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IB Biology SL Paper 3 Question Bank

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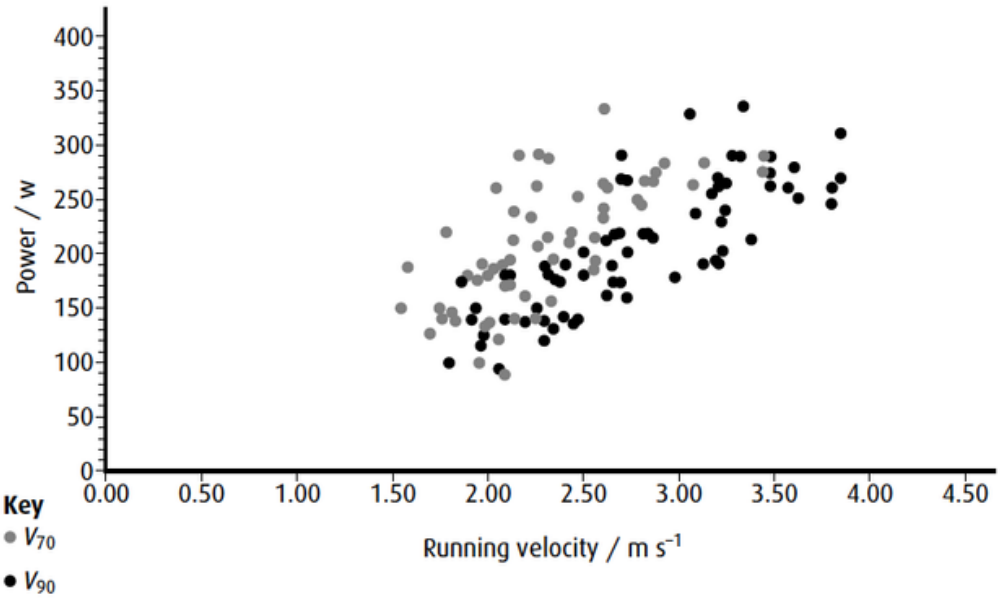
SECTION-A

1. A reliable method of estimating cardiovascular fitness is by measuring the body's oxygen consumption when the rate of heartbeat is at its maximum (Vmax) during intense exercise. This test was used to measure fitness among 71 volunteers. Two weeks later, the same individuals were asked to run for 2.1 km at two different speeds (V70 and V90) and the power they developed during these runs was measured.

• V70 in which they ran at a speed where their rate of the heartbeat was 70% Vmax.

• V90 in which they ran at a speed where their rate of the heartbeat was 90% Vmax.



source: Leibetseder, V J *et al.* (2002) *Journal of Exercise Physiology*, **5** (3), p 11

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SECTION-A

A. State the maximum power developed by a runner at V70.
335 (±5) W

B. Outline the relationship between running velocity and power developed at V90.
As velocity increases, power increases

C. Compare the data for V70 and V90.
Both have the same/similar maximum power. Both show increased power at greater velocities.

D. Suggest why measurements of Vmax are dangerous for older people.
Risk of heart attack

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SECTION-B

2. Describe the structure of striated muscle fibers.

Striated muscle fibers are elongated, cylindrical cells that make up skeletal muscles. They have a unique structure consisting of several smaller units called myofibrils that run parallel to each other. Each myofibril is composed of repeating units called sarcomeres that are responsible for muscle contraction. The sarcomeres consist of two types of filaments: thick and thin. The thick filaments are composed of myosin, and the thin filaments are composed of actin, tropomyosin, and troponin. The arrangement of these filaments gives the striated appearance to the muscle fiber.

3. Explain how a skeletal muscle contracts.

Skeletal muscle contraction is a complex process that involves the sliding of the thin filaments over the thick filaments within the sarcomere. The process begins with the nerve impulse reaching the neuromuscular junction and causing the release of acetylcholine, which binds to receptors on the muscle fibers membrane. This results in an action potential that spreads along the T-tubules, triggering the release of calcium ions from the sarcoplasmic reticulum. The binding sites are exposed. Hence myosin head binds and a cross-bridge forms. The head bends and pulls thin / actin filament. Sarcomere shortens or distance between Z lines shortens. ATP binds to the myosin head. This breaks the cross-bridge and the head swings back to the start position.

4. Explain the need for increases in tidal volume and ventilation rate during exercise.

During exercise, the body requires more oxygen to produce ATP (adenosine triphosphate) to fuel muscle contractions. As a result, the respiratory system must work harder to supply the body with the necessary oxygen and remove carbon dioxide waste.

Tidal volume refers to the amount of air that is inspired and expired during normal breathing. During exercise, the body needs to increase the amount of air it takes in with each breath to increase the amount of oxygen available for the body to use. This is achieved by increasing tidal volume.

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Ventilation rate refers to the number of breaths taken per minute. During exercise, the body also needs to increase the number of breaths taken per minute to meet the increased oxygen demand. This is achieved by increasing ventilation rate.

Carbon dioxide (CO_2) is a waste product produced during cellular respiration. When the body produces more CO_2 than it can expel through normal breathing, it accumulates in the blood, causing a drop in pH, which can lead to fatigue, lightheadedness, and muscle weakness. The increase in ventilation rate and tidal volume during exercise helps to remove excess CO_2 from the blood, maintaining pH balance and allowing the body to continue exercising.

5. Explain the changes in cardiac output and venous return during exercise.

Cardiac output is the amount of blood pumped by the heart per minute and is determined by the heart rate and stroke volume. During exercise, the body requires more oxygen and nutrients to fuel muscle contractions. To meet this increased demand, the heart must pump more blood per minute, resulting in an increase in cardiac output. This increase is mainly due to an increase in heart rate, although stroke volume may also increase to some extent.

Fall in blood pH (due to carbon dioxide from muscle respiration) detected by chemoreceptors in carotid arteries. Impulses are sent to the sinoatrial node/pacemaker. This increase in cardiac output causes muscle contractions which squeeze veins. Increase in venous return to the heart.

6. Evaluate the risks and benefits to an athlete of using erythropoietin (EPO).

Erythropoietin (EPO) is a hormone produced by the kidneys that stimulates the production of red blood cells (RBCs) in the bone marrow. EPO has been used as a performance-enhancing drug by athletes because it can increase oxygen delivery to the muscles, which can improve endurance and performance. However, the use of EPO can have serious risks and side effects.

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One of the primary risks associated with EPO use is an increased risk of blood clots, which can lead to stroke, heart attack, or pulmonary embolism. EPO can also increase blood pressure, which can lead to hypertension and other cardiovascular complications. In addition, the use of EPO can result in anemia, as the body may stop producing its own EPO, which can cause fatigue and weakness.

The benefits of EPO use are primarily related to increased endurance and performance. Athletes may experience improved oxygen delivery to the muscles, allowing them to perform at a higher level for longer periods of time. This can be particularly beneficial in endurance sports such as cycling, long-distance running, and cross-country skiing.

7. Outline the method of ATP production used by muscle fibers during the exercise of varying intensity and duration.

During exercise, muscle fibers utilize ATP (adenosine triphosphate) to provide energy for muscle contractions. However, the amount of ATP stored in muscle fibers is limited and can only sustain muscle contraction for a short period. Therefore, the body uses various energy systems to produce ATP to meet the energy demands of the muscle fibers during exercise. For short-term, high-intensity exercises lasting less than 10 seconds, muscle fibers rely primarily on the phosphagen system to produce ATP. In this system, stored creatine phosphate (CP) is used to quickly regenerate ATP. This system is most efficient for high-intensity activities such as sprinting, jumping, or weightlifting.

For exercises lasting up to 2-3 minutes at high intensity, the glycolytic system is the primary source of ATP. This system breaks down glucose or glycogen (stored glucose in muscles and liver) to produce ATP. However, this process does not require oxygen, which makes it anaerobic. It produces lactic acid as a by-product, which can cause fatigue and muscle soreness. For low to moderate-intensity exercises lasting longer than 3 minutes, the oxidative system is the primary source of ATP. This system requires oxygen and breaks down glucose, glycogen, or fats to produce ATP. This process takes longer but is more efficient in producing ATP. It is also the primary energy system used during endurance exercises such as long-distance running, cycling, or swimming.

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8. Outline how the oxygen debt is formed and repaid.

During exercise, the body requires more energy to perform muscular work. This energy is produced by the breakdown of carbohydrates and fats in a process called cellular respiration. When there is enough oxygen available, this process can continue aerobically, producing ATP (adenosine triphosphate) and carbon dioxide. However, during intense exercise, the demand for ATP exceeds the body's ability to supply it through aerobic respiration, leading to an oxygen debt.

The oxygen debt is defined as the amount of oxygen required after exercise to return the body to its resting state. This oxygen is needed to restore the levels of ATP and creatine phosphate (CP) in muscle fibers and to clear out the lactic acid that accumulates during anaerobic metabolism.

The formation of oxygen debt occurs during the anaerobic phase of exercise when there is a shortage of oxygen available for cellular respiration. Instead, the body produces ATP through anaerobic metabolism, which results in the production of lactic acid. Lactic acid causes muscle fatigue and soreness, leading to a decreased ability to perform work.

After exercise, the body repays the oxygen debt by increasing oxygen intake. This increased oxygen intake is used to restore the levels of ATP and CP in muscle fibers, convert lactic acid to pyruvate and ultimately carbon dioxide, and restore the body's normal metabolic rate.

The repayment of oxygen debt typically occurs within a few minutes to several hours after exercise, depending on the intensity and duration of exercise. The amount of oxygen consumed during the repayment of the oxygen debt can be measured, and this measure is often used as an indicator of the body's metabolic rate during and after exercise.

9. Distinguish between fast-twitch and slow-twitch muscle fibers.

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Muscles are made up of different types of fibers, each with its unique structure, function, and properties. The two primary types of muscle fibers are fast-twitch and slow-twitch muscle fibers.
Slow-twitch muscle fibers, also known as Type I fibers, are characterized by their endurance and ability to contract repeatedly without fatigue. They contain a large number of mitochondria, which enables them to produce ATP aerobically, providing a sustained energy source. Slow-twitch fibers also have a high content of myoglobin, a protein that stores oxygen in muscle cells, giving them a dark appearance. Due to their reliance on oxygen, slow-twitch fibers are better suited for endurance activities such as long-distance running or cycling. They contract slowly and with less force than fast-twitch fibers.
Fast-twitch muscle fibers, also known as Type II fibers, are larger in diameter and generate more force than slow-twitch fibers. They rely primarily on the anaerobic glycolytic system for ATP production, which enables them to produce energy quickly but fatigue rapidly. Fast-twitch fibers contain fewer mitochondria and have a low myoglobin content, giving them a pale appearance. They contract rapidly and with great force, making them suitable for activities that require explosive power such as sprinting or weightlifting.

10. Distinguish between a sprain, a tear and a dislocation.

A sprain, a tear, and a dislocation are three different types of injuries that can occur in the body, often related to bones, muscles, and joints.

A sprain is an injury to a ligament, which is the connective tissue that holds bones together in a joint. It typically occurs when a joint is forced to move in an abnormal or extreme direction, causing the ligament to stretch or tear. Common areas where sprains occur include the ankle, wrist, and knee. Symptoms of a sprain include pain, swelling, and limited movement in the affected joint.

A tear, also known as a muscle or tendon strain, occurs when there is damage to the muscle or tendon tissue. It can occur due to overuse, sudden trauma or force, or improper lifting techniques. Symptoms of a tear include pain, swelling, and weakness in the affected area, and in some cases, bruising and muscle spasms.

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A dislocation occurs when a bone is forced out of its normal position in a joint. It can happen due to an injury, such as a fall or a blow to the joint, or due to a medical condition that weakens the ligaments and muscles surrounding the joint. Symptoms of a dislocation include intense pain, swelling, and deformity of the joint, and limited movement. It requires urgent medical attention to properly set the bone back in place.

In summary, a sprain is an injury to a ligament, a tear is an injury to muscle or tendon tissue, and a dislocation is a bone being forced out of its normal position in a joint. While these injuries share some common symptoms, they have different underlying causes and require different treatments.

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