CHAPTER 5

BIOMECHANICAL PRINCIPLES OF EQUILIBRIUM

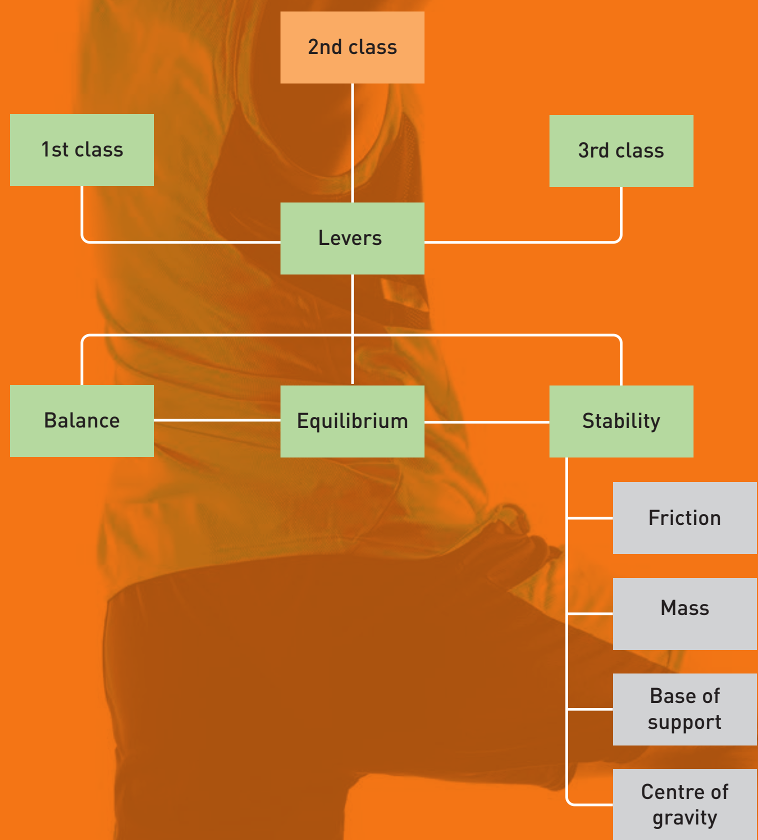
Key knowledge

» biomechanical principles for analysis of human movement including:
  - equilibrium and human movement: levers (force, axis, resistance and the mechanical advantage of anatomical levers), stability and balance (centre of gravity, base of support and line of gravity)

Key skills

» perform a qualitative analysis of a movement skill using video and systematic observation to analyse and improve a variety of movement skills

» analyse, interpret and apply graphical, visual and physical representations of biomechanical principles to improve movement skills in a coaching context



EQUILIBRIUM

The terms **equilibrium**, balance and stability are often used interchangeably, but in a biomechanical context, the three terms each have different meanings. There are many activities where maintaining balance is important, such as performing a handstand on the beam in gymnastics, or holding an arabesque in a floor routine, but many sports also require athletes to maintain their equilibrium while moving. Why is it easier to remain upright on a bike that is moving compared to when it is stationary? How do footballers remain upright while dodging and weaving around opponents? Why do swimmers and sprinters crouch low in preparation for the starter's gun?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Why do swimmers place one foot in front of the other and bend at the knees and hips on the blocks at the start of a race?

Biomechanically, the definitions of equilibrium, balance and stability are very specific. This chapter will look at how an understanding of the factors that affect equilibrium, stability and balance can be used to improve and refine performance in physical activity, sport and exercise.

An object is said to be in equilibrium when there are no unbalanced forces or torques acting on it (see chapter 3, page 57). An object in equilibrium is either motionless or moving with a constant velocity; that is, it is not accelerating (see chapter 4, pages 68–69). There are two types of equilibrium:

» static equilibrium
» dynamic equilibrium.

Static equilibrium

For the body or an object to be in static equilibrium it must not be moving or rotating. All the forces and torques acting on the body or object must add up to zero.

For an object or body to be in a state of static equilibrium, where it is completely motionless, it must meet three conditions:

1 The sum of all the vertical forces acting on the body must be zero.
2 The sum of the horizontal forces acting on the body must be zero.
3 The sum of all torques must be zero.

Dynamic equilibrium

When the body or an object is moving with a constant velocity – that is, with no change in speed or direction – it is said to be in dynamic equilibrium.

CHAPTER CHECK-UP

1 Define static equilibrium. Give two examples of an athlete in a state of static equilibrium in different sporting situations.
2 Define dynamic equilibrium. Provide two sporting examples where dynamic equilibrium can be observed.
3 A junior shot-putter holding the shot at their neck is in equilibrium just prior to beginning their action to release. Describe how the conditions of equilibrium can be changed to release the shot.

FYI
Maintaining stability of the body is largely an unconscious process. The body's balance systems automatically redistribute body weight to maintain stability.

STABILITY AND BALANCE

Equilibrium, **stability** and **balance** are closely related. Stability is the resistance to the disruption of equilibrium, and balance is the ability to control equilibrium.

When stability is increased, it is more difficult to unbalance an object; when stability is decreased, it is easier to unbalance the object or body. In some sports, the aim is to increase stability; in others it is beneficial to decrease stability. For example, swimmers use a stance on the blocks that minimises their stability, so that only a small movement is required to initiate the dive into the pool (see photo page 89). Wrestlers, on the other hand, use positions that increase their stability, making it more difficult for their opponents to disrupt their equilibrium.

Weblink

QUICKVID

Link via http://vcepe34.nelsonnet.com.au to a video clip showing the correct procedure for the Turkish get-up.

PRACTICAL ACTIVITY
BALANCE

Complete the following activities:
- Move from a sitting to standing position (e.g. get up out of your chair).
- Move from a standing to sitting position.
- Move from a lying to standing position.

Were you able to maintain your balance while completing each task?
Which was the most difficult to complete? Why?
Did you use your hands to increase your balance in any of the tasks?

Now try a Turkish get-up, after viewing the Quickvid above. You can do this with or without holding a weight, but you must have your hand above your head.

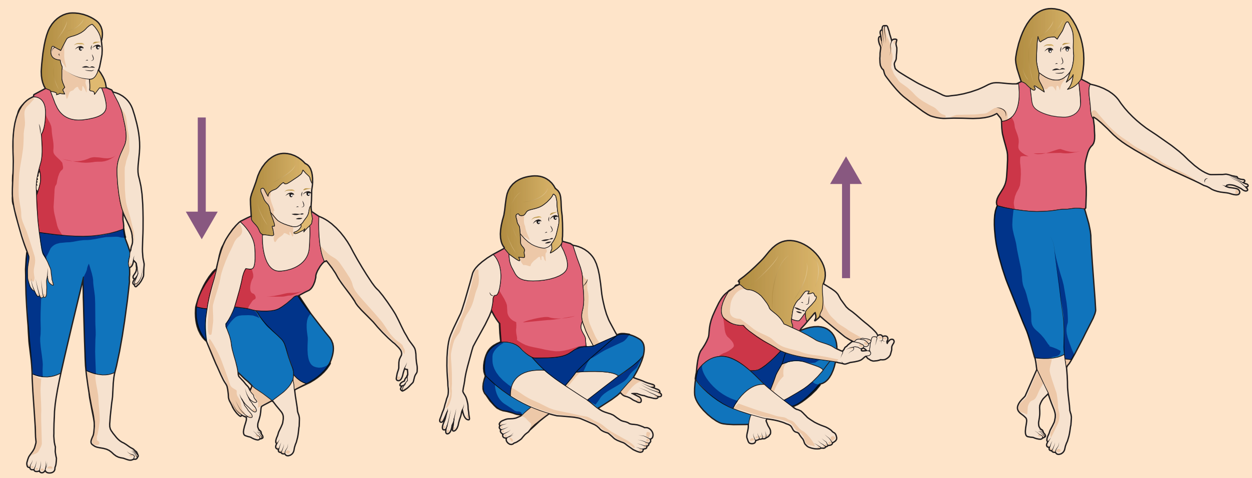
Was it difficult to maintain your balance during the exercise?
How did you adjust your body position to maintain your balance?

PRACTICAL ACTIVITY

UP AND MOVING

Try this simple sitting test for yourself:

1. Stand in comfortable clothes in your bare feet, with clear space around you.
2. Without using any type of support, lower yourself to a sitting position on the floor. This should be a controlled movement; you should not be concerned about the speed of the movement.
3. Now stand back up, without using your hands, knees, forearms or the sides of your legs for support, and without loss of balance.



SCORING

The two basic movements in the sitting-rising test – lowering to the floor and standing back up – are each scored on a scale of 1 to 5, with one point subtracted each time a hand or knee is used for support and 0.5 points subtracted for loss of balance. The maximum score achievable is 10.

Controlling the equilibrium of the body is important in lots of sporting activities. Gymnasts need good balance in order to complete routines on the floor and on the balance beam. There are times when a gymnast must hold a very stable position, such as when landing, and other times when it is advantageous to decrease their stability so they can launch into a series of movements. Controlling equilibrium while stationary or moving requires a high degree of balance, and to achieve balance we need to maximise stability.

Adequate stability is important for good performance in all sports, and balance is generally required. A platform diver must maintain their balance by holding a stationary position on the board, and a hockey player needs to maintain balance while dodging and weaving through other players on the field. A number of factors can be applied to enhance equilibrium, maximise the body's stability and therefore achieve balance.

FYI

Loss of musculoskeletal strength and flexibility have been associated with loss of balance and falls in older adults. Using a simple sitting-rising test (SRT), researchers found that the ability to sit and rise from the floor was a predictor for mortality (death) in 51–80-year-old subjects. People who scored fewer than 8 points were more likely to die in the next 6 years compared to those who scored higher in the test.

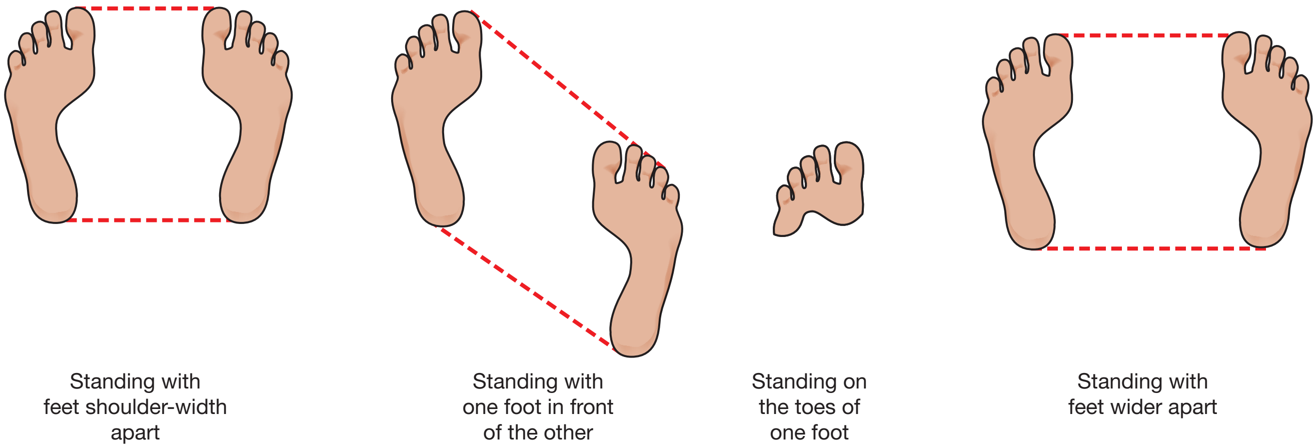
Factors affecting stability

A body's ability to maintain equilibrium is affected by:

» base of support
» centre of gravity
» body mass
» friction between the body and the surface or surfaces contacted.

Base of support

Generally, the larger the base of support, the greater the stability of an object. The base of support is the area bound by the outside edges of the body parts in contact with the supporting surface. The diagram below shows how different feet positions can produce different areas for the base of support.



Base of support (area inside the lines, including the feet)

Increasing the base of support can be as simple as moving your feet further apart. Moving one foot in front of the other increases your stability forwards and backwards. To increase side to side stability, move one foot further away from the midline of the body. As the area of the base of support increases, the degree of muscular effort required to maintain stability tends to decrease. Standing on one foot requires much more muscular effort to maintain balance than standing on two feet.

This principle can be applied to enhance sporting performance. Baseball and softball players will stand with one foot well in front of the other when hitting so that they can hit the ball hard without losing their balance.

Shutterstock.com/Aspen Photo

Baseball players use a wide stance to maximise stability while hitting.

Shutterstock.com/Daxiao Productions

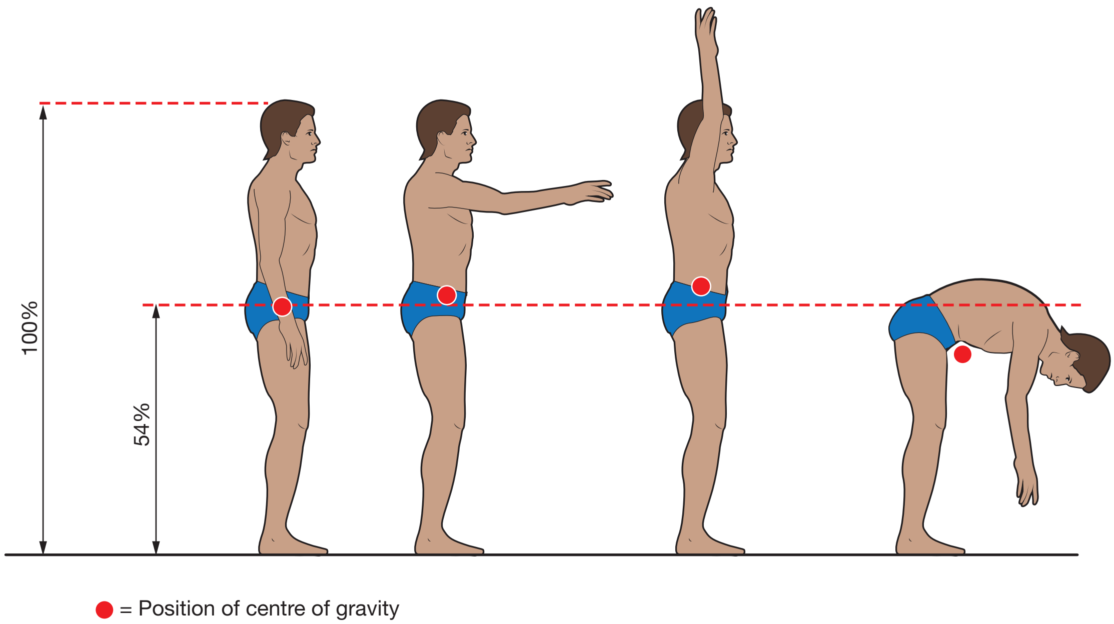
The dancer will make continual minor adjustments to ensure her line of gravity remains inside the base of support to maintain balance while performing an arabesque.

In some physical activity, the base of support for movement is very small. This means that the area that the line of gravity has to intersect is also very small. Any movement of the line of gravity in any direction except along the line of support will result in a loss of balance. Examples include movements along a balance beam in gymnastics, walking on a tightrope or performing an arabesque.

Centre of gravity

The body's **centre of gravity** is the point around which its weight is balanced, regardless of the position of the body. Generally, the centre of gravity in people is found close to the navel (belly button). Working out where our centre of gravity is and then changing it can increase stability. We can move our centre of gravity simply by moving our body parts.

The illustration below shows how the centre of gravity can shift depending on the position of the body. Stepping forward and extending both arms out in front, such as when performing a chest pass, moves the centre of gravity to just outside the body; putting your arms above your head raises it. Pregnant women often find that their balance is affected because, as their body grows to accommodate the baby, their centre of gravity moves outwards to the outer edge of the base of support.



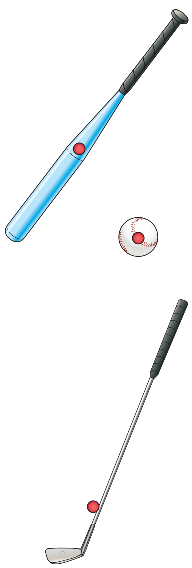
The centre of gravity can also be raised or lowered depending on the position of the body. Try standing on your toes and compare your stability to when you crouch down low. The higher the centre of gravity, the less stable a body will be, and the lower the centre of gravity, the more balanced and stable it will be. Flexing the hips, bending the knees and flexing the ankles are ways to lower the centre of gravity. These techniques are often used in sporting situations where the athlete requires greater stability.

FYI

In some sports, such as pole vaulting and high jump, the most efficient position of the centre of gravity is actually outside of the body – often below the height of the bar!

Shutterstock.com/Aspen Photo

The maximum height of the centre of gravity during pole vaulting can actually be lower than the height of the bar!



Locating the centre of gravity in a) a baseball bat; b) a baseball; c) a golf club. The centre of gravity is located towards the end with the greater distribution of mass.

Locating the centre of gravity

Biomechanists are interested in finding a body's centre of gravity because the human body behaves as though all of its mass is concentrated at that point. The path of the centre of gravity can be used to analyse performance in many events. The specific movement of the centre of gravity in elite high-jump, long-jump, pole-vault and sprint athletes has been identified as significant for improved performance.

The centre of gravity of a perfectly symmetrical object (a solid rubber ball) that has constant density and mass and uniform weight distribution will be in the exact centre. However, very few objects are like this. When the mass distribution in the object is not constant, the centre of gravity will shift in the direction of greater mass. For example, a baseball bat has greater distribution of mass towards the end away from the handle, so the centre of gravity is closer to this end. The centre of gravity of a golf club is close to the club head and slightly outside the shaft because of the weight distribution in the head of the club. You can locate the centre of gravity of a golf club or baseball bat by balancing the club or bat on your finger and finding the point where it will balance.

Finding the centre of gravity of the human body is much more difficult because of the moving parts and the different densities of the muscle, bone, fat and other body tissues, which are not equally distributed throughout the body. Many methods can be used to determine a person's centre of gravity, some of which require complicated mathematical formulas. For example, a reaction board can be used and the sum of the torques acting on the body can be calculated to find the centre of gravity. The segmental method involves looking at each segment of the body through film images, determining the centre of gravity of each segment using *x* and *y* coordinates, and then adding all the centres of gravity and dividing the result by the total body mass to find the coordinates of the total body's centre of gravity. This calculation is done using a digitised image and a computer program.

Line of gravity

Gravity acts on a body through the centre of gravity. The direction in which the gravity acts is called the **line of gravity**. When the line of gravity acts through the centre of the base of support, stability is increased. When it moves to the outside edge of the base of support or outside of the base of support, stability is disrupted. Athletes can use this to their advantage. Swimmers position themselves on the starting blocks so that their centre of gravity is close to the front of the base of support (see photo page 94). This means the swimmer is unstable and can easily accelerate forward into the dive when the starting gun sounds. Sprinters use this same principle to increase their acceleration out of the blocks (see below).

Moving the line of gravity to the edge of the base of support can actually aid in maintaining equilibrium. Rugby players will lean forward as they move towards an opposition. This moves the line of gravity closer to the oncoming force, meaning it has further to be moved before it moves outside the base of support and stability is disrupted.

Determining the centre of gravity by segmentation

Alamy Stock Photo/Aflo Co., Ltd.

Can you estimate where the sprinter's centre of gravity is located?

Alamy Stock Photo/Jeff Morgan 01

Rugby players will crouch forward as they move towards oncoming players, lowering their centre of gravity and moving the line of gravity closer to the front of the base of support.

Body mass

The greater the mass of an object or body, the greater the force required to move it, and therefore to disrupt its equilibrium (see chapter 3 for more about Newton's second law, F = ma). If all other factors are equal, the body with the greatest mass will be most stable. In some sports, such as wrestling, a greater mass and the increased stability that comes with it can be an advantage, but in sports where changes in stability are required to execute the skill, such as gymnastics, lower body mass is more beneficial.

LABORATORY

INVESTIGATING STABILITY

1 List 10 positions that have different areas for their base of support and different horizontal and vertical positions of the centre of gravity and line of gravity. These could include standing on two feet or one foot, balancing on one hand and one foot, and crawling on hands and knees.
2 With a partner, get into each position. Once in the position, have your partner gently push you. Were you able to maintain your equilibrium? Record your observations for each of the 10 positions.
3 Draw a diagram to represent the base of support of each position and comment on the stability of the position.
4 From your observations, what factors would affect the stability of the human body?
5 Provide some practical examples of sports in which athletes change the area of their base of support or the position of the centre of gravity to improve their performance.

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Waxing their board gives a surfer increased stability.

Friction

Increasing the friction between the body and the surface it is in contact with increases the person's stability. For example, a surfer waxes their board to increase the friction between their feet and the board, which in turn increases their stability. A golf glove increases the friction between a golfer's hand and the club, reducing the likelihood of the club slipping in their hand. See chapter 3, page 47 for more about friction.

Enhancing equilibrium, maximising stability and achieving balance

In summary, athletes can maximise stability by:

» increasing the size of their base of support
» ensuring the line of gravity falls within the base of support
» lowering their centre of gravity
» increasing their mass
» increasing the friction between their body and the surface or surfaces contacted
» extending their base of support in the direction of the oncoming force
» shifting the line of gravity towards the oncoming force.

CHAPTER CHECK-UP

1 Use the images provided and your knowledge of factors affecting stability to complete the table below. You can fill it in online by going to http://www.nelsonnet.com.au and using your login code.

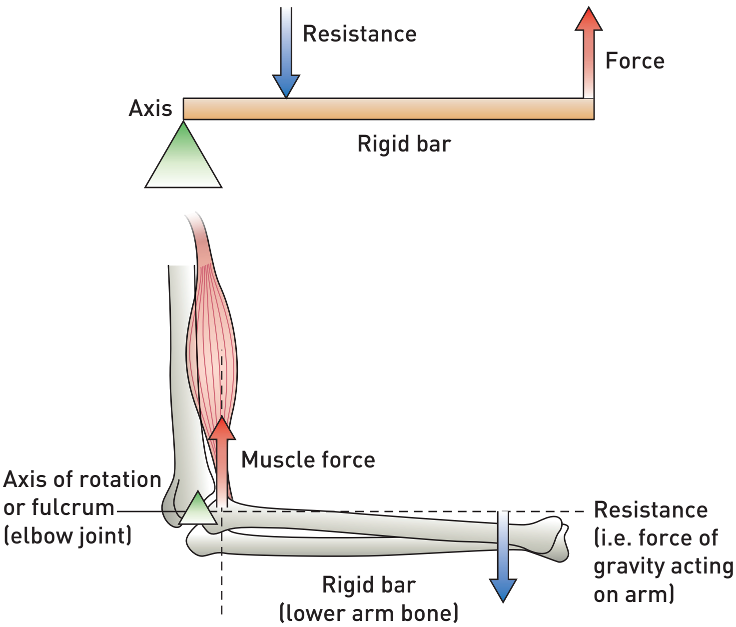
Scaffold

Sport/activity	Equipment	Effect on stability	Effect on performance
Golf – shoes			
Bobsleigh skeleton – sled			
Gymnastics – mag chalk			
Mountain bike riding – tyres			

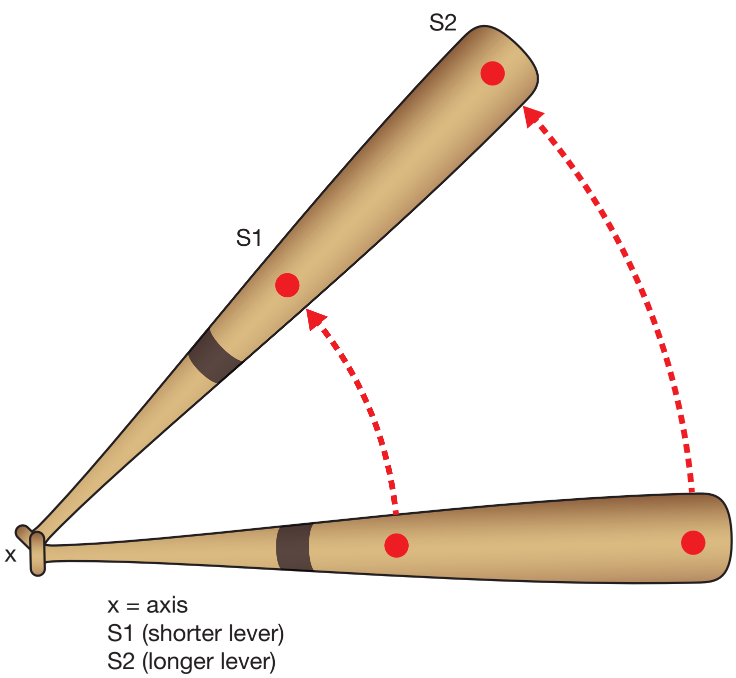
Photos, top to bottom: Shutterstock.com/urbanbuzz; Alamy Stock Photo/imageBROKER; Shutterstock.com/Paolo Bono; Shutterstock.com/homydesign

CHAPTER CHECK-UP

1 Define equilibrium, balance and stability.
2 List four sporting examples where contact surfaces are manipulated to either increase or decrease an athlete's stability.
3 List the four factors that can affect stability. Explain the effect each has on the stability of an object.
4 Coaches often instruct junior athletes to 'Bend your knees'. How would this instruction benefit a young athlete?
5 Explain how a gymnast can be balanced but also have low stability.



Components of a lever: (a) mechanical example, (b) human body example



The end of the longer lever (S2) travels a greater distance in the same time, so it moves at a greater velocity. This principle applies to sports where it is possible to increase the lever length with a racquet or bat.

LEVERS

The human body is a system of levers that allow movement to occur. A **lever** is a simple machine consisting of a rigid bar that can be made to rotate around an axis in order to exert a force on another object. In the human body, the bones represent the rigid bars, the joints are the axes and the muscles contract to apply the force (see illustration below). For a lever to move a resistance – which can be the bones themselves, the weight of the body segment or an additional load, such as a bat or racquet – a force must be applied. The mechanical advantage provided by levers allows us to apply a small force (or effort) to move a much greater resistance, or to move one point of an object a small distance, causing another point of the same object to move a relatively large distance (see diagram, left).

There are many other examples of levers in everyday life. Levers are designed to make jobs easier: a bottle opener makes it easier to open a bottle; a wheelbarrow makes it easier to shift a heavy load.

All levers have three parts:

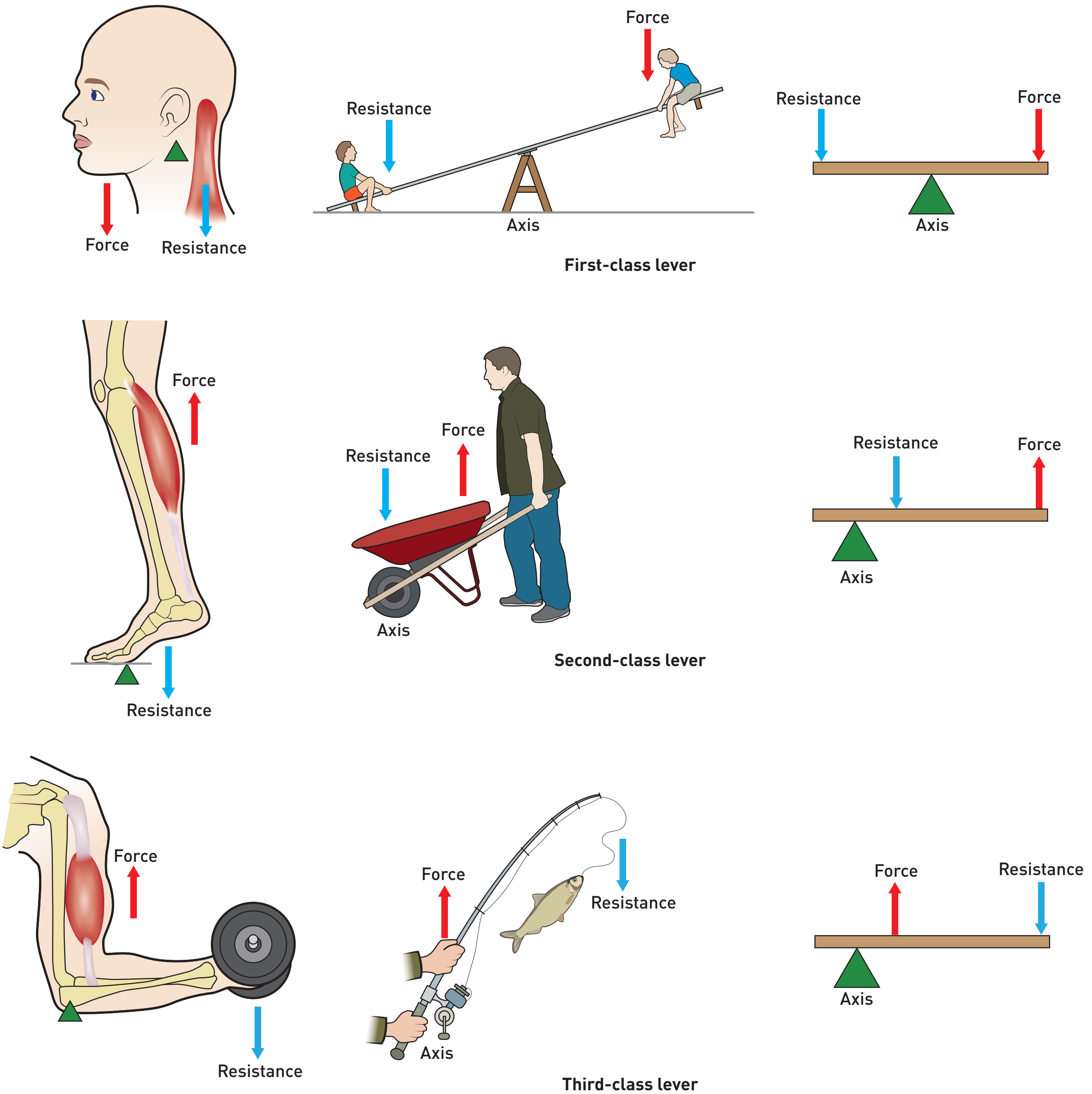
» an axis (or fulcrum or pivot point)
» a resistance (or weight or load to be moved)
» a force (or effort).

Lever classification

The position of the three components determines the class of lever: first, second or third. The illustrations on the facing page show the position of the axis, resistance and force in each class of lever.

» First-class lever – the resistance and the force are on either side of the axis.
» Second-class lever – the resistance is between the force and the axis.
» Third-class lever – the force is between the resistance and the axis.

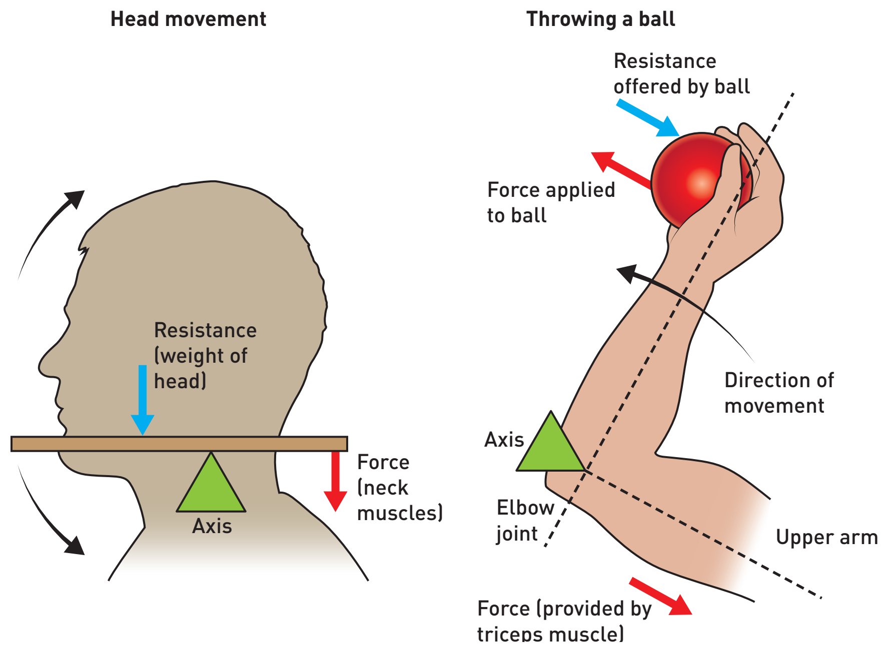
The lever system in the human body is designed for speed and range of motion, not force production. Most of the muscles and bones in the body operate as first-class or third-class levers, with a mechanical advantage of less than 1.



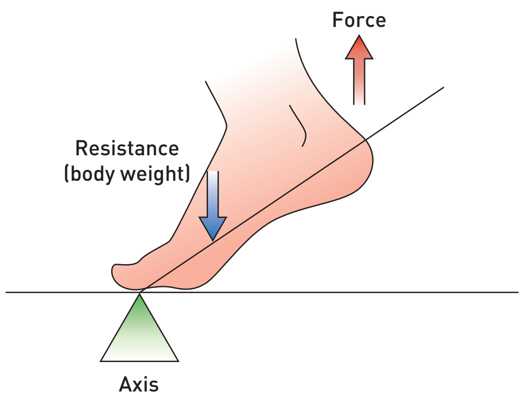
Classification of levers

First-class levers

In the human body, muscles work in pairs, on opposites sides of a joint axis. This is an example of a first-class lever. The agonist muscle provides the applied force and the antagonist muscle provides the resistance. First-class levers can be manipulated to increase either the force output by increasing the distance from the axis to the force (force arm), or the speed and range of motion of the lever. By increasing the distance from the axis to the resistance (resistance arm), an increase in the range of motion of the lever is achieved, as well as an increase in how quickly the resistance is moved.



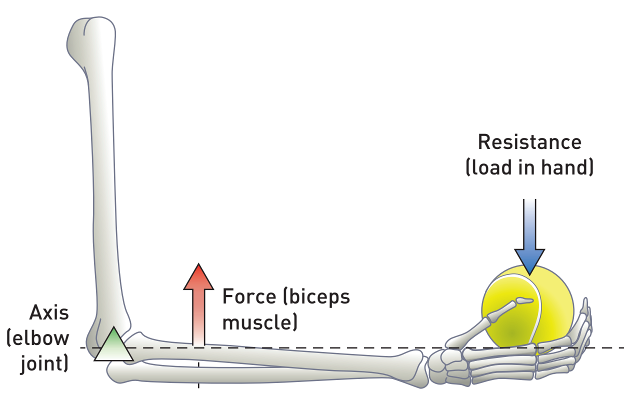
First-class levers in the human body



A second-class lever in the body is used when standing on tiptoes.

Second-class levers

There are very few examples of second-class levers in the human body because the body is not designed to apply great force through its system of levers. The resistance in a second-class lever is closer to the axis than the force, so the force arm is longer than the resistance arm. An example of a lever in which the resistance is positioned closer to the axis in the human body is a person standing on tiptoes. The resistance to be moved is the weight of the body, the axis is the toes and the force is the tension generated in the calf muscles as they contract, as shown at left. Second-class levers are beneficial in increasing the force output. They are useful when a heavier load needs to be moved.



Third-class lever in the human body

Third-class levers

Third-class levers are the most common type of lever both in the human body and in sporting applications of human movement. In human movement, the resistance is generally at the end of the lever. For example, the weight to be moved is often a bat, club or ball held in the hand. The axis of rotation is the joint and the force is applied by the contracting muscle. In third-class levers, the resistance is further from the axis than the force being applied. Third-class levers require greater force to move a given resistance, but greater range of motion and speed are gained. A simple example is to look at flexion of the elbow. When the elbow is flexed, the axis is the elbow joint, the force is the attachment of the biceps muscle close to the joint and the resistance is something being held in the hand, such as a dumbbell or a ball.

LABORATORY

USING LEVERS IN THE HUMAN BODY

Perform a sit-up under the following conditions:

- Legs bent, arms by your sides
- Legs bent, arms extended above your head
- Legs bent, arms behind your head
- Legs bent, holding a 2.5-kg weight above your head

QUESTIONS

1 From which position was it easiest to perform the sit-up? Which was most difficult? Rank the four positions from easiest to hardest.
2 Draw a diagram and label the axis of rotation, resistance and force. (Hint: The force will be the muscles responsible for the movement, the resistance will be the weight that has to be moved and the axis is where the rotation occurs). Draw in the resistance and force arms.
3 Explain your findings in terms of your understanding of levers.

The mechanical advantage of anatomical levers

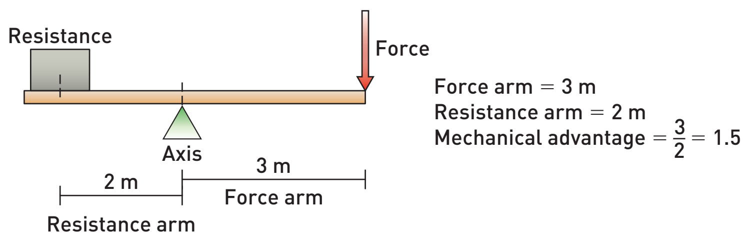
Understanding the role of levers in sport and human movement requires an understanding of the **mechanical advantage** a lever system can have. The mechanical advantage can be calculated by dividing the **force arm** by the **resistance arm**.

$$\text{mechanical advantage} = \frac{\text{force arm}}{\text{resistance arm}}$$

The force arm is the distance from the axis to the force and the resistance arm is the distance from the axis to the resistance. This is shown in the next diagram.

In the example shown here, there is a mechanical advantage because the ratio is greater than 1, which means that the force required to move the load is less than the force of the resistance. In simple terms, this means that in this type of lever system, a greater weight can be moved with less effort. All second-class levers have a mechanical advantage greater than 1.

When the resistance arm is greater than the force arm, there is no mechanical advantage – the ratio is less than 1 – but the range of motion of the lever is increased. All third-class levers have a mechanical advantage of less than 1. A greater force is required, but it only needs to be applied over a very small distance to achieve a large range of motion of the resistance. This in turn increases the angular speed of the lever.



Force arm and resistance arm of a (second class) lever

Most lever systems in the human body are third class. The force arm of anatomical levers is often very short, as the force is applied where the muscle attaches to the bone (not in the muscle belly), close to the axis. This means that anatomical levers will have a mechanical advantage of less than one. Levers in the body are designed to increase the speed and range of motion of the lever – the arm or leg for example. This in turn increases the angular speed of the body part, but the force generated must be greater than the resistance force.

Mechanical advantage >1	Less effort to move a resistance
Mechanical advantage <1	Increased range of motion Increased angular speed

Lever length

Anatomical levers in the human body are often extended in sporting situations through the use of a racquet, bat or club. This increases the distance from the axis to the resistance so the resistance arm is longer than the force arm. A greater force is required to swing the club or bat, but the advantage is an increase in the range of motion, resulting in an increase in velocity. The increased velocity translates to a ball being hit or kicked further.

Skilled athletes are able to increase the length of the levers they are using to maximise the velocity of the club or racquet, the hand releasing the ball or the foot kicking the ball, so that the velocity of the hit, kicked or thrown ball is greater.

The photo below shows an Australian Rules football player kicking a football. Notice that her leg is fully extended to maximise the length of the lever. This in turn imparts a greater velocity to the ball. The same thing can be observed when a tennis player serves the ball; they are at full extension when they connect with the ball.

Getty Images/Michael Dodge

Tayla Harris of the Demons kicks the ball for a goal during a Women's AFL exhibition match between Western Bulldogs and Melbourne at Etihad Stadium on 16 August 2015 in Melbourne, Australia. Fully extending her leg when kicking allows for maximum lever length.

Junior tennis players often serve from the wrist; others extend their elbow rather than their shoulder. Coaches encourage juniors to reach up to hit the ball during the serve, which allows for extension of the arm, maximising the length of the lever.

Children benefit from modified sporting equipment that is smaller and lighter than regular equipment. Longer levers can be more difficult to swing because of the length and greater mass. This increases the moment of inertia (see chapter 3, page 49). Increasing velocity is not as simple as increasing the lever length. Children will instinctively 'choke' a bat that is too big for them, which shortens the lever length, decreasing the moment of inertia and making it much easier to swing.

Image courtesy of Wilson Sporting Goods, www.wilson.com. Used with permission.

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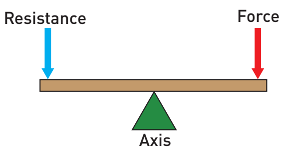
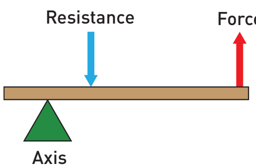
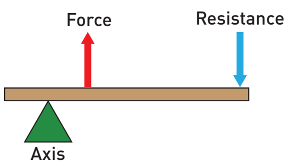
Modified sporting equipment increases the ability of a child to control the equipment, as shorter levers are easier to control.

TABLE 5.1 Summary of lever characteristics

Class	Arrangement	Direction of force vs resistance	Functional design	Mechanical advantage	Practical example	Human body example
1st	force – axis – resistance 	Resistance and force applied in same direction	Balanced movements (axis in middle)	= 1	Seesaw	Extending the head
			Speed and range of motion (axis near force)	<1	Scissors	Overhead elbow extension
			Force motion (axis near resistance)	>1	Crow bar	N/A
2nd	axis – resistance – force 	Resistance and force applied in opposite directions	Force motion (large resistance can be moved with relatively small force)	Always >1	Wheel-barrow	Plantar flexing the foot to raise the body to stand on the toes
3rd	axis – force – resistance 	Resistance and force applied in opposite directions	Speed and range of motion (requires large force to move a relatively small resistance)	Always <1	Catapult	Flexing the elbow

Adapted from Floyd, 2015

PRACTICAL ACTIVITY

LEVER LENGTH AND DISTANCE

AIM

To investigate the effect of lever length on the distance a ball will travel when hit

EQUIPMENT

Tennis balls, bat tennis bats, tennis racquets, markers, measuring tape and a large outdoor space

METHOD

1. Mark out a starting position from which to complete each trial.
2. Hit the tennis ball with your hand, using an underarm forehand action. Measure the distance the ball travels before it reaches the ground. Record your result. Repeat four times.
3. Repeat step 2 using the bat tennis bat and then the tennis racquet.
4. Record all your data in a table.
5. From your results, calculate the average distance travelled by the ball in each trial: hand, bat tennis bat and tennis racquet.

DISCUSSION

1. Which trial produced the greatest distance?
2. Explain why longer levers can hit the ball greater distances.
3. Golf clubs vary in length. From your findings, suggest reasons for the different club lengths used in golf.

REAL WORLD FOCUS

Levers in tennis

Alamy Stock Photo/PA Images

Australian tennis player Sam Groth uses his height to his advantage when serving. The extra length his height gives him is reflected in the length of his anatomical levers. Groth is tall – 193 cm – and has a big serve. He holds the world record for the fastest recorded serve, with a top speed of 263.4 km/h. This demonstrates the advantage of longer levers in generating velocity.

Elite players can extend the length of the lever not only with the racquet and by connecting with the ball with their arm fully extended, but also by making their spine the axis of rotation by rotating their body. This extends the length of the anatomical lever that is imparting the force.

CHAPTER CHECK-UP

1. An example of a second-class lever in the human body is the downward phase of a biceps curl. Draw a diagram labelling the axis, force and resistance. Explain the role of the muscle in this example.
2. Paddling a canoe is an example of which class of lever? What effect does sliding your hand down closer to the end of the paddle have on the functioning of the lever?
3. Push-ups can be a challenging exercise to perform. Using the principle of levers, explain how performing a push-up against a wall, on a bench and the on then ground will gradually increase the difficulty of the exercise.
4. Explain, in terms of levers, why a children's tennis, baseball, softball, golf or cricket coach should insist on modified equipment.

QUICKVID

Video

If you did not watch this video in chapter 3 or 4, go to your student website via http://www.nelsonnet.com.au and use your login code. In the resources for page 105 is a video interview with Dr Elaine Tor, a biomechanist from the Victorian Institute of Sport, discussing the role of biomechanics in sport.

QUICKVID

Video

Watch a clear explanation and summary of levers in the human body by one of the authors. Go to your student website via http://www.nelsonnet.com.au and use your login code. Then look at the resources for Chapter 5, page 105 and choose the `interactive'.

CHAPTER SUMMARY

- Equilibrium is a state of motion where there are no unbalanced forces or torques acting on the body. Equilibrium can be static or dynamic.
- Balance is the ability to maintain and control the equilibrium of the body in different situations.
- Stability is the body's ability to resist any changes or disruptions to its state of equilibrium. Stability is affected by mass, friction, base of support and centre of gravity.
- Levers consist of an axis, a force and a resistance. The positioning of each of these factors determines the mechanical advantage the lever will have.
- First-class levers have the axis between the force and the resistance.
- Second-class levers have the resistance between the axis and the force.
- Third-class levers have the force between the resistance and the axis.
- The human body is made up mainly of third-class levers. They are designed to increase the range of motion and speed of an object.
- The mechanical advantage determines the role of a lever. A lever with a longer force arm will have a mechanical advantage greater than 1 and increase the force output. A lever with a longer resistance arm will have a mechanical advantage less than 1 and increase the range of motion and speed of the lever.
- Longer levers have greater inertia and therefore are more difficult to swing. Junior sporting equipment is often modified to overcome this difficulty.

CHAPTER REVIEW

Multiple-choice questions

1 A lever designed to decrease the force required to move a load would be a
   A first-class lever, where the force arm is shorter than the resistance arm.
   B second-class lever, where the force arm is shorter than the resistance arm.
   C third-class lever, where the resistance arm is longer than the force arm.
   D both A and B

2 Stability is increased by
   A lowering the centre of gravity, increasing the base of support and decreasing the mass of an object.
   B lowering the centre of gravity, increasing the friction between the two surfaces and decreasing the mass of the object.
   C positioning the centre of gravity towards the oncoming force, lowering the centre of gravity and increasing the friction between two surfaces.
   D increasing the mass of the object, increasing the height of the centre of gravity and increasing the base of support.

Short-answer questions

3 How could a school athletics coach use the biomechanical principles associated with maximising stability to increase students' acceleration out of the blocks in the 100-metre and 200-metre sprint at the school athletics carnival?

4 Patrick is 13. His father gave him his old set of golf clubs to use to see if he likes golf. Why would using his father's old clubs be detrimental to the development of Patrick's skills?

5 Compare and contrast a standing sprint start and a crouched sprint start. Draw a diagram to show the relative bases of support, the position of the centre of gravity and the line of gravity.

6 Explain how a gymnast can increase their stability on landing.

7 Explain the biomechanical difference between a sit-up performed with your arms across your chest compared to a sit-up performed with your arms extended above your head.