.

\*Some say that in trained performers you don’t need to deplete 7 days before, just rest and lots of carbs!

|  |  |
| --- | --- |
| **Benefits of Glycogen Loading** | **Drawbacks of Glycogen Loading** |
| Increased glycogen synthesis | Water retention and bloating |
| Increased muscle glycogen | Weight increase |
| Increased endurance capacity | Fatigue and muscle soreness |
| Delays fatigue/ reduces risk of hitting the wall | Irritability during depletion phase |

**Planning Training Programmes**

You must remember the SPORM/T and FITT principles as a coach….

**Periodisation**

***Organisation of training into blocks or cycles which have a particular focus to enable the performer to peak at the right time.***

Three periods:

* **Macrocycles:** long term performance goal. Athlete- Olympics, footballer year long season.
* **Mesocycles:** sub divisions of a macrocycle, lasting 2-8 weeks. Usually have a particular focus e.g. development of speed in pre season training.
* **Microcycles:** sub divisions of mesocycles, usually a week in duration. More detail with regard to volume and intensity of training.
* Training unit..

**Macro cycle**

Focussed on peaking at major competition/ event.

**Three phases: preparation, competition and Transition or recovery**

**Preparation Phase (Phases 1 and 2)**

Similar to pre-season training.

* **General conditioning stage**

High volume- low intensity work, develop an endurance base. Aerobic, muscular endurance strength and mobility.

* **Competition specific training**

Increase in intensity. Lots of strength and speed work. Technique and tactical application

**Competition Phase (Phases 3, 4 and 5)**

* Develop optimal competition performance. Volume of training is decreased but intensity of training is increased.

**Phase 3 (6-8 weeks)**

* Competition period. Trials and qualifying period

**Phase 4 (4-6 weeks)**

* Mini transition period recover and prepare for phase 5.

**Phase 5 (3-4 weeks)**

* Culmination of the training year!!
* Training tapered for peak performances. 10-21 days, can vary.
* Transitional Period (Phase 6)
* Very important. Active recovery, recharge the batteries.

**Key Terms:**

**Peaking**: the planning and organisation of training so a performer can be at the height of physical and psychological conditioning during major competitions.

**Tapering:** reduction in the volume of training prior to a major competition. It enables an athlete to reach peak performance.

**Mesocycle- short term training goal**

* 2- 8 weeks in duration. With the focus of a particular component of fitness i.e. strength.

**Microcycle- the training week**

* Details of intensity, volume and sequence of training programmes. 3:1 ratio. Work to rest days.

**Training unit**

* Single training session.

Ie improve lactate tolerance

5 x 100m on 4 minutes, max effort

3 x 200m on 5 mins max effort

8 x 75m on 3 mins, max effort.

Double periodisation …..

**Thermoregulation during exercise**

Body regulates its temperature by heat loss and production. Core temperature is 36.5-37.5 degrees Celsius.

The temperature is regulated by the hypothalamus of the brain- similar to a thermostat that reacts to change both internally and from environment.

There are lots of thermo receptors in the body that feed information to the hypothalamus to maintain core temperature.

**Body Temperature during exercise**

Increased muscular activity increase heat, the muscle can’t store the heat and so the enzymes become denatured in the body at high temperatures.

**Heat Loss**

**Conduction**

* Heat is lost through the physical contact between one object and another. Always from warmer to cooler object.

**Convection**

* Losing heat through contact between skin and moving air or water. Eg standing inn front of a fan.

**Radiation**

* Losing heat via inferred rays. Where no contact is made. Body temperature is warmer than the environment.

**Evaporation**

* Process by which the body loses heat by conversion of liquid to vapour. I.e. sweating.
* As the core body temperature increases the hypothalamus reacts by increasing the blood flow to the skin, this stimulates the sweat glands.
* Sweat- water and electrolytes such as potassium, sodium and chloride.
* We can lose up to 1-2 litres of sweat during moderate exercise.
* The amount depends on many things such as fitness of individual, humidity, intensity of exercise.

**Humidity:-** this can compromise the body keeping cool as in order to have a cooling effect, water must be evaporated off the skin. High humidity prevents this from happening and as a result can lead to heat stroke and dehydration.

**Cardiovascular Drift:-** as you sweat blood plasma thickens as fluid is lost through sweating. If blood volume decreases there is a fall in venous return. Starlings Law

****Also stroke volume decreases in heat as more blood is redirected to the skin so less venous return. Starlings Law.

**Exam Tip!**

Training improves the thermo regularity of the body by enhancing the sweating ability of the body. Training increases the total blood volume and maximal cardiac output which improves blood flow to the skin, allowing earlier onset of sweat secretion.

**The Nature of Injury in Sport**

**Injuries come from two main areas:**

|  |  |
| --- | --- |
| **Intrinsic Factors** | **Extrinsic Factors** |
| * Age * Sex * Body weight and composition * Muscle weakness * Joint hyper laxity * Poor flexibility | * Training methods * Training volume * Playing surfaces * Inappropriate equipment * Inappropriate clothing- footwear * Environmental conditions |

**Injury Prevention**

Preparation from both coach and performer!

|  |  |
| --- | --- |
| **Intrinsic considerations** | **Extrinsic considerations** |
| Ensure proper warm up | Avoid abrupt and drastic changes in training routine |
| Ensure necessary fitness levels | Ensure use of correct and appropriate equipment |
| Allow sufficient recovery to make sure they are not fatigue | Ensure use of correct and appropriate clothing |
| Strengthening exercise to avoid imbalances | Pay attention to environmental factors |
| Sound nutritional programme | Abide by the rules |

**Injury Management**

Assessment of why the injury occurs and then treatment, maintaining and minimising loss of fitness and then rehabilitation.

This needs to be carefully planned.

**Stage 1**

First Aid- immediate treatment

**Stage 8**

Gradual return to competition

**Stage 2**

RICE

**Stage 3**

Early management: diagnosis and treatment plan

**Stage 7**

Attention to performing correct technique and appropriate equipment

**Stage 6**

Developing sports specific fitness

**Stage 4**

Maintenance of cardio fitness whilst resting injured part

**Stage 5**

Strengthening and stretching exercises

**Sports Rehabilitation**

**Exam Tip!**

For each rehabilitation method you need to know what is involved, the physiological reasons for its use, those performers likely to benefit, and give an opinion on if you think it is appropriate or not.

**Use of Hyperbaric Chambers to treat sports injuries**

Originally developed to treat decompression sickness

Chamber delivers oxygen at a high pressure 2 ½ greater than atmosphere.

100% oxygen

As pressure rises so does the amount of oxygen inspired by the performer. Haemoglobin becomes fully saturated, and any excess oxygen is dissolved in the plasma.

This high pressure allows oxygen to be delivered to parts of the body a higher concentrations that it wouldn’t normally reach. Improves blood supply, formation of new cells enhancing growth and repair of tissue.

**Used to treat:**

* Soft tissue injuries and swelling
* Tendon and ligament damage
* Tissue infections
* Compromised immune system

**Use of oxygen tents to treat sports injuries**

Hypoxic tents have widely been used by footballers.

Also endurance athletes who want to mimic the effects of altitude.

Chambers that regulate amount of oxygen delivered to performer whilst asleep

Replicate low oxygen conditions then the body produces more red blood cells, which allows the fitness of the performer to be maintained even if not training.

Used to preserve the fitness not heal injury.

**The use of ice baths to treat sports injuries**

Can treat tissue swelling and soreness that follows exercise and is believed to speed up recovery process.

Immersion in cold water constricts the blood vessels surrounding the muscles, squeezing and draining the blood and waste products form the leg.

Exiting the bath after 6 mins or so causes a blood rush which flushes the muscles with fresh oxygen

Bit like an oil change!

**Delayed onset of muscle soreness DOMS**

Feelings of tenderness in days after exercise

New to exercise or eccentric contractions

Microscopic tears in the muscle fibres and connective tissue and then swelling.

**How to avoid:**

* Warm up properly
* Progress low intensity to high n training session
* Start a new activity slowly and build up
* Limit the amount of eccentric contractions you do in a session.

**Can you?**

Name the method, State what it involves

Physiological reasons for its use,

Who benefits, Does it work?

**Water and Electrolyte Balance**

Heat exposure combined with exercise can also result in hypo hydration (low fluid levels) if we do not replace them as we exercise.

We lose water through sweating and inadequate fluid intake.

All levels of dehydration are associated with a decrease in performance.

High temperatures and humidity all increase the amount of fluid lost by sweat.

**Symptoms of dehydration:**

* Lethargy, nausea, loss of appetite, anxiety, dizziness and vomiting
* Eventually leading to heat stroke which can be fatal.

**How does dehydration affect performance?**

Not really sure! But it is thought that a decrease in blood plasma volume, means less oxygen is delivered to the working muscles and increase breathing and heart rates.

**Prevention of Dehydration**

* Attention to fluid intake before during and after event.
* 500-1,000ml two hours before
* Drink at regular intervals during the exercise
* Thirst does not provide an adequate indicator!!
* High intensity exercise- possibly high carbohydrate drinks- these help replace electrolytes e.g. sodium, potassium and chlorine.

**Exercise in extreme conditions**

* The body can acclimatise to hot conditions over a few weeks which will improve the efficacy of the body in removing excess heat.
* Performance can also decrease in very cold environments- shivering and vasoconstriction of arterioles as the body attempts to stay warm. Can also get wind chill.
* Cold reduces the strength of muscles, they generate less force and produce more lactate.

**Key Terms:**

**Hyperthermia:** a condition in which body temperature is elevated to a high levels

**Hypohydration:** a condition in which there are very low fluid levels in the body.

**The Mechanics of Movement: Learning Objectives**

* Define and give units of measurement for quantities of linear motion.
* Apply each of Newton’s three laws of motion to sporting activity
* Describe the application of forces in sporting activities
* Explain the concept of impulse in sprinting.
* Explain the relevance of momentum in sporting techniques.
* Use high jump to demonstrate the concept of net forces
* Identify the nature of forces acting upon a sports performer
* Sketch free body diagrams identifying the size, type and application of forces acting on a sports performer or object at a given moment in time.
* Explain the factors that govern the flight of projectiles using a shot put as reference
* Apply each of Newton’s three laws to angular motion
* Define and give units of measurement for quantities of angular motion.

**Linear Motion**

**Vector Vs Scalar Quantities**

* **Scalar**- Magnitude. Car travelling at 30mph
* **Vector-** Magnitude and direction. Car travelling at 30mph in north westerly direction.

**Mass Vs Weight**

* **Mass-** quantity of matter a body possesses. Greater the density and volume of the body, the greater the matter and bigger the mass. Shot has a greater mass than a table tennis ball, and is greater in density and volume. Always remains the same at any place. Scalar quality.
* **Weight-** force which a given mass feels due to gravity. If on the moon mass is same i.e. 60kgs, but your weight becomes less by one sixth. Measures in Newtons, always acts downwards from centre of mass- direction as well as magnitude. Vector quality.



**Calculating Weight Force**

If mass is 60kgs, weight is 60X10= 600 newton’s

Force = mass X acceleration (Newtons second law)

**Inertia**

Reluctance of a body to move or change its state of motion. The bigger the mass of an object the harder it is to move/ change its motion- therefore the larger the quantity of inertia.

Eg Sumo wrestler- large inertia

Moving objects that have a higher inertia will need more force to change the state of motion. Ie two rugby players running with the ball at same speed. Heavier one will take more to stop than the lighter player.

**Top Tip!**

If equal force is applied to a cricket ball and a shot put, the acceleration of the cricket ball will be greater as it has a lower inertia.

**Distance Vs Displacement**

* **Distance-** amount of ground and object covers during its motion.
* **Displacement**- how far the position of the object has changes as a result. Measured as the crow flies.

**Speed Vs Velocity**

* **Speed-** rate of change of distance or a body movement per unit of time and has no consideration for direction. Scalar quantity.

Speed (ms-1) = Distance (m)

Time (Sec)

* **Velocity**- rate of change of displacement, vector quality. With direction!

**Acceleration and Deceleration**

* The rate of change of velocity of an object.
* Vector quantities
* **Acceleration-** rate of increase in velocity
* **Deceleration**- rate of decrease in velocity

Acceleration (ms-2) = Change in velocity (ms-1) = Vf –Vi

Time (sec) t

Vf= final velocity, Vi= initial velocity, t= time taken.

Can you calculate acceleration from data given?

**Momentum**

The amount of motion a body possesses and is the product of mass x velocity

**Momentum = Mass(kg) x Velocity (ms-1)**

Unit of measurement is kgms-1 (kilogram meters per second)

**Example:**

Momentum of a 90kg prop travelling forwards at a speed of 10ms-1 is 900kgms-1

Mass of an object/ performer in sport tends to remain constant, any changes in momentum must be a result of a change in velocity i.e. Acceleration/ Deceleration

Consider an object in flight- Long jumper; neither mass or velocity can be altered so momentum is conserved.

Needs to maximise their velocity during the run up and take off as it can not be changed whilst in the air! Newtons first Law of Motion- law of conservation of movement.

****

**Top Tip!**

Ensure you remember the calculations needed for the various measurements o Linear motion. Short answer questions may require you to interpret data accurately.

**Impulse**

We can think of force in another way called impulse.

Impulse is concerned with the length of time the force is applied to an object/ body and relates to a change in momentum as a consequence.

**Impulse = Force X time**

A change in momentum is synonymous with a change in acceleration

Impulse is equal to a change in momentum.

**In sport it is used to add speed to a body or object**

Eg. Shot, 1 ¾ turn before release maximises the time over which a force is applied to the shot, increasing outgoing acceleration.

Follow through on a racket or stick increases the time the racket or stick is in contact with the ball and increases outgoing momentum.

**Slow down moving bodies slowly on impact**

Fielder in cricket will cradle a fast moving ball by meeting it early and moving his hands backwards in the direction of the balls motion, increasing the time that his hands are in contact with the ball and so slowing its momentum.

**For the exam we need to link it to 100m Sprint.**

As the **sprinter drives out of the blocks, a** **large positive impulse** is produced which allows the sprinter to accelerate.

As long as the **positive impulse exceeds the negative impulse created when landing on the track, acceleration will occur.**

The sprinter moves with a **constant velocity in the middle of the race when positive and negative impulse are equal**

Towards the end of the race, fatigue sets in and the sprinter cannot generate as much force as earlier in the race. As a consequence the **negative impulse becomes greater than the positive impulse and we get deceleration.**

**Remember!!** The area below the graph (negative impulse) represents the body landing on the ground. The area above the graph (positive) represents the impulse of a body due to the ground reaction force.

**Newton’s Laws of Motion**

**Newton’s First Law of Inertia**

***Every body at rest, or moving with constant velocity in a straight line , will continue in that state unless compelled to change by an external force exerted upon it.***

**Example : A golf ball resting on a tee**

**First force:** Earth’s gravitational pull, exerting a downwards force through the centre of mass of the ball – weight force

**Second force**: reaction force form the tee which pushes back on the ball

As these two forces are equal in magnitude and pull in opposite directions they balance each other out. In equilibrium and remains at rest. Will remain there untill struck with the golf club- action force causing it to overcome its moment of inertia and change its state of motion.

Once the golf ball has been struck, it will travel with constant velocity in a straight line as long as the forces remain balanced.

**Newton’s Second Law- Acceleration**

***The rate of change of momentum of a body is proportional to the force causing it and takes place in the direction in which the force acts***

So, in order to produce acceleration, a performer must generate proportionally greater forces.

**Example:** Golf ball receives a greater change in velocity when teeing off that it would in a putt.

The golf ball will accelerate in the direction of the force.

Greater the mass the greater to force required to give acceleration.

**Top Tip!**

**Second law can be stated as F=ma**.

Suggesting that if the mass of the object remains constant then acceleration id equal to the size of the force causing it. This means that assuming the action force remains constant the lighter the object the faster the acceleration.

**Newton’s Third Law- Action and Reaction**

***For every force that is exerted by one body on another there is an equal and opposite force exerted by the second body on the first. For every action there is an equal and opposite reaction***.

In every interaction there is a pair of forces acting. Size of the force on the first object is equal to the size of the force second object. The direction of the force on the first object is in the opposite direction to the force of the second object.

**Example:** the golf club receives an equal and opposite force from the golf ball to that which is imparted onto the golf ball by the golf club.

**Top Tip!**

In the exam you will not be required to define Newton’s laws but to apply them to a specific scenario.

Apply Newton’s Laws of Motion to the following sporting situations:

* High jumper at take off
* Footballer taking a penalty
* High diver preforming a dive

**The role of force in sporting activity**

We need forces to be able to jump, kick and throw in sport.

* Force can be push or pull.
* More force is needed to move a larger object
* When a force is applied to an object the velocity of that object changes, this constitutes acceleration. So, forces are ties to acceleration.

**Forces can:**

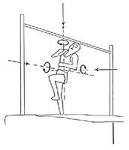
* Cause a body at rest to move
* Cause a moving body to accelerate
* Cause a moving body to decelerate
* Cause a moving body to change direction
* Cause a body to change shape.

**Balanced Vs Unbalanced Force- Net Force**

**Balanced Forces** occur when two or more forces are in operation that are of equal size but opposite in direction. All the forces cancel each other out so that there is zero net force. The body will remain stationary or if moving will continue to do so at constant velocity.

**Unbalanced Forces** occur where a force actin in one direction is larger than that acting in the opposite direction so that the body or object will start to move or accelerate/ decelerate in the direction of the bigger force.

**\*\*\*Force is measured in Newtons (N). A newton is the force required to give a 1kg mass an acceleration of 1ms-1.\*\*\***



**Types of Force**

***Vertical: weight, normal reaction***

***Horizontal: friction, Air resistance***

**Vertical Forces**

**Weight**

***Weight = mass x acceleration due to gravity (10ms2)***

Always downwards toward the centre if the earth.

**Reaction Force**

****Always act at right angles to the contacted surface (free body diagrams)

**Top Tip!**

When describing a force make sure you state or show:

* Point of application
* Direction shown by the arrowhead
* Magnitude/ size shown by the length of the arrow.



**Horizontal Forces**

**Friction**

* Friction opposes movement
* Not all bad- need it to walk and run otherwise we would just slip!
* Force that appears when two things rub together or slide over one another.
* Even smooth surfaces are jagged under a microscope.

**Factors affecting friction:**

* **Roughness of the surface**: rougher the surface the greater the friction. Ie spikes, studs, hard courts.
* **Greater the down force of mass of an object, greater the friction:** mountain biker will sit back over back wheel when going downhill to gain a better grip of the tyre on the surface.
* **Warmth of surface:** dependent on the surface this will increase or decrease friction. Metal blade of ice skate will heat up and create a thin film of water which decrease the friction between the two surfaces.

**Air Resistance**

Form of fluid friction, opposes motion. Degree of air resistance (Drag) experienced will depend on the following.

* **Velocity of the moving body** – faster an object is moving the more it is subject to effects of air resistance
* **Frontal cross Section of moving body**- larger the frontal cross section the greater the effects of air resistance.
* **Shape and surface characteristics of the moving body-** less streamlined and rougher the surface the more it is affected by air resistance. And drag.

**????**

***Can you describe how performers such as swimmer and cyclists try to reduce the effects of air resistance and drag?***

**Free Body Diagrams**

You may be needed to draw or interpret free body diagrams in the exam….

These are used to show relative magnitude and direction of the forces that are acting on a performer.

**Length of arrow** reflect magnitude of force and **position of arrow head** indicates the direction in which the force is acting.

**Top Tip!**

When drawing free body diagrams always….

* Draw on a direction of motion arrow
* Add your vertical forces: weight and reaction

***If W = R the object remains at the same height***

***If R > (greater than) W then the object will accelerate upwards.***

* Add you horizontal forces: friction and air resistance

***If F>AR (greater than) then the object/ body will be travelling at constant velocity***

***If F< AR (less than) the object/ body is decelerating.***

**Projectile Motion**

* Object and implements are used as projectiles in sports such as Basketball, Tennis and athletics. The human body is a projectile in high jump, ski jumping and gymnastics events.
* Once in the air projectiles are subject to forces of gravity and air resistance, although you can produce a lift in some activities.
* Gravity remains constant; any changes in the velocity of the projectile are due to air resistance.
* Foe some projectiles like the shot and the human body the effects if air resistance are minimal and the flight path will be parabolic.
* For other such as a shuttle cock or table tennis ball, the effects of air resistance are greater which causes the flight path to veer off a parabolic path to form a distorted parabola.

**Factors that determine the horizontal displacement of a projectile:**

1. Velocity of release
2. Height of release
3. Angle of release.

**Velocity of Release:** increase in velocity means an increase in the horizontal displacement of the projectile. Throwing events are very technical. The shift or rotation of a shot putter is designed to ensure that the shot leaves the performers hand at maximum velocity.

**Height of Release:** Increase in the release of the height of the projectile will increase in the horizontal displacement of the projectile. Taller shot putter have an advantage over shorter ones.

**Angle of Release:** optimum angle of release is dependent on the relative height so release and landing.

* ***Release height and landing height are the same*** i.e. long jump, optimum angle 45degrees.
* **Release height is greater than landing height** i.e. shot putt the optimum angle is less than 45 degrees.
* ***Release height is below the landing height*** i.e. basket baller performing a free throw, the optimum angle of release is greater than 45 degrees.

**Vector components of parabolic flight**

Air resistance of a shot is negligible, therefore there are no additional forces acting on the shot other than the action force that is applied by the performer. The shot maintain its initial horizontal vector quantity throughout the duration of the flight. Note the horizontal arrow of the flight path is the same throughout.

Other than the initial vertical vector quantity applied by the performer, the only vertical force acting on it is gravity. This means the vertical vector component changes at a rate of 9.8ms-1 for every second the shot remains in the air. As the vertical component changes at a regular rate the horizontal component stays the same throughout the flight. This makes a parabolic flight path.

The exact shape of a parabola depends on the relationship between the vertical and horizontal components of a vector.

Steep parabola is produced when vertical component is much larger than the horizontal

A less steep parabola is produced when the vertical component is smaller than the horizontal component.

**Angular Motion**

Angular motion occurs when a force acts outside the centre of mass of a body or object. The off centre force is called eccentric force and is needed if rotation os to occur.

**Example**

A gymnast performing a backflip will lean back just before take off so the internal force generated by her leg muscles passes outside her centre of mass and initiate rotation.

A footballer may kick the ball slightly off centre so that is spins and follows a curved flight path around a defensive wall.

**Rotational Movements**

Axes of rotation- actions always occur in one of the three axis.

**Torque or moments of Force**

Torques are the turning effects or rotational consequences of a force.

Torque caused by a force depends on the size of the force and the distance the force acts from the axis of rotation.

Torque = size of force (F) x Moment Arm (d)

**Quantities of Angular Motion**

* Angular distance
* Angular displacement
* Angular speed
* Angular velocity
* ****Angular acceleration

**Key Terms**

**Angular Distance:** The angle turned about an axis, measured in degrees or radians

**Angular Displacement**: The smallest angle between starting and finishing positions, measured in degrees or radians

**Angular Speed**: The angular distance travelled in a specified time. Angular speed is measured in red/sec **Angular distance (rad)**

**Time taken (sec)**

**Angular Velocity:** The angular displacement travelled in a specified time.

**Angular displacement (rads)**

**Time taken (sec)**

**Angular acceleration**: The rate of change of angular velocity

**Angular velocity (rad/sec)**

**Time taken (sec)**

**Angular Analogues of Newton’s Laws**

**First law:** a rotating body will continue to turn about its axis of rotation with constant angular momentum unless an external couple or eccentric force is acted upon it.

**Second law:** the rate of change of angular momentum of a body is proportional to the torque causing it and the change takes place in the direction in which the torque acts.

**Third law:** for every torque that is exerted by one body or another there is an equal and opposite torque exerted by the second body on the first.

**Moment of Inertia (MI)**

This is the measure of resistance if an object to rotation and the desire of a body to want to continue to rotate once it has been set in motion. Depends on two factors: mass of an object and distribution of mass around the axis of rotation.

**The mass of the object:**

Greater the mass of an object the greater the moment of inertia. Ten pin bowling ball more difficult to roll than a volleyball.

**The distribution of mass form the axis of rotation**:

The further the mass is distributed away from the axis of rotation, the greater the moment of inertia. A 4 kg medicine ball should have a higher moment of inertia than a 4kg shot as the mass is spread further away from the axis of rotation. The shot has a mass concentrated around its axis, so the moment of inertia is lower and therefore the shot will rotate faster. Apply to humans too!!

**Applying moment of inertia to sports**

Trampolinist: tucked somersault speed of rotation is faster than when performing a straight back somersault. Due to the mass of the trampolinist being spread further away from the axis in the flat back somersault, this increase moment of inertia and reduces angular velocity.

By altering body shape we can change the moment of inertia to speed up or slow down the movement.

Ie ice skater spinning. Arms up and closer to body = closer to axis of rotation = increase in angular velocity/.

**Angular momentum**

**Relationship between angular velocity and moment of inertia is inversely proportional.** One goes up the other goes down proportionally. This means angular momentum must remain constant when an object is n flight and can not change unless an external force is applied . **Known as the law of conservation of angular momentum**. Related to Newton’s first law.

**The law of conservation of angular momentum**

Angular momentum cannot be changed during flight. This is important for sports such as diving and figure skating where many rotations have to be performer.

To ensure maximum angular momentum at take off the skater prepares for the jump so that at take off the arms are out to the side and one leg behind them. The idea being to generate as much torque (turning movement) as possible. The larger the force or the further the force is away from the axis of rotation the larger the torque.

The larger the torque the greater the angular momentum.

Once in flight, the skater pulls their arms and legs in as close to the longitudinal axis as possible which decreases moment of inertia and increase angular velocity enabling the skater to rotate very quickly. Upon landing the skater spreads arms out once again to increase moment of inertia and decrease angular velocity.

Can you apply this to a diver???