PE.MA2 Movement Analysis: Lever Systems in Sport

AQA 8582 · Calculator allowed · about 50 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Which of the following best describes a lever?

- [ ] A) A rigid rod that rotates about a fixed point when a force is applied to it
- [ ] B) A muscle that shortens to pull on a bone
- [ ] C) The total range of movement possible at a joint
- [ ] D) A type of joint found in the shoulder and hip

(Total for Question 1 is 1 mark)

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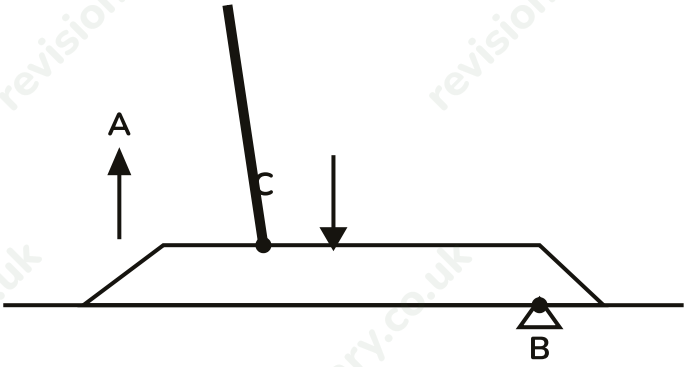
2 Diagram 1 shows the side view of a foot rising onto the ball of the foot during a calf raise, as when a player rises up to contest a header. Point A shows where the calf muscle pulls upward on the heel. Point B shows where the ball of the foot presses against the ground. Point C shows the ankle joint, through which the weight of the body acts downward.

Side view of a foot rising onto the ball of the foot (a calf raise



(a) Identify which labelled point, A, B or C, is the fulcrum of this lever. **(1)**

(b) Identify which labelled point is the effort. **(1)**

(c) Identify which labelled point is the load. **(1)**

(Total for Question 2 is 3 marks)

3 In a first class lever, the fulcrum sits between the effort and the load. When heading a corner kick, a footballer extends their neck sharply to drive their head forward and down into the ball.

(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) The fulcrum in this example sits between the effort (behind the head) and the load (the front of the head). Explain why this arrangement is classed as a first class lever, and state one other sporting example of a first class lever at a different joint. **(2)**

(Total for Question 3 is 5 marks)

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4 During the follow-through of a volleyball spike, a player's triceps brachii extends the elbow sharply to drive the hand down and over the top of the ball.

(a) Identify the fulcrum, the effort and the load in this example. **(3)**

(b) State whether the effort arm in this example is longer or shorter than the load arm, and explain what this means for the mechanical advantage of the movement. **(2)**

(Total for Question 4 is 5 marks)

5 A goalkeeper rises up onto the balls of their feet, pushing off the ground through a calf raise, to reach a high crossed ball at a corner kick.

(a) State whether this second class lever arrangement favours force or speed. **(1)**

(b) Explain why this favouring of force is useful for a goalkeeper in this situation. **(1)**

(c) Suggest one disadvantage of this lever arrangement for a goalkeeper who needs to jump quickly and explosively. **(2)**

(Total for Question 5 is 4 marks)

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6 A rock climber pulls their body weight upward on a hold by flexing the elbow, using the biceps brachii.

(a) Identify the fulcrum, the effort and the load in this example. **(3)**

(b) Explain why this lever arrangement means the biceps has to work especially hard to lift the climber's full body weight. **(2)**

(Total for Question 6 is 5 marks)

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7 In which class of lever does the effort act between the fulcrum and the load?

- ☐ A) First class lever
- ☐ B) Second class lever
- ☐ C) Third class lever
- ☐ D) None of these

(Total for Question 7 is 1 mark)

8 Table 1 gives four descriptions relating to lever classes.

Table 1

Row	Description
(a)	The load sits between the fulcrum and the effort
(b)	The fulcrum sits between the effort and the load
(c)	A swimmer's triceps straighten the elbow to push the arm backward during the pull-through phase of front crawl - name the lever class
(d)	This lever class is the most common in the human body

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

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

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

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

(Total for Question 8 is 4 marks)

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

(Total for Question 9 is 1 mark)

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10 Which class of lever always has a mechanical advantage greater than 1, favouring force over speed?

- ☐ A) First class lever
- ☐ B) Second class lever
- ☐ C) Third class lever
- ☐ D) All lever classes favour force equally

(Total for Question 10 is 1 mark)

11 A fast bowler's forearm acts as a third class lever as the elbow extends explosively during the delivery action, with the triceps acting close to the elbow joint. In a simplified model of this action, the effort arm (elbow to triceps insertion) measures 3 cm and the load arm (elbow to the ball in the hand) measures 33 cm.

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

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(b) State whether this represents a mechanical advantage or a mechanical disadvantage, and explain your answer. **(2)**

(c) Explain why this large mechanical disadvantage is actually beneficial to a fast bowler. **(2)**

(Total for Question 11 is 6 marks)

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12 A footballer swings their leg forward and extends the knee sharply, using the quadriceps, to strike a ball during a shot at goal.

(Total for Question 12 is 2 marks)

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13 A boxer throws a jab, extending the elbow sharply using the triceps to drive the fist forward.

(Total for Question 13 is 2 marks)

14 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 14 is 4 marks)

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

(Total for Question 15 is 2 marks)

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16 A weightlifter performs a heavy overhead press, while a sprinter drives their arms explosively during a race. The weightlifter's shoulder relies on a lever arrangement suited to force, while the sprinter's arm action relies on a lever arrangement suited to speed.

(Total for Question 16 is 3 marks)

17 Nadia is a rugby prop forward whose role in the scrum requires her to drive forward against the opposition pack with maximum force through her legs and shoulders, but who also needs to pass the ball quickly and accurately to a team-mate immediately after winning it.

Discuss how the body's lever systems help to explain why Nadia can generate high force in the scrum but can also make a fast, accurate pass, referring to at least two different lever classes and to mechanical advantage. Evaluate whether the human body is generally better suited to producing force or to producing speed and range of movement.

(Total for Question 17 is 9 marks)

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18 A swimmer pushes off the pool wall, extending both elbows to drive their arms out ahead of them into a streamlined position.

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

(Total for Question 18 is 1 mark)

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19 State one similarity and one difference between a first class lever and a third class lever.

(Total for Question 19 is 2 marks)

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20 Unlike second and third class levers, a first class lever does not always favour the same outcome.

(Total for Question 20 is 2 marks)

Mark scheme · PE.MA2 Movement Analysis: Lever Systems in Sport

Question 1

- **B1** A
- **Answer: A**

Question 2

- (a) **B1** B
- **(a) Answer: B.**
- (b) **B1** A
- **(b) Answer: A.**
- (c) **B1** C
- **(c) Answer: C.**

Question 3

- (a) **B1** the joint between the skull and the top of the spine (the atlanto-occipital joint), oe
- **(a) Answer: The joint between the skull and the top of the spine.**
- (b) **B1** the neck extensor muscles (e.g. trapezius/splenius capitis), pulling on the back of the skull, oe
- **(b) Answer: The neck extensor muscles, pulling on the back of the skull.**
- (c) **B1** the weight of the front of the head/face (in front of the pivot point), oe
- **(c) Answer: The weight of the front of the head and face.**
- (d) **B1** the fulcrum lying between the effort and the load is, by definition, a first class lever, oe
- (d) **B1** a correct different example, e.g. the triceps extending the elbow, with the elbow joint (fulcrum) between the triceps insertion (effort) and the hand (load), oe
- **(d) Answer: It is a first class lever because the fulcrum lies between the effort and the load. A different example is the triceps extending the elbow, where the elbow joint (fulcrum) lies between the triceps insertion (effort) and the hand (load).**

Question 4

- (a) **B1** fulcrum: the elbow joint
- (a) **B1** effort: the triceps brachii, pulling on the ulna just behind the elbow, oe
- (a) **B1** load: the weight of the forearm and hand, oe
- **(a) Answer: Fulcrum: the elbow joint. Effort: the triceps brachii, pulling on the ulna just behind the elbow. Load: the weight of the forearm and hand.**
- (b) **B1** the effort arm is shorter than the load arm
- (b) **B1** this gives a mechanical advantage of less than 1, meaning more effort force is needed than the load itself, but the hand moves further and faster than the muscle insertion, favouring speed, oe
- **(b) Answer: The effort arm is shorter than the load arm, giving a mechanical advantage of less than 1: more effort force is needed than the size of the load, but the hand moves further and faster than the muscle insertion, favouring speed.**

Question 5

- (a) **B1** favours force
- **(a) Answer: It favours force.**
- (b) **B1** it allows the calf muscles to lift the goalkeeper's full body weight upward without needing to generate more force than that body weight, oe
- **(b) Answer: It allows the calf muscles to lift the goalkeeper's full body weight upward without needing to generate more force than that body weight.**
- (c) **B1** a mechanical advantage above 1 means the ball of the foot (the load end) moves through a smaller range and less quickly than the effort (the calf) contracts, oe
- (c) **B1** so this lever arrangement is comparatively slow at producing height/range of movement, which could be a disadvantage when explosive, fast movement is needed to reach a fast-moving ball, oe
- **(c) Answer: Because the mechanical advantage is above 1, the ball of the foot moves through a smaller range and less quickly than the calf muscle itself contracts, so this arrangement is comparatively slow to produce height, which could be a disadvantage against a fast, high ball.**

Question 6

- (a) **B1** fulcrum: the elbow joint
- (a) **B1** effort: the biceps brachii, pulling on the radius close to the elbow joint, oe
- (a) **B1** load: the weight of the climber's body, acting through the hand gripping the hold, oe
- **(a) Answer: Fulcrum: the elbow joint. Effort: the biceps brachii, pulling on the radius close to the elbow. Load: the weight of the climber's body, acting through the hand.**
- (b) **B1** the effort (biceps insertion) is much closer to the elbow than the load (the hand) is, so the effort arm is short compared with the load arm, oe
- (b) **B1** this gives a mechanical advantage below 1, meaning the biceps must produce a force greater than the climber's own body weight to move the hand, oe
- **(b) Answer: The effort (biceps insertion) acts much closer to the elbow than the load (the hand), so the effort arm is short compared with the load arm, giving a mechanical advantage below 1: the biceps must produce a force greater than the climber's own body weight to move the hand.**

Question 7

- **B1** C
- **Answer: C**

Question 8

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

Question 9

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

Question 10

- **B1** B
- **Answer: B**

Question 11

- (a) **M1** 3 / 33, oe
- (a) **A1** awrt 0.09 cao
- **(a) Answer: Approximately 0.09.**
- (b) **B1** a mechanical disadvantage (a ratio below 1)
- (b) **B1** because the effort arm is much shorter than the load arm, so more effort force is needed than the size of the load being moved, oe
- **(b) Answer: A mechanical disadvantage, because a ratio below 1 means the effort arm is much shorter than the load arm, so more effort force is needed than the load being moved.**
- (c) **B1** the small mechanical advantage means a small, fast contraction of the triceps close to the elbow produces a much larger and faster movement at the hand, oe
- (c) **B1** this large range and high speed of movement at the hand is exactly what is needed to release the ball at high velocity, which is the fast bowler's goal, oe
- **(c) Answer: The small mechanical advantage means a small, fast contraction of the triceps close to the elbow produces a much larger and faster movement at the hand, which is exactly what a fast bowler needs to release the ball at high velocity.**

Question 12

- **B1** third class lever
- **B1** the quadriceps (effort) inserts on the tibia close to the knee joint (fulcrum), between the fulcrum and the foot/ball (load), oe
- **Answer: Third class lever, because the quadriceps (effort) pulls on the tibia close to the knee (fulcrum), which lies between the fulcrum and the foot/ball (load).**

Question 13

- **B1** first class lever
- **B1** the elbow joint (fulcrum) lies between the triceps insertion (effort) and the fist (load), oe
- **Answer: First class lever, because the elbow joint (fulcrum) lies between the triceps insertion (effort) and the fist (load).**

Question 14

- **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, 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 movement over force.**

Question 15

- **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 a very heavy load places a large strain on the muscle (and the joint), limiting the maximum load that can safely be moved this way, 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 moved this way.**

Question 16

- **B1** advantage of a mechanical advantage above 1 (force-favouring): a large load, such as a heavy weightlifting bar, can be moved using comparatively less muscular effort force, oe
- **B1** disadvantage of a mechanical advantage above 1: the load end of the lever moves through a smaller range and less quickly, which is a disadvantage where speed is the priority, oe
- **B1** in contrast, a mechanical advantage below 1 (speed-favouring, as in the sprinter's arm drive) sacrifices force for a much larger, faster movement at the end of the limb, which is exactly what a sprinter needs, oe
- **Answer: A mechanical advantage above 1, as used to lift the weightlifter's heavy bar, means a large load can be moved with comparatively less muscular force, but the load end of the lever moves through a smaller range and less quickly, which would be a disadvantage for a sprinter. A mechanical advantage below 1, as in the sprinter's arm drive, sacrifices force for a much larger, faster movement at the end of the limb, which is exactly what a sprinter needs.**

Question 17

- **Level 3** (7-9): A detailed and coherent response that accurately explains how at least two different lever classes and their mechanical advantage relate to Nadia's scrummaging force and her fast passing action, applying the discussion specifically to her situation, and reaches a well-justified evaluative judgement about the body's overall bias towards speed and range of movement. Sustained, accurate use of lever/mechanical-advantage terminology throughout.
- **Level 2** (4-6): Some accurate explanation of lever classes and mechanical advantage, with partial application to Nadia's scrummaging and passing, but coverage of both actions or the evaluative judgement may be incomplete or underdeveloped.
- **Level 1** (1-3): Basic or generic statements about levers with little or no application to Nadia's specific situation, and little or no evaluation of force versus speed.
- **Level 0** (0): No relevant content.
- **Indicative content:**
  - Force in the scrum: leg drive at the ankle (calf raise, plantarflexion) is a second class lever, with the effort arm (heel to ball of foot) longer than the load arm (ankle to ball of foot), giving a mechanical advantage above 1.
  - This means Nadia's calf muscles can generate a large forward driving force relative to the muscular effort used, which is well suited to the sustained, powerful push needed in a scrum.
  - Speed in the pass: extending the elbow to release the ball, using the triceps, is a first class lever (fulcrum between effort and load); with the triceps inserting close to the elbow, the effort arm is short relative to the load arm, giving a mechanical advantage below 1.
  - This means a small, fast contraction of the triceps produces a much larger, faster movement of the hand, which is exactly what is needed for a fast, accurate pass immediately after the scrum.
  - Most joint actions used in passing/throwing (elbow, wrist) are third class or, as here, first class levers with a low mechanical advantage, favouring speed and range of movement over force.
  - Evaluative point: because most lever systems in the human body have the effort acting close to the fulcrum (mechanical advantage below 1), the body as a whole is generally better suited to producing speed and range of movement than raw force.
  - Evaluative point: the scrum example shows force-favouring arrangements do exist (mainly at the ankle and in similar second class arrangements), but they are the exception rather than the rule in the body's overall lever system.
  - Balanced conclusion: Nadia's two actions show that the same body can produce both outcomes, but only because a small number of joints (like the ankle) provide the force-favouring arrangement that most of the body's mainly speed-favouring levers do not.

Question 18

- **B1** A
- **Answer: A**

Question 19

- **B1** similarity: both involve a muscle (effort) pulling on a bone across a joint (fulcrum) to move a load, oe
- **B1** difference: in a first class lever the fulcrum sits between the effort and the load, whereas in a third class lever the effort sits between the fulcrum and the load, oe
- **Answer: Similarity: both involve a muscle (effort) pulling on a bone across a joint (fulcrum) to move a load. Difference: in a first class lever the fulcrum sits between the effort and the load, whereas in a third class lever the effort sits between the fulcrum and the load.**

Question 20

- **B1** in a first class lever the fulcrum can sit anywhere between the effort and the load, so the effort arm can be longer than, shorter than, or equal to the load arm, oe
- **B1** this means, unlike a second class lever (always mechanical advantage above 1, favouring force) or a third class lever (always mechanical advantage below 1, favouring speed), a first class lever's mechanical advantage depends on the specific position of the fulcrum, so it can favour either force or speed, oe
- **Answer: In a first class lever, the fulcrum can sit anywhere between the effort and the load, so the effort arm can be longer than, shorter than, or equal to the load arm; unlike a second class lever (always mechanical advantage above 1) or a third class lever (always mechanical advantage below 1), a first class lever's mechanical advantage depends on the specific position of the fulcrum, so it can favour either force or speed.**