CHAPTER 2: Muscular skeletal system - Biomechanics

Exam style questions - pages 32 - 35

1) A Level. Warm up is considered to be an essential element of a training programme. Explain how the muscular and skeletal systems respond to a warm up. Support your answer with details of intensity and duration of the warm up for a sport of your own choice. 15 marks

Answer:

3 marks for definitions:

- *A warm-up can be passive or active.*
- *Passive warm-up involves raising muscle or core temperature without depleting energy substrates, by using hot showers, baths and massage etc.*
- *And is most impractical for active performers.*

- *Active warm-up usually consists of a series of low level aerobic exercises.*
- *Type of active warm-up depends on whether the activity or competition is aerobic or anaerobic.*
- *Which can be sport specific or general in nature.*
- *A general warm-up increases temperature using non-specific body movements, such as a 5 minute jog and light stretch.*
- *A sports specific element usually includes exercises of increasing intensity and duration that are specific to the performer's event.*
- *An example of a selected sport: 400 metres hurdles.*

7 marks for 7 of:

- *The muscular system responds to warm-up in the following ways:*
  - *The greater the intensity of an active warm-up the greater strength of contraction due to improved elasticity of muscle fibres, needed in preparation for 400 meter hurdles training or competition.*
  - *The faster speed of contraction due to an increased speed of nerve transmission to the muscle fibres.*
  - *Which prepares the performer for speed and strength required for required between and over hurdles.*
  - *The faster speed of contraction and relaxation of the muscle fibres due to an increase in muscle temperature.*
  - *Which influences certain metabolic responses during subsequent high-intensity exercise.*
- *Increased speed of strength of contraction due to an improvement in coordination between antagonistic pairs because of a reduction in muscle viscosity.*
- *And hence improved hurdling and sprinting technique.*
- *Increased speed and strength of contraction due to increased availability of oxygen in muscle fibres.*
- *And thus delay in blood lactate response during high-intensity exercise.*
- *And therefore increased anaerobic energy provision in warmer muscle fibres.*
- *Which will enable athlete to maintain anaerobic energy levels for longer during 400 meter training session.*
- *A sports specific warm-up with take longer to complete as it would normally include of skill drills that are specific to sports performer's event.*
- *For example, a 400 meter hurdler would spend time performing skill drills that break down the skills required for hurdling technique, such as leg lead drills.*
- *Reduced risk of injury to muscle tissue, despite an increase in speed of strength of contraction due to an increase in blood flow and oxygen to the muscle.*
- *Prepares tendons to improve the stability and contractile activity of skeletal muscles that are ready to react to increased activity.*
- *Stretching and working leg musculature during an active warm-up is vital for 400 meter hurdles training.*

4 marks for 4 of:

- *The skeletal system responses to warm-up are less specific when compared with the muscular responses:*
- *Warm-up increases the production of synovial fluid from the articular cartilage (McCutchen's weeping theory of lubrication).*
- *Synovial fluid is squeezed in and out of the articular cartilage at the points of contact.*
- *Providing the articular surfaces with nutrients and oxygen, and reduces friction between joints.*
- *Skeletal flexibility improves the range of motion possible around a specific joint or a series of articulations in preparation for the training session or competition.*
- *For example, hip flexibility needs to be worked on to achieve circumduction needed for hurdling technique.*
- *Effect of warm-up on bone density is not known.*

1) (continued)

1 mark for conclusion:

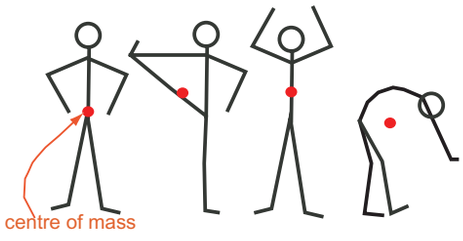
- *There are many benefits of warm-up on the muscular and skeletal systems.*
- *The most imported consideration is building a warm-up programme is that is specific to the performer's needs.*

2) a) Explain with diagrams what is meant by the centre of mass of a body. 2 marks

Answer:

- *The centre of mass of a body is the point (which can lie inside or outside the body) at which the weight (force) of the body acts for the body as a whole.*
- *See figure Q2.1 for an idea of where the centre of mass is in a body depending on shape.*

figure Q2.1 – centre of mass position in the body



b) Explain with the aid of pin-man diagrams how the centre of mass of a long jumper changes from the take-off position to the flight phase shown in figure 2.18 5 marks

figure 2.18 – a long jumper in flight

Answer:

For the long jumper:

- *Three marks for 3 diagrams showing the approximate position of the centre of mass - see figure Q2.2.*
- *The idea is that this red dot represents the position of the overall mass of the body.*

figure Q2.2 – centre of mass position for long jumper

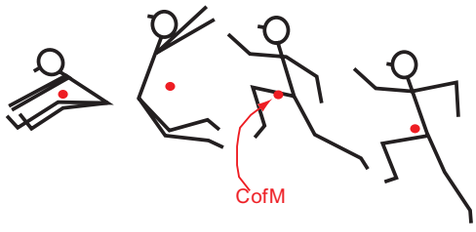


figure 2.19 swimmer starting a race

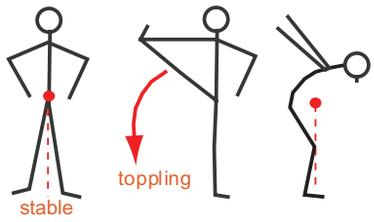
3) Figure 2.19 shows a swimmer holding a balance just before the start of a race. Explain how the position of the centre of mass can affect the swimmer's balance. Describe how the swimmer in figure 2.19 can use his knowledge of balance to achieve his most effective block start. 5 marks

Answer:

3 marks for 3 of:

- *The swimmer's centre of mass must lie directly above the base of support – in this case his feet.*
- *The bigger the area of support (the further apart his feet) the more stable (able to keep on balance) he will be.*
- *The lower the centre of mass the easier it will be to maintain balance.*
- *If he moves so that the centre of mass moves away from a position directly above his feet, he will begin to topple (see figure Q2.3).*
- *Since his line of action of his weight (the force exerted by gravity on his centre of mass) will not pass through his feet.*
- *Which causes a turning (moment) of the swimmers body – he topples.*

figure Q2.3– centre of mass position affects stability



To make a block start - 2 marks for 2 of:

- *The swimmer will lean forward so that the centre of mass of his body moves forward.*
- *The centre of mass of the swimmer then lies forwards of the block.*
- *And outside his base of support (his feet) - see figure Q2.4..*
- *So he will topple forward into the pool - he then pushes hard with his legs to drive forwards in the direction of his swim.*

figure Q2.4 – swim start and toppling

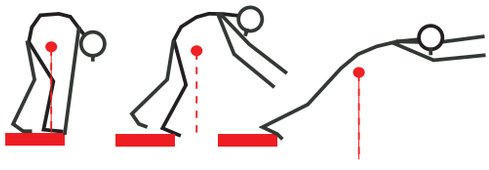
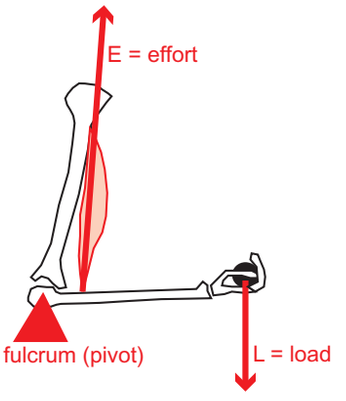


figure Q2.5 – the elbow and forearm lever



4) Sketch the lever system which would represent the action of the biceps muscle in flexing the arm. Show on your diagram the resistance arm of the lever. 3 marks

Answer:

- *See figure Q2.5.*
- *E is the effort force in the biceps muscle.*
- *L is the load force applied at the hand.*
- *The triangle is the pivot or fulcrum of the lever.*
- *The resistance arm is the structure (forearm) between hand (load) and elbow (fulcrum).*

figure Q2.6 – jumper's knee 1

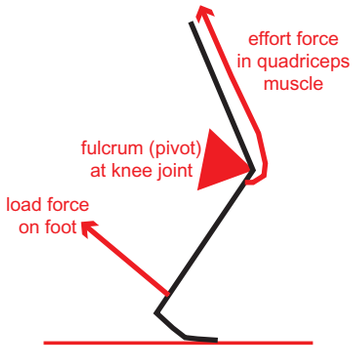


figure Q2.7 – jumper's knee 2

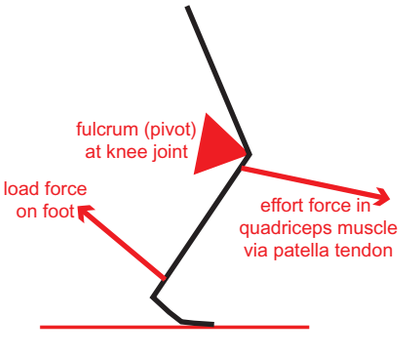
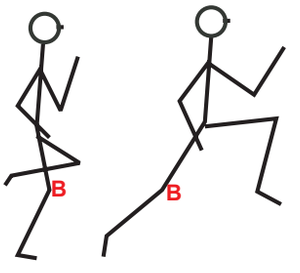


figure 2.20 – long jumper taking off

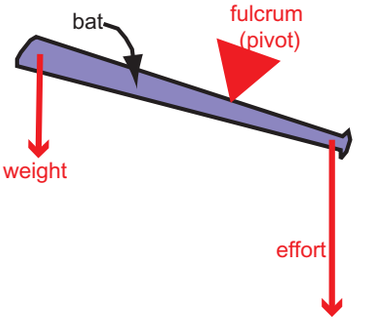


5) In figure 2.20 of a jumper taking off, name, sketch and label the lever system operating at knee **B** during this action. 3 marks

Answer:

- *See figures Q2.6 and Q2.7.*
- *This is a class 3 lever (effort between pivot and load).*
- *Note that the effort (figure Q2.6) is transmitted to the tibia via the patella tendon, which passes over the knee and inserts below the joint (figure Q2.7).*

figure 2.21 – softball bat



6) In softball, what order (class) of lever is shown in the hitting action in figure 2.21? State **one** disadvantage and **one** advantage of reducing the bat length for a beginner. 3 marks

Answer:

- *This is a class 1 lever.*

Advantage of shortening bat length is:

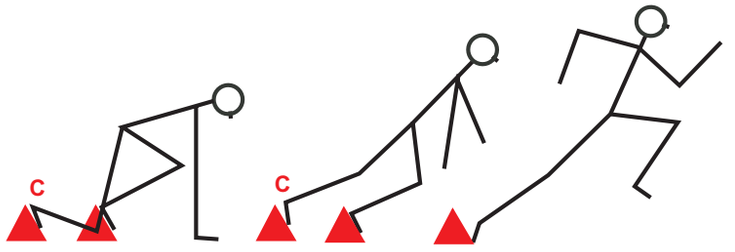
- *Learning the skill involved may be easier - since the strike point is nearer the hand.*

Disadvantage of shortening the bat would be:

- *Less force can be applied as a load for a given effort, hence the strike on the ball would impart less speed to the ball.*

7) Name, sketch and label the lever system which is operating at the ankle of leg **C** when doing the sprint set action illustrated in figure 2.22. 3 marks

figure 2.22 –ankle lever system



Answer:

- *See figure Q2.8.*
- *This is a class 2 lever.*
- *Note that the load force is a combination of the weight of the athlete acting downwards through the tibia/fibula on the ankle joint, and the reaction to the accelerating force driving the sprinter forwards.*

figure Q2.8 – ankle foot lever

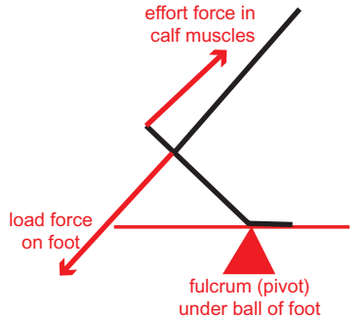


figure 2.23 – a press-up

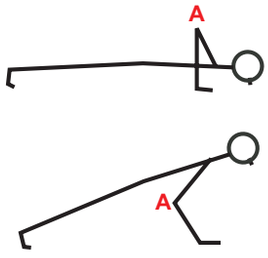
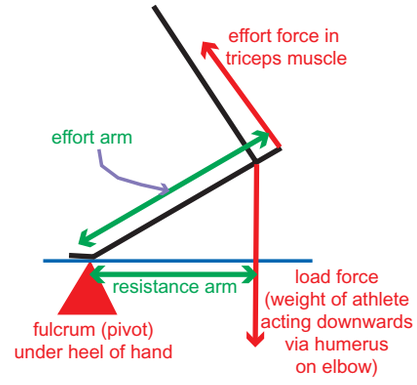


figure Q2.9 – elbow triceps lever



8) a) Figure 2.23 shows an elbow joint A of a person performing an exercise.
Draw a simplified sketch to show the lever system, indicating the various forces operating. 4 marks

Answer:

- *Figure Q2.9 – this is a 2nd class lever.*
- *Normally the triceps elbow system is a 1st class lever, but here, the pivot is at the hand as shown, which forces the system into 2nd class lever shape.*

b) On your diagram draw and label the effort and resistance arm. 3 marks

Answer:

- *Resistance arm lies between pivot and weight force (the lever arm is at right angles to the force).*
- *Effort arm lies between point of elbow and pivot.*

c) Diagram 2.24 shows the elbow joint and the position of the triceps muscle in relation to it when supporting a load (a shot) behind the head. Draw a simplified sketch to show the lever system, indicating the various forces operating.
4 marks

Answer:

- *See figure Q2.10.*
- *Note the position of the fulcrum at the elbow.*
- *The forces at the triceps and hand act downwards.*
- *The effort acts at the triceps.*
- *The load acts at the hand.*

figure 2.24 – elbow joint and triceps lever

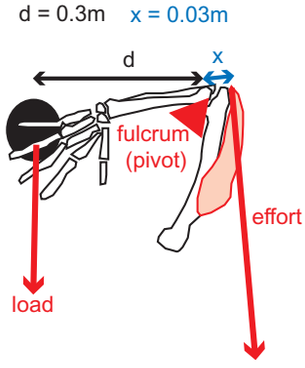
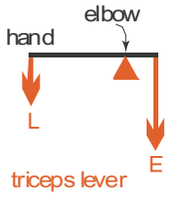


figure Q2.10 – triceps lever system

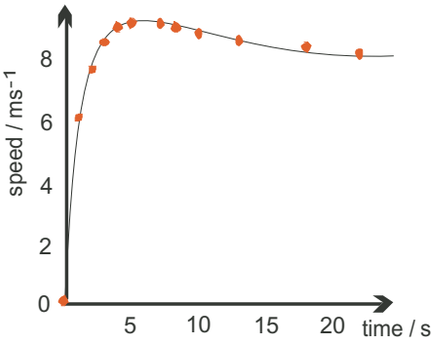


9) The table shows the speed of a 19 year-old male sprinter during a 200m race.

speed (ms^{-1})	time (seconds)
0.0	0
6.0	1
7.5	2
8.2	3
8.4	4
8.5	5
8.5	7
8.4	8
8.3	10
8.2	13
8.1	18
8.0	22

a) Plot a graph of speed against time during this race. When does he reach maximum speed and what happens to his speed between 8 and 22 seconds? 7 marks

figure Q2.11 – speed against time for 200m race



Answer:

- *See speed/time graph in figure Q2.11.*
- *Horizontal axis correctly scaled and labelled.*
- *Vertical axis correctly scaled and labelled.*
- *2 marks for points plotted correctly.*
- *Curve drawn correctly.*

Speed between 8 and 22 seconds:

- *Maximum speed is reached between 5 to 7 seconds.*
- *After 8 seconds there is a gradual slowing down.*

b) Acceleration is the change of speed per second. Use the graph to establish his speed at 0.5 seconds and 1.5 seconds and calculate the average acceleration between 0.5 and 1.5 seconds. 3 marks

Answer:

- *At 0.5 seconds, speed = 3.0 ms^{-1} (allow + or - 0.2).*
- *At 1.5 seconds, speed = 6.8 ms^{-1} (allow + or - 0.3).*
- *Acceleration = change of speed per second = 6.8 - 3.0 (in 1 second) = 3.8 ms^{-2}.*

c) Successful games players are often able to change their velocity rapidly in the game situation. Explain the biomechanics behind this ability using examples from a game of your choice. 6 marks

Answer:

6 marks for 6 of:

- *The force applied to the person is that between footwear and ground - friction.*
- *The factors which govern the size of friction force are the weight of the individual, the nature of the surface and footwear used.*
- *Newton's 3rd law applies between foot and ground.*
- *The sportsperson pushes on the ground (the action force), the ground pushes back with a reaction force (which is equal in size but opposite in direction to the action force) on the person.*
- *Acceleration = rate of change of velocity, velocity includes the direction.*
- *Newton's 2nd law tells us how much acceleration is produced by the force acting.*
- *The formula: force = mass x acceleration, enables you to work out the acceleration.*
- *Hence the bigger the force (the stronger the person) the greater the change in velocity.*
- *If the force is sideways to the direction of motion at the time, then the direction is changed.*
- *A sideways force causes swerving (change of direction but no change of speed).*
- *A force in the direction of motion causes increase or decrease in speed.*

10) a) A sprinter uses her calf muscles to push on the blocks at the start of a run. Explain, using Newton's laws, how this enables her to accelerate forwards out of the blocks. 3 marks

Answer:

- *Newton's 3rd law of motion - action and reaction are equal and opposite in direction.*
- *When the sprinter pushes down and back on the ground.*
- *The ground pushes up and forward on her.*
- *Newton's 2nd law of motion - if a force is exerted, then this produces an acceleration in the same direction as the force (forwards).*

b) If the resultant forward force was 300 newtons and the runner's mass was 60 kg, what would be her acceleration? 2 marks

Answer:

- *Newton's 2nd law gives force = mass x acceleration.*
- *Therefore: 300 N = 60 kg x acceleration.*
- *Hence: acceleration* $= \frac{300}{60} = 5\ ms^{-2}$.

c) What would be the speed of the runner after 1.5 seconds, assuming that the acceleration is the same over that period of time? 2 marks

Answer:

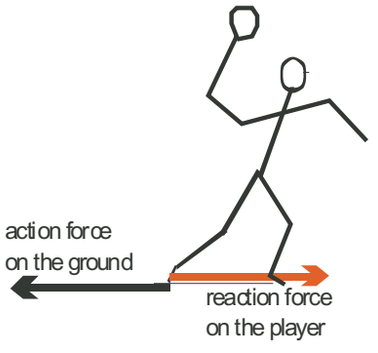
- *Speed changes by 5 ms^{-1} each second.*
- *Therefore total change of speed in 1.5 seconds* $= 7.5\ ms^{-1}$.

d) A squash player drives forward into a forehand stroke. Show how Newton's third law of motion explains his ability to do this. 3 marks

Answer:

- *Newton's 3rd law says that for every action there is an equal and opposite reaction.*
- *In this case the action is the force exerted by the player pushing backwards on the ground (squash court).*
- *The reaction is the forward force exerted by the ground on the player.*
- *See diagram Q2.12.*

figure Q2.12 – forces acting on a squash player



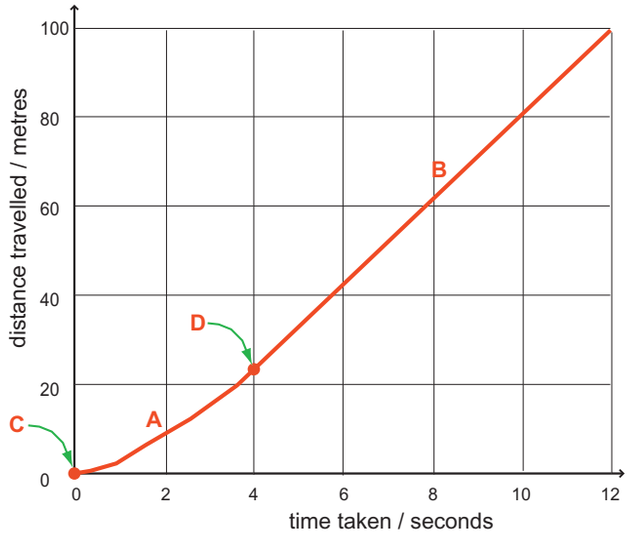
e) Explain why the turn in the discus throw produces greater horizontal range than the standing throw. 3 marks

Answer:

- *Force is applied to the discus over a larger distance.*
- *Over a longer period of time.*
- *Therefore acceleration is produced for a longer time (Newton's 2nd law of motion).*
- *Hence greater velocity given to the discus over and above the standing throw.*

11) Figure 2.25 shows the distance/time graph for a 100m sprint.

figure 2.25 – distance time graph for 100m sprint



a) Describe the motion of the sprinter in sections A and B. 2 marks

Answer:

- ***A** - acceleration, the slope/gradient of the graph increases, therefore the speed increases.*
- ***B** - constant speed, the slope of the graph remains the same.*

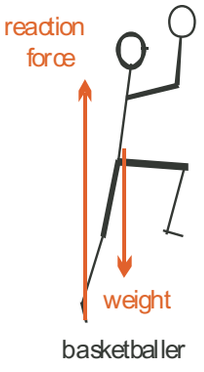
11) b) Calculate the speed at points C and D and the average acceleration between the points. 3 marks

Answer:

- ***C*** *- the athlete is about to start (just started), and speed is therefore zero.*
- ***D*** *- the gradient of the graph is approximately 19m in 2 seconds.*
- *Giving a speed of 19/2 = 9.5 ms^{-1}.*
- *The average acceleration is 9.5 ms^{-1} in 4 seconds.*
- *Giving acceleration of 9.5/4 = 2.375 metres per second per second (ms^{-2}).*

12) a) Use the diagram in figure 2.26 of a basketballer just about to take off into a jump shot, and your knowledge of Newton's Laws of motion explain why the basketball jumper takes off. 3 marks

figure 2.26 – basketballer about to take off



Answer

- *The upward force is bigger than the downward force on the jumper.*
- *Therefore there is a net upward force acting on the jumper.*
- *Newton's 2nd Law says that acceleration is linked to force applied.*
- *Therefore there will be an upward acceleration and the jumper will take off.*

b) If the vertical upward ground reaction force on the jumper is 2000N, and the weight of the jumper is 800N, estimate the net upward force acting on him. 1 mark

Answer

- *Net upward force F = 2000 - 800 = 1200 N.*

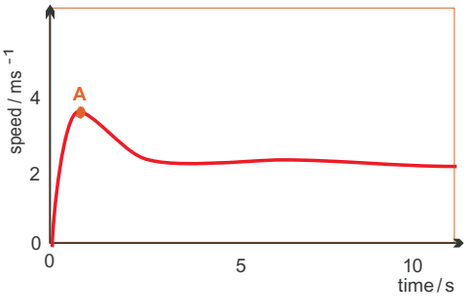
c) The mass of the jumper is 80 kg, calculate his upward acceleration during this part of the jump. 2 marks

Answer

- *Newton's Second law gives : Force = mass x acceleration,*
  Force = 1200 N,
  mass = 80 kg.
- *therefore 1200 = 80 x acceleration.*
  acceleration = $\frac{1200}{80}$ = 15 ms^{-2}.

figure 2.27 – speed against time for a swim race

13) a) The graph in figure 2.27 shows the start of a 100m sprint swim race. Using Newton's laws of motion, explain how the swimmer achieves the initial forward motion. 3 marks



Answer

- *Newton's 3rd Law.*
- *Every action has opposite and equal reaction.*
- *Backward force exerted by the swimmer on the block.*
- *Equal force forward from the block onto the swimmer.*

b) Describe what has happened to the swimmer at point A and explain the motion that occurs. 3 marks

Answer

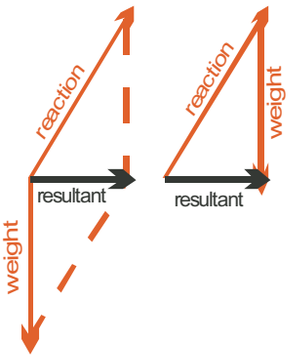
- *The swimmer has hit the water/enters the water at this point.*
- *At this point the swimmer begins to experience drag/fluid friction.*
- *And hence deceleration occurs, the swimmer slows down.*

14) a) What characterises a vector quantity? 2 marks

Answer:

- *A vector has size (or value or magnitude).*
- *And direction. For example, force. velocity, acceleration, weight.*

figure Q2.13 – resultant force

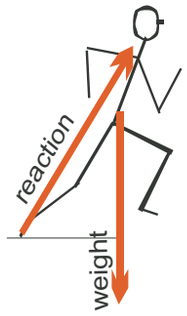


b) Figure 2.28 shows the forces acting on a runner at the start of a race. Use a vector diagram to show how you could work out the resultant force acting. 3 marks

Answer:

- *See figure Q2.13.*
- *Note that the parallelogram rule is used to estimate the resultant.*
- *The resultant is horizontal, showing that the net force is forwards.*

figure 2.28 – forces acting on a runner



c) Sketch a pin man drawing of a person standing still showing all the forces acting on him. 2 marks

Answer:

- *See figure Q2.14.*
- *Note that the force arrows are equal indicating that the forces cancel out - there is zero net force.*
- *The upward reaction force R acts at the feet, the weight W acts at the centre of mass.*

figure Q2.14 – forces acting on a person standing still

15) Tennis players have to change direction quickly during a match to recover to the centre of the court. Figure 2.29 shows a tennis player just after hitting a forehand and then starting to recover to the centre of the court in the direction shown.

a) Draw a pin diagram of the tennis player as he pushes off the court surface to recover to the centre of the court, showing all forces acting on the tennis player at this point. All forces must be clearly identified. 3 marks

Answer:

- *See figure Q2.15.*

figure 2.29 – a tennis player moves between strokes

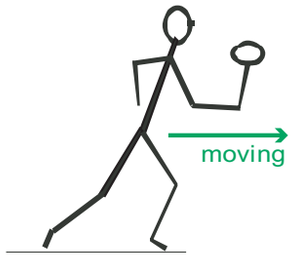
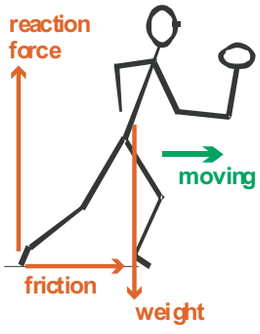


figure Q2.15 – forces acting on a tennis player between strokes



- *Weight acts downwards from centre of mass of tennis player.*
- *Friction acts forwards from the rear foot (in the same direction as the proposed direction of motion).*
- *Reaction force acts upwards on the rear foot (length of arrow the same or bigger than the weight arrow).*

b) Explain the factors that affect the horizontal force at this point. Apply Newton's second law of motion to explain the effect of this force on the player. 4 marks

Answer:

2 marks for 2 of:

- *Type or roughness of footwear.*
- *Type or roughness of court surface.*
- *Amount of reaction force - how hard player presses into ground - friction force depends on the contact force pressing the two surfaces (foot and ground) together.*

2 marks for 2 of:

- *Using Newton's 2nd law, F = m x a, or acceleration is proportional to force.*
- *Greater frictional force the greater the acceleration of player.*
- *Direction of frictional force = direction of acceleration = direction of motion of the player.*

16) Explain the effects of warming up muscle tissue. Why is it more important to warm up prior to an anaerobic training session as opposed to a 3 mile easy jog? 12 marks

Answer:

3 marks for definitions:

- *A warm-up can be passive or active.*

- *Passive warm-up involves raising muscle or core temperature without depleting energy substrates, by using hot showers, baths and massage etc.*
- *And is most impractical for active performers.*

- *Active warm-up usually consists of a series of low level aerobic exercises.*
- *Type of active warm-up depends on whether the activity or competition is aerobic or anaerobic.*
- *Which can be sport specific or general in nature.*

- *A general warm-up increases temperature using non-specific body movements, such as a 5 minute jog and light stretch.*
- *A sports specific element usually includes exercises of increasing intensity and duration that are specific to the performer's event.*
- *An example of a selected sport: 400 metres hurdles.*

7 marks for 7 of:

- *The muscular system responds to warm-up in the following ways:*

- *The greater the intensity of an active warm-up the greater strength of contraction due to improved elasticity of muscle fibres, needed in preparation for 400 meter hurdles training or competition.*

- *The faster speed of contraction due to an increased speed of nerve transmission to the muscle fibres.*
- *Which prepares the performer for speed and strength required for required between and over hurdles.*
- *The faster speed of contraction and relaxation of the muscle fibres due to an increase in muscle temperature.*
- *Which influences certain metabolic responses during subsequent high-intensity exercise.*

- *Increased speed of strength of contraction due to an improvement in coordination between antagonistic pairs because of a reduction in muscle viscosity.*
- *And hence improved hurdling and sprinting technique.*
- *Increased speed and strength of contraction due to increased availability of oxygen in muscle fibres.*
- *And thus delay in blood lactate response during high-intensity exercise.*
- *And therefore increased anaerobic energy provision in warmer muscle fibres.*
- *Which will enable athlete to maintain anaerobic energy levels for longer during 400 meter training session.*

- *A sports specific warm-up will take longer to complete as it would normally include skill drills that are specific to sports performer's event.*