CHAPTER 6
The biomechanics of human movement

OUTCOMES
On completion of this chapter, you will be able to:
- explain how body structures influence the way the body moves (P7)
- describe biomechanical factors that influence the efficiency of the body in motion. (P9)

OVERVIEW

INTRODUCTION TO BIOMECHANICS

FLUID MECHANICS
- Flotation
- Centre of buoyancy
- Fluid resistance

FORCE
- How the body applies force
- How the body absorbs force
- Application of force on an object

MOTION
- Linear motion
- Velocity
- Speed
- Acceleration
- Momentum

BALANCE AND STABILITY
- Centre of gravity
- Line of gravity
- Base of support
INTRODUCTION TO BIOMECHANICS

Biomechanics is a science concerned with forces and the effect of these forces on and within the human body.

The word biomechanics originates from two words. ‘Bio’ means life. Mechanics is a branch of science that explores the effects of forces applied to solids, liquids and gases.

Biomechanics is very important to understanding techniques used in sport. It is of value to both coach and player because it is concerned with the efficiency of movement. A knowledge of biomechanics helps us to:

- choose the best technique to achieve our best performance with consideration to our body shape. For instance, an understanding of the biomechanical principles that affect athletic movements, such as the high jump, discus throw, golf swing and netball shot, improve the efficiency with which these movements are made. This improves how well we perform the skill.
- reduce the risk of injury by improving the way we move
- design and use equipment that contributes to improved performance.

MOTION

Motion is the movement of a body from one position to another.

In biomechanics, the term motion is used to describe movement and path of a body. Some bodies may be animate (living), such as golfers and footballers. Other bodies may be inanimate (nonliving), such as basketballs and footballs.

We see motion in all forms of physical activity. Part of a person’s body (for example, the arm) may be moved from one position to another. The entire body may be moved from one place to another as in cycling, running and playing basketball.

There are a number of types of motion: linear, angular and general motion. How motion is classified depends on the path followed by the moving object. We will focus on linear motion in a range of sporting activities and apply the principle to enhancing performance.

Linear motion

Linear motion occurs when a body and all parts connected to it travel the same distance in the same direction and at the same speed. An example of linear motion is a person who is standing still on a moving escalator or in a lift. The body (the person) moves from one place to another with all parts moving in the same direction and at the same time.

Figure 6.1: This skier is experiencing linear motion.
The easiest way to determine if a body is experiencing linear motion is to draw a line connecting two parts of the body; for example, the neck and hips. If the line remains in the same position when the body moves from one position to another, the motion is linear. This is shown in figure 6.2.

Figure 6.2: When the lines remain parallel and equal, the motion is linear.

Examples of linear motion include swimming and sprint events where competitors race following a straight line from start to finish. Improving performance in activities that encompass linear motion usually focuses on modifying or eliminating technique faults that contribute to any non-linear movements. Excessive up and down, rotational and lateral movements are examples of faults that erode performance directed towards achieving the shortest, most efficient pathway. Sprinters who rotate their arms across their bodies and swimmers who use an irregular arm pull that results in a zigzag movement pattern along the pool surface are examples of poor application of linear motion.

### Linear motion and swimming performance

The 50 metre sprint in swimming is an example of the application of predominately linear motion in a sporting event. Poor swimming technique can result in wasted energy and poor performance. The aim in sprinting is to direct all body action directly up the pool by eliminating excessive rotational and lateral movements.

Use the Freestyle weblink in your eBookPLUS to read an article about correct freestyle technique.

Read the technique points and watch each of the short videos.  
1. List 10 points that you consider to be fundamental to better freestyle technique.  
2. On an excursion to a swimming centre, take turns with a partner in swimming a distance of about 20 metres. Focus on trying to swim efficiently, being mindful of the points you have listed on better technique. The observer should provide feedback from your list about your technique following each swim.
Application of linear motion to swimming
Discuss how the application of linear motion principles can enhance swimming performance.

**Velocity**

Velocity is equal to displacement divided by time.

\[
\text{Velocity} = \frac{\text{displacement}}{\text{time}}
\]

Velocity is used for calculations where the object or person does not move in a straight line. An example is a runner in a cross-country race, or the flight of a javelin, the path of which has both distance and incline/decline. Activities to improve speed may also relate to velocity. Improving the velocity of implements such as javelins or arrows requires specialised training, as does improving the performance of athletes in non-linear events such as marathons.

![Diagram of a cross-country course](image)

**Figure 6.3:** In this cross-country course, the displacement is equal to one kilometre. However, the distance run is actually far greater because the direction is variable.

**Speed**

Speed is equal to the distance covered divided by the time taken to cover the distance.

When an object such as a car moves along a road, or a person runs in a race, we often refer to how fast each is moving. This is called speed. If the runner covers a 100 metre track in 12 seconds, speed is determined by dividing the 100 metre distance by the time:

\[
\frac{100}{12} = 8.3 \text{ metres per second (m/s)}
\]

Speed is important in most sports and team games. The player who can move quickly has a distinct advantage in games such as touch football, rugby and soccer because not only is that player difficult to catch, but he/she can use their speed to gather opponents quickly in defence.
Much of our potential for speed is genetic and relates to the type of muscle fibre in our bodies. However, individuals can develop their speed as a result of training and technique improvements, the basis of which is the development of power and efficiency of movement.

Figure 6.4: Speed can be developed through application of biomechanical principles.

Improving speed

This application requires students to perform the 30 metre flying speed test.

1. Use the 30 metre flying speed test weblink in your eBookPLUS to establish how the test is conducted.
2. Record your times for the first 30 metres and the entire 60 metre sprint. Use the inbuilt calculator to predict your 100 metre time.
3. Use the Momentum Sports and Perfect Condition weblinks in your eBookPLUS to establish the characteristics of good technique in running.
4. Work in pairs with one person observing while the other performs short sprints for analysis. You could develop a rating scale using the points listed in Table 6.1 to show progress in acquiring better technique through feedback from practice.

Table 6.1: Rating scale for progress in acquiring better technique through feedback from practice

<table>
<thead>
<tr>
<th>Technical point</th>
<th>Excellent</th>
<th>Good</th>
<th>Needs improvement</th>
<th>Advice from observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toe up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heel up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reach out</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Claw back</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core stability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
When, in the opinion of the observer, technique has improved sufficiently, re-run the test and compare times with the previous effort.

1. Comment on the effect that better running technique made to speed improvement over a short distance.
2. Discuss the importance of good technique in other sporting activities such as surfing, downhill skiing and speed skating where speed with stability is crucial to success.

**Acceleration**

The powerful sprinter, like a car, is able to increase speed quickly. This is called **acceleration**.

*Figure 6.5:* A sprinter aims to develop a technique that enables maximum acceleration.

When a person or object is stationary, the velocity is zero. An increase in velocity is referred to as positive acceleration, whereas a decrease in velocity is called negative acceleration. For instance, a long jumper would have zero velocity in preparation for a jump. The jumper would experience positive acceleration during the approach and until contact with the pit, when acceleration would be negative.
Like speed, acceleration is a skill that is highly valued not only in sprinting but in many individual and team sports. The long jumper needs to accelerate quickly, reaching maximal speed at the take-off board. Football, softball, baseball and cricket players all need to accelerate quickly to cover short distances in beating the ball or opponents. The ability to accelerate depends largely on the speed of muscular contraction, but use of certain biomechanical techniques, such as a forward body lean, can significantly improve performance of the skill.

**APPLICATION**

**eBookplus**

**Speed, acceleration and performance**

Use the [Run faster](https://www.ebookplus.com) weblink in your eBookPLUS and watch the video *How to run faster: Speed and acceleration specifics* (5 minutes). As you view the video, note the five laws that relate to improved acceleration. As a class, select students to demonstrate the laws during short sprints as illustrated in the video. All the laws mentioned relate to the development of power through better technique.

**INQUIRY**

1. List and explain six principles that assist in improving acceleration.
2. Discuss the relationship between better technique and improved acceleration.

**Momentum**

*Momentum* (biomechanics) is a term commonly used in sport. For instance, we sometimes refer to the way in which momentum carried a player over the line in a game of football.

Momentum is a product of mass and velocity. It is expressed as follows:

\[ \text{momentum} = \text{mass} \times \text{velocity} \quad (M = mv) \]

The application of the principle of momentum is most significant in impact or collision situations. For instance, a truck travelling at 50 kilometres per hour that collides with an oncoming car going at the same speed would have a devastating effect on the car because the mass of the truck is much greater than that of the car. The car would be taken in the direction that the truck was moving.

The same principle can be applied to certain sporting games such as rugby league and rugby union, where collisions in the form of tackles are part of the game. However, collisions between players in sporting events tend to exhibit different characteristics to that of objects due to a range of factors, including:

- **the mass differences of the players** — in most sports, we do not see the huge variations in mass that we find between cars, bicycles and similar objects.
- **elasticity** — the soft tissue of the body, which includes muscle, tendons and ligaments, absorbs much of the impact. It acts as a cushion.
- **evasive skills of players**, which often result in the collision not being 'head-on'.

In some cases there may be some entanglement just prior to collision, such as a palm-off or fend. This lessens the force of impact.

The momentum described in the previous situation is called linear **momentum** because the object or person is moving in a straight line. However,
Angular momentum is the quantity of angular motion in a body or part of a body.

there are numerous instances in sport where bodies generate momentum but they do not travel in a straight line; for example, a diver performing a somersault with a full twist, a tennis serve, football kick, discus throw and golf swing. In each of these cases, the body, part of it, or an attachment to it such as a golf club or tennis racquet, is rotating. We call this angular momentum.

![Image of a person performing a somersault]

**Figure 6.6:** When moving bodies do not travel in a straight line, it is called angular momentum.

Angular momentum is affected by:
- **angular velocity.** For example, the distance we can hit a golf ball is determined by the speed at which we can move the club head.
- **the mass of the object.** The greater the mass of the object, the more effort we need to make to increase the angular velocity. It is relatively easy to swing a small object such as a whistle on the end of a cord. Imagine the effort that would be needed to swing a shot-put on a cord.
- **the location of the mass in respect to the axis of rotation.** With most sport equipment, the centre of mass is located at a point where the player is able to have control and impart considerable speed. Take baseball bats and golf clubs for example. Here, the centre of mass is well down the shaft on both pieces of equipment. This location enables the player to deliver force by combining the mass of the implement at speed in a controlled manner, thereby maximising distance.

**Angular momentum in stick games**

1. Choose two pieces of sporting equipment used for hitting, such as golf clubs or hockey sticks. Select the type of ball normally hit with this type of equipment. Shorten the shaft of one of the sticks (you may have a piece of damaged equipment that could be used, or move your hands well down the shaft of the equipment).

2. Place the ball on the ground and hit each of the balls as far as possible. Measure the distance that each of the balls was hit.

3. What were the distances of each of the respective hits?

4. Explain the difference in terms of the ability to generate angular momentum.

5. Sportspeople such as golfers and hockey players sometimes need to ‘shorten the shaft’ to play a particular shot. Use sporting examples to explain why this change of technique might be necessary and the implications for momentum on performance.
**Principles of motion**

Copy the mind map in figure 6.7 into your workbook and then complete it by identifying specific principles that support the motion principles identified.

![Mind map](image)

**Figure 6.7:** Mind map to summarise the principles of motion

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**Balance and Stability**

The centre of gravity of an object is the point at which all the weight is evenly distributed and about which the object is balanced.

**Centre of gravity**

Knowing the position of the centre of gravity is very important to improving sport performance. In a rigid object such as a cricket ball or billiard ball, the centre of gravity is in the centre of the object. This means that the mass is equally distributed around this point; that is, the weight is equally balanced in all directions. If the object has a hollow centre, such as a tennis ball or basketball, the centre of gravity is located in the hollow centre of the ball (see figure 6.8(a)).

However, some objects commonly used in sport are not exactly spherical or have an unevenly distributed mass; for example, the tenpin bowling ball or the lawn bowl. Both have a ‘bias’; that is, a slight redistribution of the mass to one side of the object. When the object is rolled on a flat surface, it gradually moves in the direction of the side with the greater mass (see figure 6.8(b)).

In the human body, the position of the centre of gravity depends upon how the body parts are arranged; that is, the position of the arms and legs relative to the trunk. Because the
human body is flexible and can assume a variety of positions, the location of the centre of gravity can vary. It can even move outside the body during certain movements (see figure 6.9).

![Image of a person in a crouched position with a dot indicating the centre of gravity.]

**Figure 6.9:** The point of the centre of gravity in the human body varies according to the position of the body.

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**APPLICATION**

**Varying the centre of gravity to enhance performance**

Use a range of commonly used starting positions for the 100 metre sprint. Vary the centre of gravity so that, in some starts, it is well forward, others about centre and the remainder, well back. Use both crouch starts and upright starts. Time each of the starts over 10 metres and record your information.

1. How were the times affected by varying the position of the centre of gravity?
2. Which position was the most successful in terms of time?
3. You are to teach the start to a group of young students. Suggest the biomechanical principles that you consider to be most important in generating a good start.
Varying the centre of gravity in the execution of a skill can enhance performance. Skilled high jumpers and long jumpers both lower the centre of gravity in the step or steps immediately preceding take-off. This enables them to propel their body over a slightly longer vertical path than would otherwise be possible.

In high jump events, the athlete needs to clear the bar for the jump to be successful. Most jumpers currently use the Fosbury flop technique to do this (see figure 6.10). The 'flop' is a more efficient method because the centre of gravity does not need to clear the bar by the same margin as is required in conventional jumps, such as the scissors. The lower the centre of gravity remains in relation to the bar (but with the body still making a clear jump), the more efficient the movement because the jumper requires less effort to clear the bar. Using the scissors technique, the jumper propels his or her body considerably higher because the centre of gravity is located higher in the body at the moment the bar is being cleared.

Static balance activities such as headstands and handstands require precise manipulation of the centre of gravity. To balance on your hands as in a handstand, or on your head and hands as in a headstand, the centre of gravity must be controlled by the base of support. If it moves away from a perpendicular position directly over the base, the gymnast falls.

Most learners find it difficult to assume headstand and handstand positions because when they prepare to kick up, they do not push their centre of gravity far enough forward prior to the kick. As a result, the body falls back in the direction of the centre of gravity unless it is stopped by a push from the legs. As shown in figure 6.11, the centre of gravity, which is located approximately about the waist, needs to be pushed well forward during the kick-up phase and then moved back above the base of support to balance.

Manipulating the centre of gravity requires considerable skill and contributes to the difficulty of skills such as the headstand and handstand.

**APPLICATION**

**Observing control of the centre of gravity**

On mats and with appropriate support and assistance, try to perform headstands and handstands. Observe the movements in both successful and unsuccessful attempts.

1. Discuss why some attempts were successful and others unsuccessful.
2. What advice could you give to improve the success rate?

**APPLICATION**

**Observing and controlling the centre of gravity**

Divide the class into half, with group one being the observers and group two the subjects. Those in group one are to run and, at the sound of a whistle, stop quickly...
and maintain balance. Group two is to observe and record group one's success in achieving balance immediately the whistle is blown.

1. Discuss the level of success or otherwise in achieving balance quickly.
2. In what way were the arms, legs and feet manipulated in order to improve the chances of success?

Like static balance, dynamic balance activities also require skilful control of the centre of gravity. In many moving activities, such as skiing and surfing, there is a fine line between the balance necessary for control and loss of balance resulting in a fall.

**Manipulating the centre of gravity to improve performance**

Select two or three students to perform a range of evasive movements, such as a swerve, sidestep and change of direction, on a flat surface. Observe the angle of the body in each movement as the direction is changed. Repeat the movements a number of times and record your information using a series of stick figures.

1. Plot the approximate location of the centre of gravity on each of the stick figures. Then draw three or four lines through each stick figure, dividing it into equal segments. Can you detect any changes in the location of the centre of gravity?
2. Discuss how the centre of gravity was being relocated to enable the change of direction to occur.
3. Explain how controlled manipulation of the centre of gravity can enhance performance.

**Line of gravity**

The line of gravity is an imaginary vertical line passing through the centre of gravity and extending to the ground. It indicates the direction that gravity is acting on the body. When we are standing erect the line of gravity dissect the centre of gravity so that we are perfectly balanced over our base of support (the base of support is discussed more fully in the next section). This is illustrated in figure 6.12.

Our base of support has a limited area. Widening our stance increases the size of the base of support. However, rules of some sports and competitions limit the size of the base of support; for example, the starting blocks for competitive swimmers. The closer the line of gravity moves to the outer limits of the base of support, the less stable we become.

Movement occurs when the line of gravity changes relative to the base of support. Movement results in a momentary state of imbalance being created, causing the body to move in the direction of the imbalance. In specialised sporting movements, such as the start in athletics, diving and rhythmic gymnastics, the precision with which the line of gravity moves in relation to the base of support directly affects the quantity and quality of movement.

During practice of specialised skills, athletes progressively develop a feel for the line of gravity relative to the base of support, enabling the controlled
instability required for movement. This means that less force is required to initiate the desired movement. For example, swimmers on the blocks bend forward, moving the line of gravity to the edge of the base of support so that less force is required to execute the dive. Springboard divers do likewise by moving the line of gravity to the front edge of their base of support, enabling forward movement with the take-off. This is illustrated in figure 6.13.

![Figure 6.13: The line of gravity relative to the base of support moves to initiate movement.](image)

**Line of gravity and the sprint start**

Use the Sprints weblink in your eBookPLUS to observe the seven photographs and read the technique points for the standing, crouch four point, 40 yard dash, three point and block starts. Print the information sheet and draw a thick line that identifies the exact position of the base of support in each of the photographs. Try to locate the centre of gravity for individuals in each of the photographs. Then draw the line of gravity through the centre of gravity and extend to the base of support. Comment on how far the line of gravity is relative to the extreme edge of the base of support and if you think this would enable a more efficient start. Justify your answer.

The **base of support** refers to an imaginary area that surrounds the outside edge of the body when it is in contact with a surface.

**Base of support**

Sustaining the balance of all individuals and objects is a **base of support**. It affects our stability or our ability to control equilibrium. A narrow base of
support allows the centre of gravity to fall close to the edge of the base of support. Only a small force is needed to make the person lose their balance (see figure 6.14). A wide base of support is essential for stability because the centre of gravity is located well within the boundaries.

The relative position of the centre of gravity to the base of support is important for stability. The further the centre of gravity is from the base, the more unstable is the body or object. There are many examples where athletes use the base of support to their advantage.

- The gymnast performing a pirouette has a very narrow base of support and must work hard to ensure that their centre of gravity remains within the base.
- Wrestlers widen their base of support to prevent their opponents from moving them into a disadvantageous position.
- Tennis players lower the centre of gravity and widen the base of support in preparation to receive a fast serve. This enhances balance and enables the centre of gravity to be moved in the desired direction more readily.
- Swimmers on the blocks widen their feet and move the centre of gravity forward to improve their acceleration.
- Golfers spread their feet to at least the width of their shoulders to enhance balance when they rotate their body during the swing.

**APPLICATION**

Have five students assume a range of positions with varying bases of support; for example, a pirouette, headstand, crouch balance, start and boxing stance. Try to move each student from their position. Record the results.

1. Draw the shape and size of the base of support for each activity above.
   Compare the amount of effort required to displace each person from their position.
2. Discuss the degree to which the mass of the student affected your ability to dislodge each from their position.

**APPLICATION**

Base of support and changing stances

Choose a golf club or hockey stick. Hit five balls with your feet together (narrow base of support) and five balls using a normal stance. Measure the distances for each hit and calculate an average distance for each piece of equipment.

1. How much variation was there in average distances between the different stances?
2. Discuss why there was a difference.
3. Suggest five other activities where knowledge of the base of support is important to improving performance.

**INQUIRY**

Base of support and improving skills

Choose any sport or activity. Discuss how knowledge of the centre of gravity and base of support could enhance performance in a range of skills in that sport.
Fluid mechanics is a branch of mechanics that is concerned with properties of gases and liquids. An understanding of fluid mechanics is important for performance improvement because physical activities such as running, throwing and swimming all take place in fluid environments, be it air, water or a combination of both.

The type of fluid environment we experience impacts on performance. For example, when we throw a javelin, hit a golf ball or swim in a pool, forces are exerted on the body or object and the body or object exerts forces on the surrounding fluid. Knowledge about how to equip ourselves and better execute movements in specific fluid environments improves safety and can significantly enhance performance.

Figure 6.15: Examples of fluid environments in which we perform

Flotation

To float is to maintain a stationary position on the surface of the water.

Buoyant force is the upward force on an object produced by the fluid in which it is fully or partially submerged.

You have probably observed that some people appear to float better in water than others. Many people are able to push and glide from the pool wall, floating momentarily but then sinking, usually feet first. Others have difficulty getting under the surface of the water during a 'duck dive', their feet kicking and splashing on the surface as they try to submerge.

The ability to float — to maintain a stationary position on the surface of the water — varies from one person to another. Flotation impacts on swimming, survival in water and even our ability to learn to swim. To better understand flotation, we need firstly to understand the impact of forces that act on a floating body or object.

Our body floats readily on water when the forces created by its weight are matched equally or better by the buoyant force of the water. For an object to float, it needs to displace an amount of water that weighs more than itself. Conversely, if the object displaces a quantity of water that weighs less than itself, it sinks. Hence, wearing a personal flotation device (PFD) increases buoyancy because its size displaces a lot of water with only a minimal increase in weight.

The water displaced by the object does not lie directly below it, as illustrated in figure 6.16, but spreads throughout the pool (or whatever confines the water) and exerts forces on all surfaces of the body or object.

Figure 6.16: The swimmer's weight is resisted by upward forces equal to the weight of the displaced fluid.
Body density, or its mass per unit volume, also impacts on the ability to float. Density is an expression of how tightly a body's matter is enclosed within itself. The density of the human body varies from one person to another. The average weight density of the human body is approximately equal to that of water. If our weight density is high, that is, we are relatively fat free, the body sinks in water. Conversely, if we have higher proportions of less compact tissue such as fat, we tend to float. In other words, a body or object floats if its density is less than that of the fluid. A cork, for example, is less dense than water, allowing it to float, while a solid metal bar has a far greater density and consequently will sink.

**How buoyancy works**

Use the How Stuff Works weblink in your eBookPLUS to discover more about density and buoyancy.

1. Explain why the bowling ball sank to the bottom of the tank while the basketball stayed close to the surface.
2. Discuss the effect of body composition on flotation.

You have probably observed that the human body does not float evenly if left in the prone position. This is because the density of the human body (body composition) is not uniform as it is composed of different materials. Diverse body tissue including bone, fat and muscle each has a specific density. Some materials are considered to be relatively dense, such as teeth and bones, whereas other parts such as lung tissue and intestines have lower densities.

Again, the distribution of organs and tissue throughout the body makes some areas less dense in comparison to others. For example, the upper body contains the lungs (low density tissue), making this area less dense than the lower body, which contains a high percentage of bone and muscle. Because human body density is not uniform, average total body density is the determining factor in flotation.

The degree of density changes the buoyancy of an object or body. Objects with densities higher than that of water (more mass) sink, while those with densities lower than that of water (less mass) float. However, it is common for people to sink non-uniformly from a horizontal, stationary floating position and this usually begins with the feet. The positioning of tissue such as the lungs relative to the legs impacts on flotation and affects which parts sink first.

**Sink or float**

1. Explain why some people float better than others.
2. Why might it be necessary for some people to wear personal flotation devices (PFDs) when performing skills in deep water?
3. Explain why deep inhaling and holding breath might enhance one's ability to float.
4. Why does the sculling arm action allow us to remain on the surface of the water?
5. Explain why you float when you stretch out but sink when you roll your body into a ball.
6. Explain why, when we push and glide, we remain on the surface of the water but begin to sink as our forward movement stalls.
Centre of buoyancy

If our average total body density is higher than that of water, we sink but this does not happen uniformly. To understand why this happens we need to understand the link between the body's centre of gravity and its centre of buoyancy. Every floating object has a centre of gravity and centre of buoyancy. We saw on page 231 that the centre of gravity is the point around which the body's weight is equally balanced in all directions. While differing body shapes contribute to variations in the exact location of the human body's centre of gravity, even when floating the centre of gravity is generally found about the waist, as illustrated in figure 6.17.

![Figure 6.17: The centre of gravity of the human body is located about the waist.](image)

The centre of buoyancy is the centre of gravity of the fluid displaced by a floating object. Around this point, all the buoyancy forces are balanced.

During unassisted horizontal flotation, the human body's centre of buoyancy is not vertically aligned to its centre of gravity. The lungs, which contain a large volume of air, draw the centre of buoyancy towards the chest. As illustrated in figure 6.17, the body's centre of gravity (centre of mass) is located more towards the hips and the exact position varies from one individual to another. During an attempt to float, gravity pulls the lower body downwards (greater mass) while the buoyant forces push the chest and upper body upwards (less mass in this area). The result is that the body rotates until the centre of mass lies directly below the centre of buoyancy. This leaves the body in varying degrees of diagonal positions depending on the position of the centre of mass in each individual. The impact of varying body compositions on flotation is illustrated in figure 6.18.

![Figure 6.18: Body composition influences the relationship between centre of mass and centre of buoyancy, changing the depth and angle of flotation.](image)

**APPLICATION**

Centre of buoyancy

Work in pairs at a swimming pool with one person observing and the other recording the observations. During the course of the exercise, the person in the water needs to assume positions listed in table 6.2 and hold each for a period of 10–15 seconds.
The recorder observes what happens to the unassisted floating body in terms of buoyancy and rotation and records the information in the second column.

**Table 6.2: Buoyancy and rotation of unassisted floating body**

<table>
<thead>
<tr>
<th>Position in water</th>
<th>Flotation and body position changes</th>
<th>Why it happened</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone float</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back float</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kneel to chest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prone float with arms and legs spread</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prone float with legs supported by kickboard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body vertical, arms by side, feet together</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side float</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duck dive (unassisted by hands and feet kick)</td>
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<td></td>
</tr>
</tbody>
</table>

**INQUIRY**

1. In pairs, use the third column in table 6.2 to explain flotation and body position changes.
2. As a class, discuss the relevance of flotation to performance of survival skills and swimming generally.

**Drag** is the force that opposes the forward motion of a body or object, reducing its speed or velocity.

**Lift** is the component of a force that acts at right angles to the drag.

**Fluid resistance**

When a body or object moves, whether it be in air or water, it exerts a force and simultaneously encounters a resisting force from that medium. In sporting competitions such as swimming and athletics, **drag** and **lift** forces are constantly responding to the object or body’s thrust. When competitors throw objects such as the discus or javelin, or propel themselves forward, maximum length/speed is generated when drag is minimised. Lift is the force that operates at right angles to the drag.

While in most activities lift is essential in keeping the implement airborne, sometimes negative lift is an advantage. An example of using technology to create favourable negative lift is the use of an inverted wing on Formula 1 cars (see figure 6.19) to maximise downforce and ultimately improve performance.

**Figure 6.19:** Negative lift helps maximise traction and improve performance.
There are many types of forces exerted by fluids that resist an implement or body trying to move through it. At the same time, technological improvements have enabled us to better use the specific fluid to decrease resistance; for example, better configuration of the dimples on a golf ball can improve its flight performance. This is explored more fully when we examine the Magnus effect (see page 245).

Drag is the force that opposes the forward motion of a body or object, reducing its speed or velocity. It is a resisting force because it acts in opposition to whatever is moving through it. Drag forces run parallel to the flow direction (airflow, water), exerting a force on the body in the direction of the stream. An example of where we find drag forces in sport is to watch a swimmer push off the pool wall following a turn. The swimmer's forward motion gradually decreases due to resisting forces applied by the water, which makes the swimmer stop unless arm or leg action begins. A body that is streamlined (contoured to reduce resistance) and technically efficient moves through the medium, creating less drag than a body that is not as streamlined. This difference in the amount of drag created by non-streamlined and streamlined bodies is illustrated in figures 6.20 and 6.21.

**Figure 6.20:** When a body is not streamlined, considerable drag is created, making it more difficult to move through the fluid.

The amount of drag experienced depends on a number of factors, including:
- **fluid density.** Because water is denser than air, forward motion in this fluid is more difficult.
- **shape.** If a body or object is streamlined at the front and tapered towards the tail, the fluid through which it is moving experiences less turbulence and results in less resistance.
- **surface.** A smooth surface causes less turbulence, resulting in less drag.
- **size of frontal area.** If the front of a person or object (area making initial contact with the fluid) is large, resistance to forward motion is increased.

**Figure 6.21:** The streamlined body creates much less drag allowing it to move more efficiently through the medium.

There are two types of drag forces — surface drag and profile drag. Surface drag or skin friction refers to a thin film of the fluid medium sticking to the surface area of the body or object through which it is moving. This layer sticks to the next layer and progressively to neighbouring layers. However, attachment to outer layers becomes increasingly weaker until there is no attachment at all.

The fluid in the immediate vicinity of the surface of a projectile comprises the boundary layer. When an object such as a discus is projected into a
Laminar flow is a streamlined flow of fluid with no evidence of turbulence between the layers. In the medium in which the fluid flows, pockets of fluid in the boundary layer become unstable as the object moves through it. The thrust of the object disturbs air that is in laminar flow to make way for its mass. This air is then forced to detour around the object but becomes mixed in the process. Some attaches itself to the object and even rotates with it if the object is spinning. Turbulence develops, causing forces known as surface drag to be exerted on the object (and in turn exerts forces on the fluid), causing forward movement to be slowed.

The coarser or less streamlined the surface of the object, the thicker is the boundary layer. This is illustrated in figure 6.22 where the air ahead of the golf ball is in laminar flow until disturbed by the advancing ball and causing the formation of a boundary layer to develop around the ball. The thick, turbulent air attached to the ball slows its progress.

Profile drag (also called form or pressure drag) refers to drag created by the shape and size of a body or object. As they move through fluids, bodies or objects cause the medium to separate, resulting in pressure differences at their front and rear. The separation causes pockets of high and low pressure to form, resulting in the development of a wake or turbulent region behind the body or object. Pressure drag is a component of the total drag, all of which combine to slow down the object.

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When we swim, for example, fluid pressure at the front of our body is greater than fluid pressure behind our feet. Objects with bigger cross-sectional areas produce more form drag in comparison to streamlined objects, which, because of their shape and smoothness, cause less drag. Cyclists try to reduce form drag by reducing the size of their frontal area (bending forward) and by 'drafting' or following closely behind other cyclists to reap the benefits of being in the low pressure area.

Figure 6.23(a) demonstrates an object with a large cross-sectional area causing an extensive wake at its rear. The wake encompasses whirling currents that tend to flow in an upstream direction, giving rise to forces that oppose the forward motion of the body or object. The more streamlined object in figure 6.23(b) causes less interference to airflow, resulting in a smaller low pressure area and subsequently less drag.

Figure 6.23: The blocking effect of bigger objects causes greater turbulence and more drag than more streamlined objects.
The effects of drag on performance

Examine the illustrations in the left column of table 6.3. Use the right column to identify types of drag and the effect of this on performance. Discuss your findings with the class.

**Table 6.3: Types of drag and effects on performance**

<table>
<thead>
<tr>
<th>Body or object</th>
<th>Types of drag and effect on flight/performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golf ball in flight</td>
<td></td>
</tr>
<tr>
<td>Airflow Turbulence</td>
<td></td>
</tr>
<tr>
<td>Downhill speed skiing</td>
<td></td>
</tr>
<tr>
<td>Discus in flight</td>
<td></td>
</tr>
<tr>
<td>Cycle racing</td>
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</tbody>
</table>

(continued)
Much has been done to try to minimise resistance forces that oppose movement in fluid mediums. Most developments have taken place in regard to technique, tactics, clothing and equipment design. For example:

- **technique.** Cyclists, speed skaters and downhill skiers all bend forward at the trunk.
- **tactics.** Distance runners and cyclists follow one another closely where possible.
- **clothing.** Tight bodysuits made of special friction-reducing fabrics are worn by runners, cyclists and swimmers.
- **equipment design.** Designs of equipment such as golf balls, golf clubs, cricket bats, bicycle helmets, footballs and surfboards are continually being modified to make them more aerodynamically efficient.

### Using biomechanics to improve performance

In table 6.4, compare performance A with performance B for the three activities. In the space under performance A, identify relevant types of drag and elaborate on the effect this has on performance. Under performance B, identify any technique, equipment, design and other modifications that have influenced performance/design.

### Table 6.4: Effects of drag on performance

<table>
<thead>
<tr>
<th>Performance 1A</th>
<th>Performance 1B</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Swimmer" /></td>
<td><img src="image" alt="Swimmer" /></td>
</tr>
</tbody>
</table>

Types of drag and impact on performance:  
Technique/equipment modifications to reduce drag:
### INQUIRY

Applying fluid mechanics principles to movement and performance

Choose one sport from the three categories shown in table 6.4. Explain how the principles of fluid mechanics have influenced changes designed to improve movement and performance.

---

#### The Magnus effect

The **Magnus effect** explains why spinning objects such as cricket and golf balls deviate from their normal flight paths. When an object such as a cricket ball or golf ball is bowled or hit into the air, its spinning motion causes a whirlpool of fluid around it that attaches to the object. According to the direction of spin, the object’s movement is affected.

We are familiar with three types of spin, **topspin** occurs when a ball or object rotates forward on its horizontal axis causing it to drop sharply. **Backspin** is the opposite and occurs when a ball or object rotates backwards, causing it to fall slowly at the end of flight. Both topspin and backspin shorten
**Sidespin** refers to rotation around a vertical axis causing the ball or object to curve left or right during flight.

Spinning causes the formation of pockets of high and low pressure. The size of the pressure pockets depends on the speed of rotation and roughness of the surface. Fast bowlers shine one side of a cricket ball to enhance the streamlining effect while leaving it rougher (through contact with the pitch) on the other side. This assists a properly delivered ball to swing during flight as one side of the ball is able to move through the air with less resistance than the other side. This is illustrated in figure 6.24. The cricket ball experiences a force towards the side of the low pressure causing it to move in that direction. In fact, where pressure differences occur, objects always move from the area of high pressure to low pressure.

![Diagram of airflow and pressure zones on a cricket ball](image)

**Figure 6.24:** The seam alignment, together with surface differences on each half of a worn cricket ball, can be used to enhance its ability to swing.

Two sports that rely heavily on backspin and topspin are tennis and table tennis. While the surface of the table tennis ball is relatively smooth, the dimpled face of the bat allows considerable velocity to be imparted, enhancing the Magnus effect. The comparatively rougher surface of the tennis ball enhances its ability to ‘grab’ air in the boundary layer and dip quickly when hit over the net with topspin. The impact of topspin and backspin is illustrated in figure 6.25.

![Diagram of airflow and pressure zones on a tennis ball](image)

**Figure 6.25:** (a) Topspin and (b) backspin. The direction of rotation of an object causes pressure differences that affect ball flight.
Using fluid resistance principles to advantage

Use the following diagram to explain how the Magnus effect affects the flight of dimpled and non-dimpled golf balls.

Using the Magnus force to enhance performance

Choose a sporting skill such as baseball pitching or goal kicking in soccer where the Magnus force influences the flight of the projectile. Investigate what players do to vary the Magnus effect and use it to improve performance. Present your findings in a short PowerPoint presentation.

Observing the Magnus effect on ball movement

1. Colour one half of a table tennis ball (as illustrated) to enable better vision of its flight path.
2. Have an experienced table tennis player in the class serve a range of balls using different bat surfaces to impart backspin, topspin and sidespin. Observe the flight of the ball with each sequence of serves, noting its swing, rise or dip.
3. Take turns in trying to return serves and note changes in technique to enable a successful return.
4. As a class discuss:
   a. the techniques/types of surfaces used to impart the various types of spin
   b. adjustments that need to be made in technique to address each type of spin.

Applying spin to an object

Using soft plastic golf balls try to impart spin during a hit. You will hear the golf ball spinning if you hit it well enough. To maximise spin, you need to hit the ball into the ground as illustrated in the following diagram.
FORCE

Force (biomechanics) is the push or pull acting on a body.

Applied forces are generated by muscles working on joints. Reaction forces are equal and opposite forces exerted in response to applied forces.

How the body applies force

Players are able to apply forces (biomechanics) to objects such as the ground to enable them to run faster, or to a tennis racquet to enable them to hit the ball harder. In doing this, the players are confronted with opposing forces such as gravity, air resistance and friction.

Forces can be internal or external. Internal forces are those that develop within the body; that is, by the contraction of a muscle group causing a joint angle to decrease (for example, the contraction of the quadriceps when kicking a football). External forces come from outside the body and act on it in one way or another. For example, gravity is an external force that acts to prevent objects from leaving the ground (see figure 6.26).

There are two types of forces — applied forces and reaction forces. Applied forces are forces applied to surfaces such as a running track or to equipment such as a barbell. When this happens, a similar force opposes it from outside the body. This is called a reaction force. The result is that the runner is able to propel his or her body along the track surface because the applied force generated by the legs is being matched equally by the reaction force coming from the track surface. The greater the force the runner can produce, the greater is the resistance from the track. The result is a faster time for the distance. This is explained by Newton's third law: 'For every action, there is an equal and opposite reaction'. In other words, both the runner and the track each exert a force equal to whatever force is being applied.

Figure 6.26: Players experience both internal and external forces.

Figure 6.27: Every reaction force is matched equally by an applied force.
We see evidence of the application of force in all physical activity. Consider the following examples: the high jumper, discus thrower, cricket bowler and basketball player all exert forces when executing movement skills. How effective would they be if they were suspended and had nothing to push against?

![Image of a bowler](image)

**Figure 6.28:** Applied and reaction forces increase during the delivery stage of bowling.

**INQUIRY**

**Fast bowlers a ‘shoe-in’ for injuries**

Use the [Bowling](#) weblink in your eBookPLUS to view an ABC Science article about fast bowlers, injury and footwear.

1. How does the bowler apply force at the time of release during bowling?
2. How are the forces absorbed?
3. What type of injuries can result when forces are applied in this manner?
4. How might improved footwear assist in the absorption of forces?
The principles of forces

1. Use arrows to indicate the direction of the applied force and the direction of the reaction force in figure 6.29.

Figure 6.29

2. What would be the effect on the runner’s performance if the applied force was increased?

3. Suggest how the principle of forces could be applied to the start in running, generating a more powerful long jump or winning a scrum in rugby with a lower pack weight.

Power (biomechanics) is the ability of muscle groups to contract at speed.

To propel the body higher as in high jumping, faster as in running, or further as in long jumping, we need to develop power (biomechanics). Power is expressed by the formula

\[ \text{power} = \frac{\text{work}}{\text{time}} \]

where work is equal to force x distance.

An increase in strength (force) or an increase in the speed at which muscles shorten results in an increase in power. While an increase in both causes an increase in overall power, the athlete must decide which component (strength or speed of muscular contraction) is of greatest benefit. Jumpers and runners need to focus on rapid muscular contraction while controlling the strength aspect. This is called speed-dominated power. In contrast, the weight-lifter needs power and must be able to lift the weight. He or she needs to develop strength-dominated power. By identifying the specific requirements of the sport, the athlete can be better prepared by developing the type of power required.

How the body absorbs force

Forces exerted on the body are absorbed through the joints, which bend or flex in response to the impact. We see evidence of the body absorbing forces in activities such as rebounding in basketball, landing in high jump and stopping the bounce while on a trampoline (see figure 6.30).

When the body lands on a floor or similar surface, it exerts a force on the surface. In response, the surface exerts a force on the body. If we did not bend the knees and allow a slow, controlled dissipation of the forces by the muscles, the risk of injury to the joint would be increased. In an activity such as the
landing phase of a long jump, the muscles in the front of the thigh (quadriceps) lengthen while absorbing the force (see figure 6.31). Joint flexion helps prevent injury to surrounding tissue.

![Figure 6.30: There are many instances in sport where the body must absorb force.](image)

![Figure 6.31: Joint flexion in absorbing forces helps prevent injury to muscles, tendons and ligaments.](image)

**APPLICATION**

**Observing forces being absorbed**

Perform two long jumps — one covering a short distance and the other, the maximal distance that can be jumped. Observe the amount of knee flexion that you experience in each of the jumps.

**INQUIRY**

**Absorbing forces**

1. From your observation, was there a difference in the amount of knee flexion required for each jump in the application above?
2. Discuss why flexion is used in a movement of this type and why we may instinctively vary the degree of flexion.
3. To what degree do you think footwear and the landing surface assist in absorbing force?
4. Discuss why hard surfaces could result in more injuries than soft surfaces.

The body also absorbs forces while catching balls or similar objects. In the process of catching, a force is exerted by the ball on the hand and a force is exerted by the hand on the ball. Catching a ball can sting if the force of the ball is not absorbed effectively.

The impact felt by an object being caught is the product of:
- the force of the ball
- the distance through which the hands move while receiving the ball.
Since the force of the ball remains constant, the only variable that can be changed is the distance through which the hands move when catching the ball. To increase the catching distance and thereby absorb the force more effectively, we can use a number of techniques, including:

- the catching arm can be outstretched. When the ball meets the hand, the arm can be drawn quickly to the body.
- smothering the ball with the other hand
- catching with an outstretched arm and moving it past and behind the body to increase the distance over which the ball is caught
- pivoting the body during the catching action.

While some of these principles may help to reduce the impact from objects such as cricket balls, an overemphasis on reducing pain from impact may result in a dropped catch. Correct technique and practice are essential.

**Observation of forces being absorbed while catching**

Have two students throw an egg underarm to one another. Gradually increase the distance between the two. Closely observe the action of the hands as they receive the egg.

It would take little force to break the egg. From your observations, discuss how the students avoided breaking the egg for a period of time (if they did).

**Techniques for absorbing forces when catching balls**

1. In pairs and using a range of types of ball (such as cricket balls, softballs and baseballs), practice catching using the techniques suggested above.
2. Do you think any of the techniques suggested helped absorb the force of the balls?
3. If the techniques helped, from which technique did you find the greatest benefit? Why?

**Analysing techniques for absorbing forces**

1. How can the problem of absorbing force and developing technique be amalgamated in the development of young players?
2. Use the Biomechanics research weblink in your eBookPLUS to find out about current research in the science of biomechanics. Choose an area of research and present a short report about it to the class.

**Application of force on an object**

When applying force to objects, such as a barbell, cricket bat or netball, there are a number of considerations. First, the quantity of force applied to the object is important. The greater the force, the greater is the acceleration of the object. A small soccer player whose mass and technique allows only small effort production provides little force to the ball in comparison to the same ball being kicked by a bigger player (other factors being equal) (see figure 6.32).
Figure 6.32: The greater the force, the more we are able to accelerate the object.

Second, if the mass of an object is increased, more force is needed to move the object the same distance. For example, if a football becomes heavier as a result of wet conditions, more force is required to pass or kick it (see figure 6.33).

Figure 6.33: If mass increases, for example, a ball becomes wet, more force must be applied to move the object the same distance.

**Centripetal force** is a force directed towards the centre of a rotating body.

**Centrifugal force** is a force directed away from the centre of a rotating body.

Third, objects of greater mass require more force to move them than objects of smaller mass. The size of the discus, javelin and shot-put used in athletics competitions is smaller for younger students than older students. This assumes that older students have greater mass and are thereby able to deliver more force than younger students because of their increased size (mass) and (possibly) strength.

In many sports and activities, for example, ice skating or the hammer throw, the body rotates about an axis. When this happens, **centripetal force** and **centrifugal force** are experienced. Centripetal forces are forces directed towards the centre of a rotating body and centrifugal forces are directed
outwards. Two examples are the golf swing and hammer throw. Here a body rotates, generating powerful forces on objects (in this case, a golf club/ball and hammer ball), allowing them to be propelled distances far greater than would be possible without body rotation.

Figure 6.35: To remain balanced, a hammer thrower must lean further away from the heavy steel ball as rotation increases.
We experience these forces often in our lives. Passengers in cars experience centripetal and centrifugal forces each time a car goes around a bend. The centrifugal forces cause the passenger to slide towards the outside of the bend. Similar forces operate in the spin-dry cycle of a washing machine, removing water from the clothes. The greater the speed about the axis, the greater the force produced.

Another example is that of ice skaters who link arms to form a 'chain'. When the chain rotates about an 'axis' (the person closest to the centre), considerable speed is experienced by the person at the end of the chain. To counteract the centrifugal force, the skaters need to lean towards the centre and push outwards against the ice to maintain balance.

To manage centripetal and centrifugal forces in sporting situations it is important to:
- begin carefully so that you learn to feel the forces as they develop
- respond gradually, trying to match the force exactly
- work on your balance so that you become comfortable leaning beyond where you would normally be balanced
- ensure you have a firm handgrip if holding an object such as a bat or high bar
- bend your knees and ensure you have good traction if working on a track, field or circuit.

### Applying forces

1. Place two objects of varying mass (for example, a shot-put and a tennis ball) on the classroom floor. Move each using a similar force, such as a finger flick.
2. Which implement could you move the furthest?
3. Explain the differences in distance in terms of application of force to the masses of the respective objects.

### Applying forces when changing direction

Set up two lines of markers approximately five metres apart as shown in the figure below.
Run to each marker, then change direction by pushing off the foot nearer that marker. Keep your pattern of directional changes to the finish.

1. Explain how forces work in changing direction.
2. In what activities might more effective change of direction improve performance?

**Applying forces during the take off in a long jump**

Use the Forces in long jump web link in your eBookPLUS to review the information and drills. Identify ways of maximising force application to improve the distance jumped.

**Applying forces to objects**

Use the Tennis serves web links in your eBookPLUS to view the short videos on developing correct serving technique in tennis. Notice how force is gradually added to the serve once control is established.

1. Discuss what a player can do to gradually increase the amount of force applied to the ball while maintaining control of the serve.
2. Why is the development of force an advantage in most sporting activities?

**SUMMARY**

- Biomechanics is a science concerned with forces and the effect of these forces on the human body. A knowledge of biomechanics helps us choose appropriate equipment, improve technique and reduce the risk of injury.
- Motion is the movement of a body from one position to another.
- There are three types of motion — linear, angular and general.
- Velocity is equal to displacement divided by time. It is useful when calculating how quickly people or objects travel when their path is irregular (cross-country runner) or curved (javelin thrower).
- Speed is equal to the distance covered divided by the time taken.
- Acceleration is the rate at which velocity changes in a given amount of time. It is very important in short distance events.
- Momentum is the quantity of motion a body possesses. It is most apparent in collision situations. When this happens, momentum continues in the direction of the body with the greater mass (as long as other factors are equal).
- Momentum can be linear (in a straight line) or angular (moving around a point). Angular momentum can be seen in most activities, particularly when we use equipment such as sticks, bats and clubs.
- The centre of gravity of an object is the point about which all the weight is evenly distributed. The centre of gravity in humans is located approximately at waist height and in the middle between the front and back of the trunk.
- Knowledge of the location of the centre of gravity has important implications for sporting events such as high jump.
• The line of gravity is an imaginary vertical line passing through the centre of gravity and extending to the ground.
• The base of support refers to an imaginary line that surrounds the outside of the body when it is in contact with a surface. We improve balance by using a wide base of support. It becomes increasingly difficult to balance as we narrow the base of support.
• Fluid mechanics is a branch of mechanics concerned with properties of gases and liquids.
• Our body floats when the forces created by its weight are matched equally or better by the buoyant force of the water.
• Body density, or its mass per unit volume, impacts on the ability to float. A body or object floats if its density is less than that of the fluid.
• The weight and distribution of organs and tissues throughout the body influences flotation and the way the body floats (or sinks).
• The centre of buoyancy is the centre of gravity of a volume of water displaced by an object when it is immersed in that water.
• Drag is the force that opposes the forward motion of a body or object, reducing its speed or velocity.
• Lift is the component of a force that acts at right angles to the drag.
• The amount of drag is influenced by fluid density, object shape (bulky or streamlined), surface smoothness and size of the frontal area.
• Surface drag or skin friction refers to a thin film of the fluid medium sticking to the surface area of the body or object through which it is moving.
• Profile drag (also called form or pressure drag) refers to drag created by the shape and size of a body or object.
• The Magnus effect explains why spinning objects such as cricket and tennis balls deviate in the air from a normal flight path.
• Force is the push or pull acting on a body. The body applies force in movements such as running and jumping. These applied forces are met equally by reaction forces. The concept of applied and reaction forces is explained by Newton’s third law.
• Power is the application of force applied rapidly. Power is important to most activities, usually of short duration, such as jumping, starting in athletics and throwing.
• In both landing and ball-catching situations, forces can cause pain and sometimes injury. A knowledge of biomechanical principles helps us learn to absorb these forces effectively.
• The mass of commonly used sporting objects, such as soccer balls, can vary within a game if they become wet. The current mass of the object determines the amount of force that needs to be applied to gain the desired result.

**QUESTIONS**

Revision

1. **Define** the term ‘linear motion’. **Identify** two different sporting activities where players utilise linear motion for some of the time. (P9) (2 marks)

2. Use a sporting example to explain the difference between speed and velocity. (P9) (2 marks)

3. Choose one athletic event where speed is an advantage. **Explain** how biomechanical principles...
could be applied to improve speed in this event. (P9) (4 marks)

4. What is acceleration? Explain how application of biomechanical principles can improve acceleration. (P9) (4 marks)

5. What is the difference between linear and angular momentum? Use an example to describe how we would identify each in a sporting situation. (P9) (4 marks)

6. What is centre of gravity? Using examples from a sporting activity, discuss how centre of gravity is controlled to improve performance. (P9, P7). (5 marks)

7. Explain the importance of the line of gravity in movement. (P7) (8 marks)

8. What is meant by the term ‘base of support’? Describe two activities that differ in the size required for the base of support. How do athletes in these activities control upper body movements from the base of support? (P9, P7) (5 marks)

9. Explain why the ability to float might vary from one person to another. (P7) (4 marks)

10. Discuss the relationship between body density and the way we float (or sink). (P7) (5 marks)

11. Explain the relationship between the body’s centre of gravity and centre of buoyancy in terms of flotation position. (P9) (6 marks)

12. Discuss how drag and lift forces impact on the flight of a javelin. (P9) (4 marks)

13. Discuss the factors that impact on the amount of drag a body or object experiences in fluid environments. (P9) (6 marks)

14. Explain the difference between surface drag and profile drag. (P9) (4 marks)

15. Use examples to explain developments that have taken place to reduce the impact of drag. (P9) (4 marks)

16. Explain the various types of spin that can be imparted on an object such as a table tennis ball. (P9) (3 marks)

17. Explain the Magnus effect in terms of pressure differences and resulting flight path. (P9) (4 marks)

18. Define Newton’s third law. Use the law to explain the difference between applied and reaction forces and how these are applied to typical sporting activities. (P9) (5 marks)

19. Discuss how forces are absorbed in the body. Using a catch in cricket as an example, explain how the absorption of forces can be more effective and less painful. (P9) (4 marks)

20. Using the topspin serve as an example, discuss the factors that affect the application of force to objects. (P7, P9) (4 marks)

Extension

21. Copy the following table on to a large piece of paper. Divide the class into four groups and complete one of the concept areas each. Have groups report their findings. Complete the full table based on class feedback and keep the information as a summary of the chapter. (P7, P9) (5 marks)

<table>
<thead>
<tr>
<th>Concept</th>
<th>Specific principle</th>
<th>Example to explain how this principle influences movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion</td>
<td>Linear motion</td>
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<tr>
<td></td>
<td>Velocity</td>
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<td>Stability</td>
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<td>Line of gravity</td>
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<td></td>
<td>Base of support</td>
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<tr>
<td>Fluid mechanics</td>
<td>Flotation</td>
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<td>Magnus effect</td>
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<td>Force</td>
<td>Applying forces</td>
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Note: For an explanation of the key words used in the revision questions above, see Appendix 2, page XXX.