PE.MA1 Movement Analysis: Levers, Planes and Axes

AQA 8582 · Calculator allowed · about 50 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Which class of lever is the most common in the human body, and is generally suited to producing speed and range of movement rather than force?

- ☐ A) First class lever
- ☐ B) Second class lever
- ☐ C) Third class lever
- ☐ D) Fourth class lever

(Total for Question 1 is 1 mark)

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2 Every lever system in the body is made up of three key components.

(a) State what is meant by the 'fulcrum' of a lever. **(1)**

(b) State what is meant by the 'effort' in a lever system. **(1)**

(c) State what is meant by the 'load' (or resistance) in a lever system. **(1)**

(Total for Question 2 is 3 marks)

3 In a first class lever, the fulcrum is positioned between the effort and the load. Extension of the elbow using the triceps brachii, for example during the push/release phase of a shot put, is an example of a first class lever.

(a) Identify the fulcrum in this example. **(1)**

(b) Identify the effort in this example. **(1)**

(c) Identify the load in this example. **(1)**

(d) Using the terms 'effort arm' and 'load arm', explain why this lever arrangement is well suited to a fast, powerful action such as putting a shot. **(2)**

(Total for Question 3 is 5 marks)

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4 In a second class lever, the load is positioned between the fulcrum and the effort. Standing up onto the balls of the feet (a calf raise), for example during the take-off phase of a vertical jump, is an example of a second class lever.

(a) Identify the fulcrum in this example. **(1)**

(b) Identify the effort in this example. **(1)**

(c) Identify the load in this example. **(1)**

(d) State whether this lever arrangement favours force or speed, and explain why, referring to the relative lengths of the effort arm and load arm. **(2)**

(Total for Question 4 is 5 marks)

5 In a third class lever, the effort is positioned between the fulcrum and the load. Flexion of the elbow using the biceps brachii, for example during the upward phase of a bicep curl, is an example of a third class lever, and this is the most common lever type in the human body.

(a) Identify the fulcrum in this example. **(1)**

(b) Identify the effort in this example. **(1)**

(c) Identify the load in this example. **(1)**

(d) Explain why third class levers, such as this one, are well suited to sporting movements that need speed and a large range of motion. **(2)**

(Total for Question 5 is 5 marks)

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6 The mechanical advantage of a lever can be calculated using the equation: mechanical advantage = length of effort arm / length of load arm. In a simplified model of a second class lever (a calf raise), the effort arm (heel to ball of foot) measures 18 cm and the load arm (ankle to ball of foot) measures 9 cm.

(a) Calculate the mechanical advantage of this lever. **(2)**

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(b) State whether a mechanical advantage of 2 represents a mechanical advantage or a mechanical disadvantage for lifting the load, and briefly explain your answer. **(2)**

(c) Explain one advantage and one disadvantage of a lever with a mechanical advantage greater than 1 (such as this one), compared with a lever with a mechanical advantage less than 1 (such as the bicep curl in Question 5), in a sporting context. **(2)**

(Total for Question 6 is 6 marks)

7 Table 1 describes the arrangement of fulcrum (F), load (L) and effort (E) for each class of lever.

Table 1

Part	Description
(a)	Fulcrum is positioned between the effort and the load
(b)	Load is positioned between the fulcrum and the effort
(c)	Effort is positioned between the fulcrum and the load
(d)	Which class of lever is used when the hamstrings flex the knee to bring the heel up towards the buttocks during the recovery phase of a sprint stride?

(a) Name the class of lever described in row (a) of Table 1. **(1)**

(b) Name the class of lever described in row (b) of Table 1. **(1)**

(c) Name the class of lever described in row (c) of Table 1. **(1)**

(d) Answer the question given in row (d) of Table 1. **(1)**

(Total for Question 7 is 4 marks)

8 The human body can move in three planes of movement.

(a) Describe the sagittal plane, and give one sporting example of a movement that takes place within it. **(2)**

(b) Describe the frontal plane, and give one sporting example of a movement that takes place within it. **(2)**

(c) Describe the transverse plane, and give one sporting example of a movement that takes place within it. **(2)**

(Total for Question 8 is 6 marks)

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9 Movement in each plane happens as the body rotates about a corresponding axis.

(a) Name the axis about which rotation occurs when a gymnast performs a forward somersault (a movement in the sagittal plane), and describe its orientation through the body. **(2)**

(b) Name the axis about which rotation occurs when a gymnast performs a cartwheel (a movement in the frontal plane), and describe its orientation through the body. **(2)**

(c) Name the axis about which rotation occurs when an ice skater performs a spin/pirouette (a movement in the transverse plane), and describe its orientation through the body. **(2)**

(Total for Question 9 is 6 marks)

10 A trampolinist performs a routine consisting of two rotating skills: a tucked front somersault, and a straight 'barani' (a somersault combined with a half twist about the body's long axis).

(a) Identify the plane of movement and the corresponding axis of rotation used for the basic tucked front somersault. **(2)**

(b) Identify the plane of movement and the corresponding axis of rotation used for the additional twisting rotation during the barani. **(2)**

(c) Explain why a skill that combines a somersault with a twist, such as the barani, involves rotation in more than one plane at the same time. **(2)**

(Total for Question 10 is 6 marks)

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11 Explain, using the term 'mechanical advantage', why most lever systems in the human body are suited to producing speed and range of movement rather than force.

(Total for Question 11 is 4 marks)

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12 A gymnast performs a straight-arm lateral raise, lifting both arms sideways from resting by the body to shoulder height.

(Total for Question 12 is 2 marks)

13 A diver performs a forward pike dive, bending sharply at the hips to bring the head towards the legs before straightening out and entering the water.

(Total for Question 13 is 2 marks)

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14 A figure skater performs an axel jump, taking off, rotating one and a half times while airborne, then landing.

(Total for Question 14 is 2 marks)

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15 State the equation used to calculate the mechanical advantage of a lever.

(Total for Question 15 is 1 mark)

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16 Explain why a second class lever, such as the calf raise described in Question 4, is well suited to supporting and lifting body weight, referencing mechanical advantage.

(Total for Question 16 is 2 marks)

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17 Explain one limitation of the human body having mostly third class levers when it comes to lifting very heavy loads.

(Total for Question 17 is 2 marks)

Mark scheme · PE.MA1 Movement Analysis: Levers, Planes and Axes

Question 1

- **B1** C (third class lever)
- **Answer: C (third class lever)**

Question 2

- (a) **B1** the fixed point/pivot around which the lever rotates (the joint), oe
- **(a) Answer: The fixed pivot point around which the lever rotates; in the body, this is the joint.**
- (b) **B1** the force applied to move the load, generated by a muscle contracting and pulling on the bone via a tendon, oe
- **(b) Answer: The force that moves the load; in the body, this is generated by a muscle contracting and pulling on a bone via a tendon.**
- (c) **B1** the weight or resistance being moved, e.g. the weight of a body part or an object being held, oe
- **(c) Answer: The weight or resistance being moved, such as the weight of a body part or an object being held.**

Question 3

- (a) **B1** the elbow joint
- **(a) Answer: The elbow joint.**
- (b) **B1** the triceps brachii, pulling on the ulna (olecranon process) behind the elbow joint, oe
- **(b) Answer: The triceps brachii, pulling on the ulna just behind the elbow joint.**
- (c) **B1** the weight of the forearm and hand, plus the shot being held, oe
- **(c) Answer: The weight of the forearm and hand, plus the shot being held.**
- (d) **B1** the triceps inserts close to the elbow joint, so the effort arm (fulcrum to triceps insertion) is short, oe
- (d) **B1** the load arm (fulcrum to hand) is much longer, so a small, fast contraction of the triceps close to the joint produces a much larger, faster movement of the hand at the end of the lever, ideal for driving the shot forward, oe
- **(d) Answer: Because the triceps inserts very close to the elbow (a short effort arm) while the hand is far from the elbow (a long load arm), a small, fast muscle contraction produces a large, fast movement of the hand, which suits the powerful, fast release needed in a shot put.**

Question 4

- (a) **B1** the ball of the foot (the metatarsophalangeal joints), oe
- **(a) Answer: The ball of the foot (the metatarsophalangeal joints).**
- (b) **B1** the calf muscles (gastrocnemius), pulling upward on the heel (calcaneus) via the Achilles tendon, oe
- **(b) Answer: The calf muscles (gastrocnemius), pulling up on the heel via the Achilles tendon.**
- (c) **B1** the body weight, acting downward through the ankle joint/tibia, oe
- **(c) Answer: The body weight, acting down through the ankle joint.**
- (d) **B1** favours force
- (d) **B1** the effort arm (heel to ball of foot) is longer than the load arm (ankle to ball of foot), so a relatively large load (body weight) can be lifted using comparatively less muscular effort, though at the cost of speed and range of movement, oe
- **(d) Answer: It favours force. The effort arm (heel to ball of foot) is longer than the load arm (ankle to ball of foot), so the calf muscles can lift the whole body weight without needing to generate as much force as the load itself, although the movement is comparatively slow and small.**

Question 5

- (a) **B1** the elbow joint
- **(a) Answer: The elbow joint.**
- (b) **B1** the biceps brachii, pulling on the radius close to the elbow joint, oe
- **(b) Answer: The biceps brachii, pulling on the radius close to the elbow.**
- (c) **B1** the weight of the forearm and hand, plus any dumbbell being held, oe
- **(c) Answer: The weight of the forearm and hand, plus any dumbbell being held.**
- (d) **B1** the effort (biceps insertion) acts close to the fulcrum while the load (hand) is much further away, so the effort arm is short relative to the load arm, oe
- (d) **B1** a small, fast contraction of the muscle close to the joint produces a much larger and faster movement of the hand at the end of the lever, ideal for fast sporting actions such as throwing, oe
- **(d) Answer: Because the effort (biceps insertion) acts close to the elbow while the load (hand) is far away, the effort arm is short and the load arm is long; a small, fast muscle contraction therefore produces a much larger, faster movement at the hand, which is ideal for quick sporting actions such as throwing.**

Question 6

- (a) **M1** 18 / 9, oe
- (a) **A1** 2 cao (no units, mechanical advantage is a ratio)
- **(a) Answer: 2**
- (b) **B1** a mechanical advantage (a ratio greater than 1)
- (b) **B1** because the effort arm is longer than the load arm, less effort force is needed than the size of the load being lifted, making it easier to lift a large load such as body weight, oe
- **(b) Answer: A mechanical advantage, because a ratio greater than 1 means the effort arm is longer than the load arm, so less effort force is needed than the load being lifted.**
- (c) **B1** advantage: it can move a larger load (such as the whole body weight in a calf raise) using less muscular effort force, oe
- (c) **B1** disadvantage: it produces a smaller range of movement and less speed at the load end compared with a lever with a mechanical advantage below 1, which is a disadvantage in sports needing fast, wide movements such as throwing, oe
- **(c) Answer: Advantage: it can lift a larger load, such as the whole body weight, using relatively less muscular force. Disadvantage: it produces a smaller, slower movement at the load end than a lever with a mechanical advantage below 1, which is a disadvantage for actions needing speed and range of movement, such as throwing.**

Question 7

- (a) **B1** first class lever
- **(a) Answer: First class lever**
- (b) **B1** second class lever
- **(b) Answer: Second class lever**
- (c) **B1** third class lever
- **(c) Answer: Third class lever**
- (d) **B1** third class lever
- **(d) Answer: Third class lever**

Question 8

- (a) **B1** the sagittal plane divides the body into left and right sides, oe
- (a) **B1** movements such as flexion and extension occur within it, e.g. a forward roll/somersault, running, a sit-up, oe
- **(a) Answer: The sagittal plane divides the body into left and right sides; flexion and extension movements happen within it, for example a forward roll in gymnastics.**
- (b) **B1** the frontal plane divides the body into front and back halves, oe
- (b) **B1** movements such as abduction and adduction occur within it, e.g. a cartwheel, a star jump/jumping jack, oe
- **(b) Answer: The frontal plane divides the body into front and back halves; abduction and adduction movements happen within it, for example a cartwheel.**
- (c) **B1** the transverse plane divides the body into upper and lower halves, oe
- (c) **B1** rotational movements occur within it, e.g. a pirouette/spin, a discus throw, a twisting dive, oe
- **(c) Answer: The transverse plane divides the body into upper and lower halves; rotational movements happen within it, for example a pirouette in figure skating.**

Question 9

- (a) **B1** the transverse axis (also called the frontal axis)
- (a) **B1** a horizontal line running from side to side (left to right) through the body's centre of mass, oe
- **(a) Answer: The transverse axis (also called the frontal axis): a horizontal line running from left to right through the body's centre of mass.**
- (b) **B1** the sagittal axis
- (b) **B1** a horizontal line running from front to back through the body's centre of mass, oe
- **(b) Answer: The sagittal axis: a horizontal line running from front to back through the body's centre of mass.**
- (c) **B1** the longitudinal axis
- (c) **B1** a vertical line running from the head to the toes through the centre of the body, oe
- **(c) Answer: The longitudinal axis: a vertical line running from the head to the toes through the centre of the body.**

Question 10

- (a) **B1** sagittal plane
- (a) **B1** transverse (frontal) axis
- **(a) Answer: Sagittal plane, rotating about the transverse (frontal) axis.**
- (b) **B1** transverse plane
- (b) **B1** longitudinal axis
- **(b) Answer: Transverse plane, rotating about the longitudinal axis.**
- (c) **B1** a somersault is a rotation about the transverse axis, taking place in the sagittal plane, oe
- (c) **B1** a twist is a separate, simultaneous rotation about the longitudinal axis, taking place in the transverse plane, so combining the two skills means the body is rotating about two different axes, in two different planes, at the same time, oe
- **(c) Answer: A somersault (rotation about the transverse axis, in the sagittal plane) and a twist (rotation about the longitudinal axis, in the transverse plane) are two separate rotations; performing both together means the body rotates about two different axes, and therefore moves in two different planes, at the same time.**

Question 11

- **B1** most levers in the body, particularly third class levers (the most common type), have the effort acting close to the fulcrum, oe
- **B1** this makes the effort arm short compared with the load arm, giving a mechanical advantage of less than 1, oe
- **B1** a mechanical advantage of less than 1 means more muscular effort force is needed than the size of the load being moved (a force disadvantage), oe
- **B1** however, this arrangement means a small movement of the muscle close to the joint produces a much larger, faster movement at the end of the limb, which is why the body is generally suited to speed and range of movement rather than raw force, oe
- **Answer: Because most levers in the body (especially third class levers, the most common type) have the effort close to the fulcrum and the load much further away, the effort arm is short relative to the load arm, giving a mechanical advantage below 1; this needs more muscular force than the load itself, but it means a small movement of the muscle produces a much larger, faster movement at the end of the limb, which is why the body favours speed and range of**

Question 12

- **B1** frontal plane
- **B1** sagittal axis
- **Answer: Frontal plane, rotating about the sagittal axis.**

Question 13

- **B1** sagittal plane
- **B1** transverse (frontal) axis
- **Answer: Sagittal plane, rotating about the transverse (frontal) axis.**

Question 14

- **B1** longitudinal axis
- **B1** transverse plane
- **Answer: Rotating about the longitudinal axis, in the transverse plane.**

Question 15

- **B1** mechanical advantage = length of effort arm / length of load arm, oe
- **Answer: Mechanical advantage = length of effort arm / length of load arm.**

Question 16

- **B1** a second class lever has the effort arm longer than the load arm, giving a mechanical advantage greater than 1, oe
- **B1** this means the calf muscles can lift a large load, such as the whole body weight, without needing to generate as much force as the load itself, which is essential for repeatedly supporting body weight during activities such as jumping and running, oe
- **Answer: A second class lever has an effort arm longer than its load arm, giving a mechanical advantage greater than 1, so the calf muscles can lift a large load such as the whole body weight without generating as much force as the load itself.**

Question 17

- **B1** third class levers have a mechanical advantage below 1 (effort arm shorter than load arm), oe
- **B1** this means the muscle must produce more force than the size of the load itself, so lifting a very heavy load places a large strain on the muscle (and the joint), limiting the maximum load that can be safely lifted, oe
- **Answer: Because third class levers have a mechanical advantage below 1, the muscle has to produce more force than the load itself, which places a large strain on the muscle and joint and limits how heavy a load can safely be lifted this way.**