THE SKELETAL AND MUSCULAR SYSTEMS

A general overview of the skeletal system is required, but will not be directly examined, so we include a general overview here.

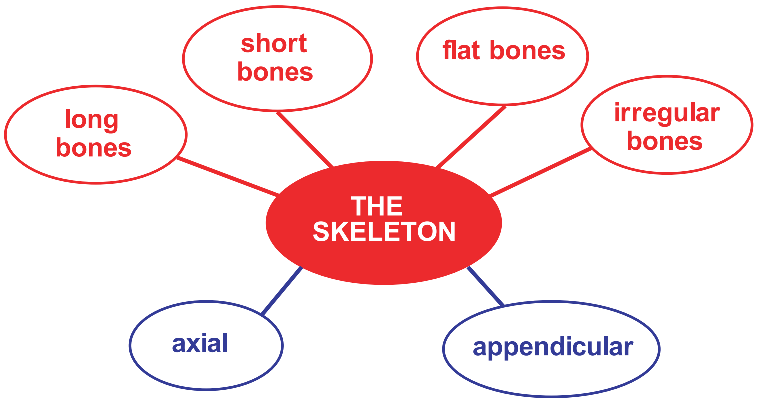
Introduction

The skeletal system

- **The appendicular skeletal system** (figure 1) consists of the shoulder girdle, skull, hip girdle, leg and arm bones.
- **The axial skeleton** consists of the skull, vertebral column, ribs and sternum.

The functions of the skeletal system are to act as a lever system, as surface area for attachment of muscle, tendons and ligaments, and to give shape and support to the body. Also, red / white blood cells are manufactured within bone marrow, and bones store fats and minerals.

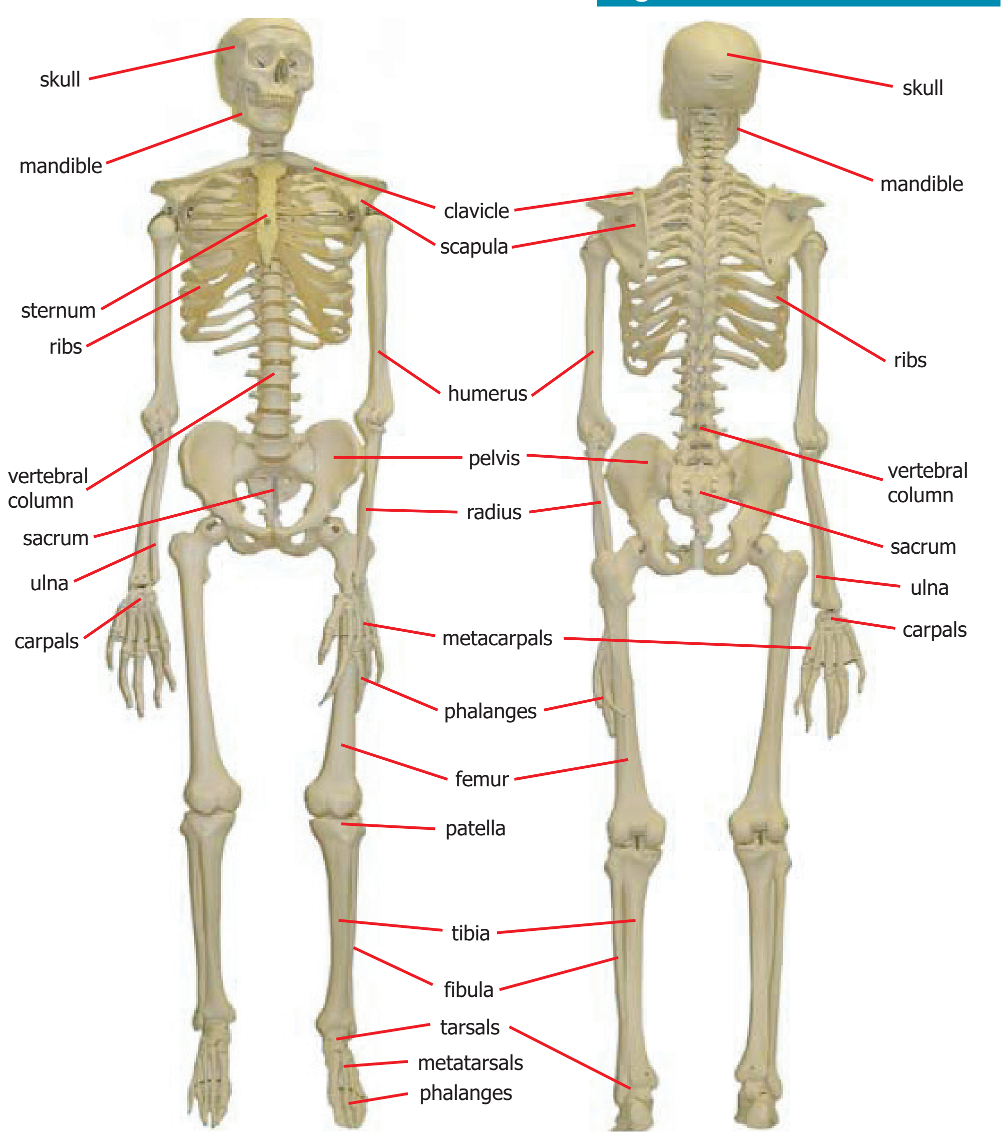
figure 1 – the skeleton



Types of bones and principal functions

- **Long bones**, for example, the femur (which acts as a lever).
- **Short bones**, for example, carpals (which have strength and lightness).
- **Flat bones**, for example, the pelvis (which has a large surface area for muscle & tendon attachments), the cranium (has the function of brain protection).
- **Irregular bones**, for example, the vertebrae (which protect the spinal cord), the patella (a sesamoid bone) which increases the mechanical advantage of the quadriceps tendon.

figure 2 – the human skeleton



STUDENT NOTE

You need to familiarise yourself with the names of bones in figure 2 (opposite) in relation to joints when you answer movement analysis questions.

Bony features

Protrusions and **depressions** act as the places on bones at which ligaments and muscle tendons attach (their shape increases the surface area on the bone available for attachment).

Cartilage

- **Hyaline (articular) cartilage** has a smooth, solid matrix which sits on the ends of bones, and forms the exact surfaces which are in contact and move across one another when a joint is used.
- **White fibro-cartilage** is tough and slightly flexible and exists between vertebrae.
- **Yellow elastic cartilage** is soft and elastic and exists in the ear lobes.

The structure and function of bone tissue

- The **periosteum** is an outer protective covering of bone which provides attachment for muscle tendons and ligaments. The deeper layers of the periosteum are responsible for growth in bone width.
- The **epiphyseal disc** or growth plate is the segment of a bone in which an increase in bone length takes place.
- **Compact bone** consists of solid bone tissue, located down the shaft of a long bone and the outer layers of short, flat and irregular bones. Its dense structure gives strength and support.
- **Cancellous bone** has a lattice-like / spongy appearance. It is light-weight and is located at the ends of a long bone, in addition to providing the internal bone tissue in short, flat and irregular bones.

Joints, movements and muscles

THE ARTICULAR SYSTEM

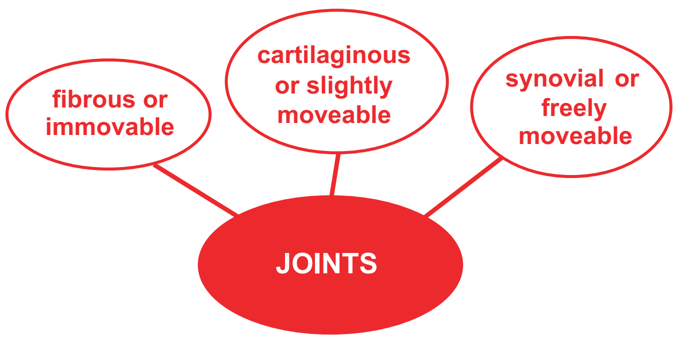
Joints

Articulation is defined **'as a place where two or more bones meet to form a joint'**.

Joint types (figure 3) are:

- **Fibrous or immovable** – for example, between bones of the cranium.
- **Cartilaginous or slightly moveable** – for example, vertebral discs.
- **Synovial or freely moveable** (classified in table 1, page 15).

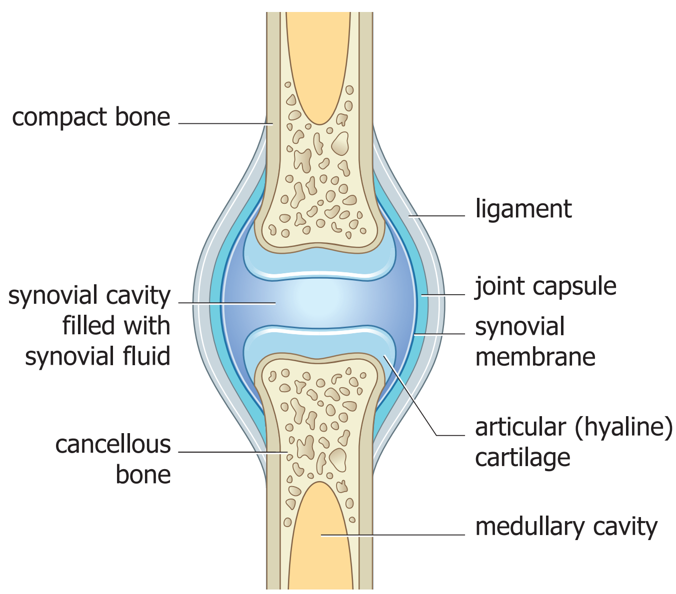
figure 3 – joint types



Synovial joint

- The **synovial fluid** reduces joint friction by lubrication, and maintains joint stability.
- The **synovial membrane** encloses fluid and secretes fluid.
- The **joint capsule** is a sleeve of tough, fibrous tissue surrounding the joint.
- A **ligament** is an extension of the joint capsule consisting of strong, fibrous connective tissue that provides stability by joining bone to bone.
- **Articular cartilage** prevents friction between bones, and cushions the ends of bones.
- **Bursae** prevent friction and wear.
- **Pads of fat** cushion the joint.
- **Menisci** help bones fit together and improve stabilisation of the joint.

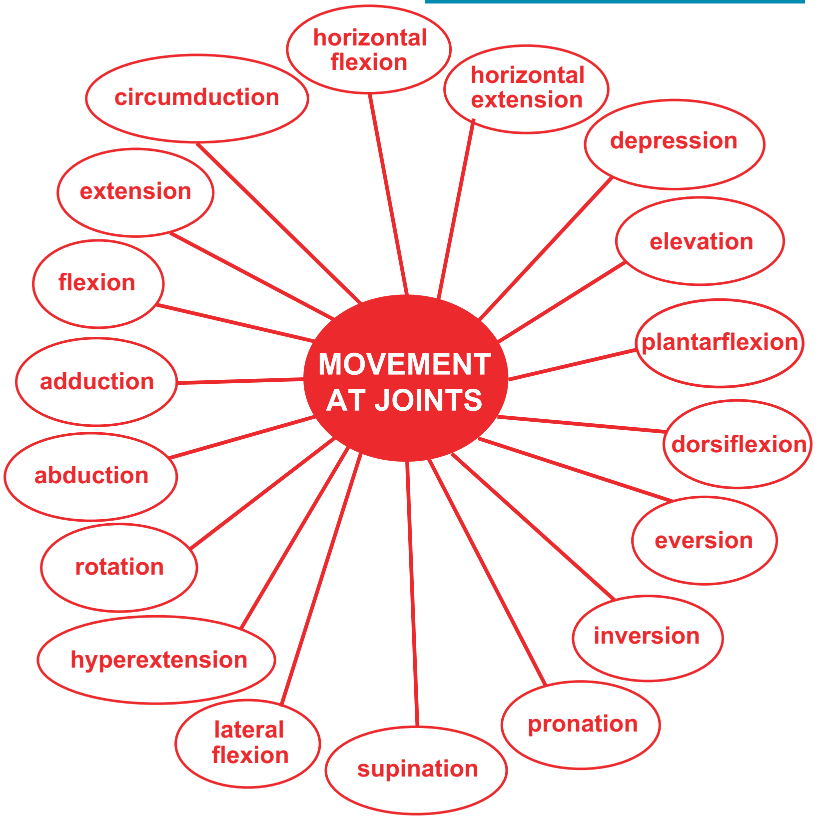
figure 4 – a synovial joint



MOVEMENT AT JOINTS – TERMINOLOGY

The possible ranges of movements within a synovial joint (see figures 5 and 6) vary according to the shape of the articular surfaces and therefore according to the joint type.

figure 5 – movement at joints



Abduction means to take away and so is characterised by movement away from the midline – for example, a cartwheel in gymnastics.

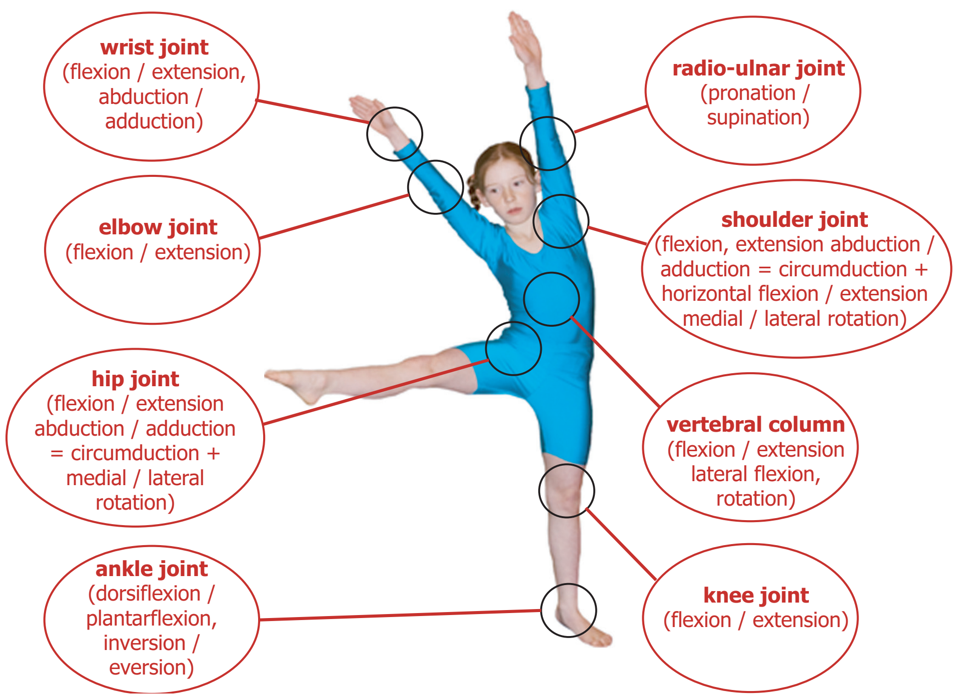
Adduction means to bring together and so is characterised by movement towards the midline – for example, bringing the lower legs back together from the inverted cartwheel.

Flexion means to bend, resulting in a decreased angle around the joint – for example, bending of the knee.

Extension means to straighten, resulting in an increased angle around the joint – for example, straightening of the knee from a bent-legged to straight-legged position.

Circumduction is a combination of flexion, extension, abduction and adduction – for example, when the upper arm moves (arm circling) so that it describes a cone with the shoulder joint at the apex.

figure 6 – major joints – movement patterns



Horizontal flexion (also known as horizontal adduction) occurs when the shoulder starts in a flexed position with the arm(s) parallel to the ground, followed by the shoulder joint moving towards the midline of the body – for example, during the press-out phase of a bench press, and the arm swing into the release phase of a discus throw.

Horizontal extension (also known as horizontal abduction) occurs when the shoulder joint, with the arm(s) parallel to the ground, move away from the midline of the body – for example, a seated row as the elbows are pulled back as far as possible, and the preparatory swing of a discus throw.

Depression describes movement of the shoulders downwards – for example, the preparation for a dead lift, gripping the bar.

Elevation describes movement of the shoulders upwards – for example, a shoulder shrug.

Plantarflexion involves extending the toes thereby increasing the angle at the ankle – for example, standing on tip-toes.

Dorsiflexion describes movement of the foot towards the shin – for example, walking on one's heels.

Eversion is the joint action at the ankle characterised by the turning of the sole of the foot laterally outwards – for example, the kick action in breaststroke.

Inversion is the joint action at the ankle characterised by the turning of the sole of the foot medially inwards – for example, a football player inverts the foot to pass the ball with the outside of his / her boot.

Pronation is characterised by the rotation of the forearm medially so that the hand faces downwards – for example, a top-spin forehand in tennis.

Supination is characterised by the rotation of the forearm laterally so that the hand faces upwards – for example, the right hand action in a hockey flick.

Lateral flexion is sideways bending.

Hyperextension is the forced extension of a joint beyond its normal range of motion – for example, the arched spine that is created in the flight phase of the Fosbury Flop high jump technique.

Rotation is the turning of a structure around its long axis.
Rotation can be inwards, hence **medial rotation** of the humerus with the forearm flexed brings the hand towards the body – for example, in the breaststroke the humerus rotates medially as the hands enter the water.
Rotation can be outwards, hence **lateral rotation** of the humerus describes a movement whereby the hand moves away from the body – for example, the humerus rotates laterally in preparation for the forehand stroke in tennis.

Most movements that occur in physical activities are combinations of movements explained above.

Table 1 **– summary of synovial joint types and movement ranges**

synovial joint types	movement range	example body place: articulating bones
ball & socket	3 axes, flexion / extension, abduction / adduction, rotation, circumduction	**hip:** femur, acetabulum of pelvis **shoulder:** scapula, humerus
hinge	1 axis, flexion / extension	**knee:** femur, tibia **elbow:** humerus, radius, ulna
pivot	1 axis, rotation	**spine: atlas:** odontoid process of axis (turns head side to side). **elbow:** proximal ends of radius and ulna
condyloid (modified ball & socket)	2 axes, flexion / extension, abduction / adduction = circumduction	**knuckles:** joint of fingers: metacarpals, phalanges. **wrist – radio-ulnar joint:** radius, carpals
saddle	2 axes, flexion / extension, abduction / adduction = circumduction	**joint at base of thumb:** carpal, metacarpal
gliding	a little movement in all directions	**centre of chest:** clavicle, sternum **spine:** articulating surfaces **wrist:** carpals **ankle:** tarsals

figure 7 – superficial anterior muscles

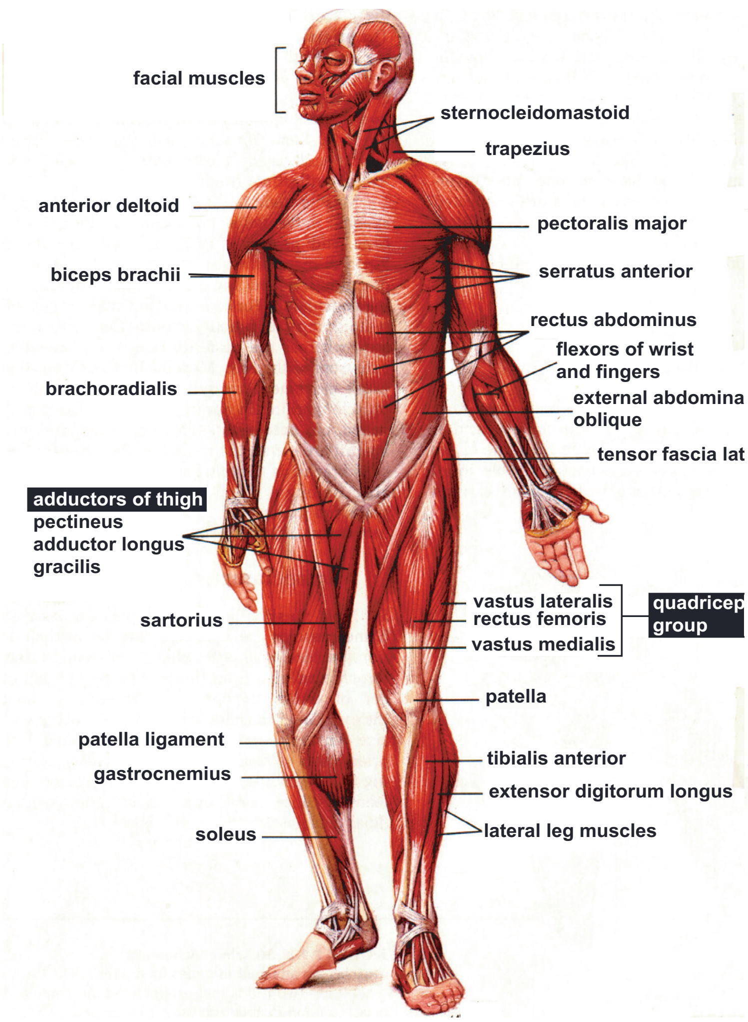
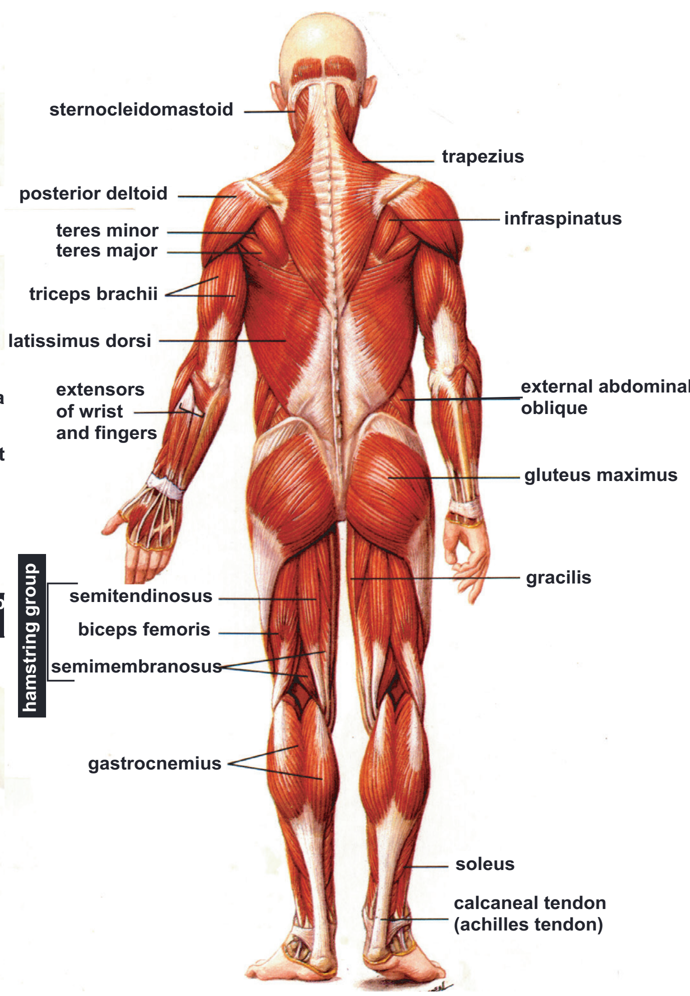


figure 8 – superficial posterior muscles



STUDENT NOTE

In your movement analysis you will need to identify major skeletal muscles of the human body (figures 7 and 8 above) in relation to joint activity and muscle analysis in tables 2, 3 and 4 below. The muscles identified in these tables give you plenty of choice to select from. However if you refer to your exam syllabus you may wish to focus on the muscles that your exam board has specified.

Table 2 – **joints, movements and muscles in the wrists and arms**

body part / joint	movement pattern	active (agonist) muscles	movement examples
wrist	extension	**extensor carpi ulnaris**, extensor digitorum	follow through in an over-arm throw
	flexion	**flexor carpi radialis**, flexi carpi ulnaris	dumbbell wrist curls
arm / elbow	flexion	**biceps brachii**, brachialis	bicep curls
	extension	**triceps brachii**, anconeus (forearm)	follow through over-arm throw, bench press, triceps dips
forearm / radio-ulnar (pivot)	supination	**supinator**, biceps brachii	catching the bar during a clean
	pronation	**pronator teres**, pronator quadratus	putting top spin on a tennis ball
shoulder joint	adduction	**latissimus dorsi**, anterior deltoid, teres major / minor	recovery phase in overarm throw, triceps dips
	abduction	**medial deltoid**, supraspinatus	preparation phase shoulder pass
4 rotator cuff muscles stabilise shoulder joint	flexion	**pectoralis major**, anterior deltoid, coracobrachialis	release phase in overarm throw, triceps dips
	extension	**posterior deltoid**, latissimus dorsi, teres major	shoulder position during javelin approach run
	medial rotation	**latissimus dorsi**, posterior deltoid, pectoralis major, teres major, subscapularis	forehand stroke / follow through at table tennis
	horizontal flexion	**pectoralis major**, anterior deltoid	arm swing into the release phase of a discus throw
	horizontal extension	**trapezius**, posterior deltoid, latissimus dorsi	preparatory swing (backward) of the arm in the discus
	lateral rotation	**infraspinatus**, teres minor	backhand stroke / follow through at table tennis
shoulder or pectoral girdle (scapula + clavicle)	elevation	**upper fibres of trapezius**, levator scapulae, rhomboids	a dumbbell shoulder shrug
	depression	**lower fibres of trapezius**, latissimus dorsi, pectoralis minor, serratus-anterior (lower fibres)	preparation for dead lift when gripping the bar
	protraction	serratus anterior	recovery phase during breaststroke
	retraction	rhomboids, trapezuis	pull phase during breaststroke
	upward rotation	**upper fibres of trapezius**, serratus anterior	arm recovery phase during butterfly stroke
	downward rotation	**rhomboids**	arm pull phase during butterfly stroke

STUDENT NOTE

The main agonist muscle for each movement is in **red bold** font type in table 2 above.

Table 3 – **joints, movements and muscles in the trunk and spine**

body part / joint	movement pattern	active (agonist) muscles	movement examples
trunk / spine	flexion	**rectus abdominus**, internal / exter transversus abdominus	sit ups
core stability muscles	extension / hyperextension supports lower back	**erector spinae group** - sacrospinalis / multifidus (deep lumbar portion)	extension - trunk position during netball shot at goal, hyperextension - flight phase of the Fosbury Flop
	rotation	**external obliques**, rectus abdominus, erector spinae	hammer throw swings, barani in trampolining / gymnastics
	lateral flexion	**internal obliques**, rectus abdominus, erector spinae, quadratus lumborum, sacrospinalis	side bends, twisting trunk / abdominal curls

Table 4 – **joints, movements and muscles in the hip, knee and ankle**

body part / joint	movement pattern	active (agonist) muscles	movement examples
hip	flexion	**iliopsoas**, rectus femoris, pectineus, sartorius, tensor fascia latae, adductor longus / brevis	squat start (low) position, high knee lift during sprinting, moving the knees up into a tuck position
	extension	**gluteus maximus**, hamstring group, adductor magnus	high jump take-off, rear leg drive during sprinting
	adduction	**adductor longus / magnus / brevis**, pectineus, gracilis	cross over phase during javelin run-up, side footing a football
	abduction	**gluteus medius / minimus**, sartorius, tensor fascia latae, piriformis	movement into the inverted phase of a cartwheel
	medial rotation	**gluteus medius / minimus**, tensor fascia latae, iliopsoas, gracilis	hip movement across circle during travel phase of a discus turn
	lateral rotation	**gluteus maximus**, psoas major, adductors, piriformis, sartorious	movement into a yoga stork position
knee	extension	**quadriceps group** - rectus femoris / vastus medialis / vastus intermedius, vastus lateralis	high jump take-off, rear leg sprint phase
	flexion	**hamstring group** - biceps femoris / semimembranosus / semitendinosus, + sartorius, gracilis, gastrocnemius	squat start (low) position, high knee lift during sprinting, moving the knees up into a tuck position
ankle	plantarflexion	**gastrocnemius**, soleus, tibialis posterior, peroneus, flexor digitorum longus	take-off phase during jumping
	dorsiflexion	**tibialis anterior**, extensor digitorum longus	landing phase from jump

STUDENT NOTE

The main agonist muscle for each movement is in **red bold** font type in tables 3 and 4 above.

THE COORDINATION OF MOVEMENT

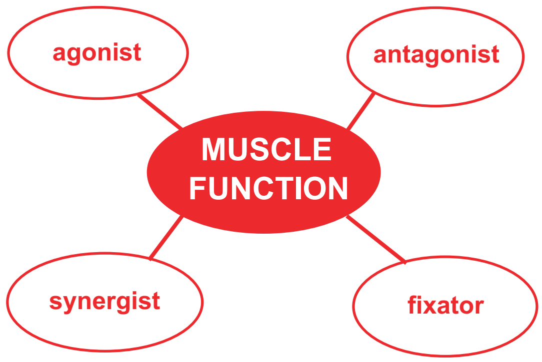
Musculo-skeletal attachments

Ligaments attach bone to bone to limit the range of movement of joints.
Tendons attach muscle to bone across joints to transmit the muscle force. They are strong and mainly inelastic – for example the Achilles tendon attaches the gastrocnemius muscle to the periosteal bone tissue of calcaneus or the heel bone.

Origins and insertion of muscles

The tendon at the static end of the muscle is called the **origin** and the tendon at the end of the muscle closest to the joint that moves is called the **insertion**.

figure 9 – muscle function



Antagonistic muscle action

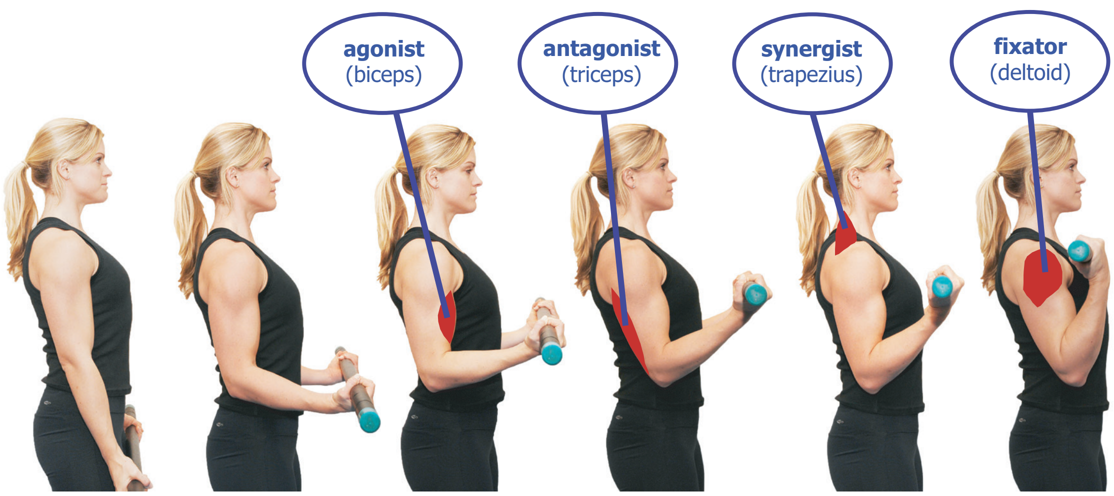
This term describes the fact that muscles work in pairs (see the summary in figure 9, and the details in figure 10).

- The **agonist** is the active muscle, the muscle under tension or doing work and functioning as the **prime mover** of a joint during the desired movement.
- The **antagonist** relaxes to allow the agonist to work as movement occurs.
- For example, curling a bar, the agonist = **biceps brachii muscle**, and the antagonist = **triceps brachii muscle.**

A **synergist muscle** holds the body in position so that an agonist muscle can operate, thus preventing any unwanted movements that might occur as the prime mover contracts. For example, the trapezius muscle holds the shoulder in place during the bar curling exercise.

A **fixator muscle** by definition is a synergist muscle, but is more specifically referred to as a **fixator** or **stabiliser** when it immobilises the bone of the prime mover's origin, thus providing a stable base for the action of the prime mover. For example, the deltoid muscle stabilises the scapula during a bar curl.

figure 10 – muscle function – curling a bar



The role of muscular contraction

During muscular contraction, a muscle may shorten, lengthen or stay the same. When a muscle changes its length, the contraction is classified as **dynamic**. When the muscle remains the same length, a **static** contraction occurs.

Static contractions – isometric muscle contraction

In **isometric contractions** (figure 11) the length of the muscle does not change, but the amount of tension **increases** during the contraction process.

figure 11 – isometric holds

In a training situation isometric work is done by exerting the maximum possible force in a fixed position for sets of 10 seconds, with 60 seconds recovery.

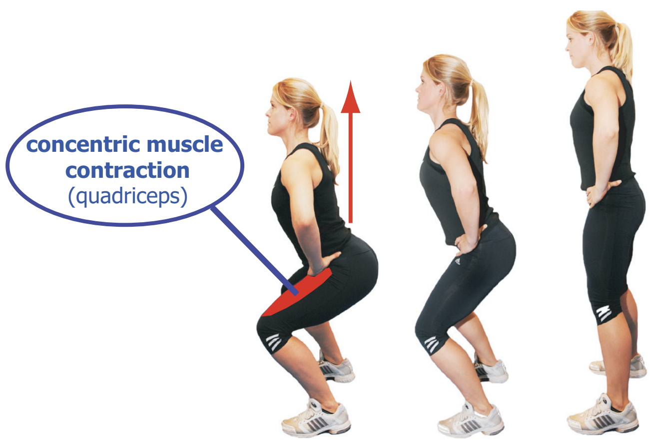
Isometric contractions are responsible for the constant length of postural muscles in the body and hence stabilise the trunk in many dynamic activities such as in sprinting.

Dynamic Muscle Contraction – concentric and eccentric contraction

Concentric muscle contraction

This type of contraction (figure 12) involves a muscle shortening under tension and is a form of **isotonic muscle contraction.** For example, in the driving upwards phase in a jump or squat, the quadriceps muscle group performs a concentric contraction as it shortens to produce extension of the knee joint.

figure 12 – concentric contraction



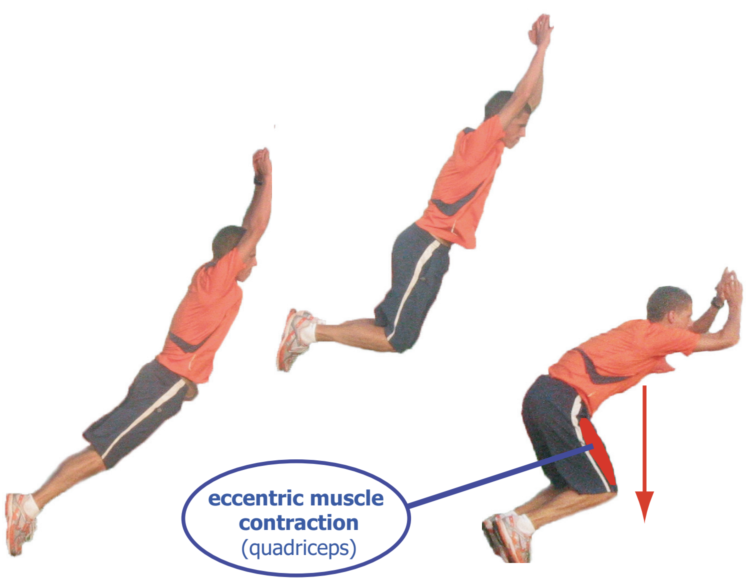
Eccentric muscle contraction

This type of contraction (figure 13) involves a muscle lengthening under tension and is a form of isotonic muscle contraction. When a muscle contracts eccentrically it is acting as a brake, thus controlling the movement. For example, during the downward moving part of a jump or squat, the quadriceps muscle group is lengthening under tension and so the work is labelled **eccentric** or **negative**. Eccentric muscle contraction produces the biggest overload in a muscle, thereby enhancing its development as far as strength is concerned. The chief practical use of eccentric muscle contraction is in **plyometric** or **elastic** / **explosive** strength work.

For eccentric contractions, the **agonist** muscle is the active muscle which in this case is lengthening. In the case of the landing from a jump or controlled downward movement in a squat, the quadriceps muscle group lengthens under tension, and is therefore the **agonist**. To be the **agonist** in this situation, a muscle **must** be under tension. The **antagonist muscle action** during the example of a downward squatting movement would be the hamstring muscle group, which gets shorter and which relaxes or acts as a fixator for the hip joints.

Many muscle contractions involve a combination of dynamic and static work in which the muscles shorten by some amount, and the degree of tension increases.

figure 13 – eccentric contraction



Movement analysis of physical activity

STUDENT NOTE

In the following movement analysis examples not all agonist muscles have been listed.
The main agonist muscle for each movement is in **red bold** font type in table 5 below.

figure 14 – high jump take-off and flight

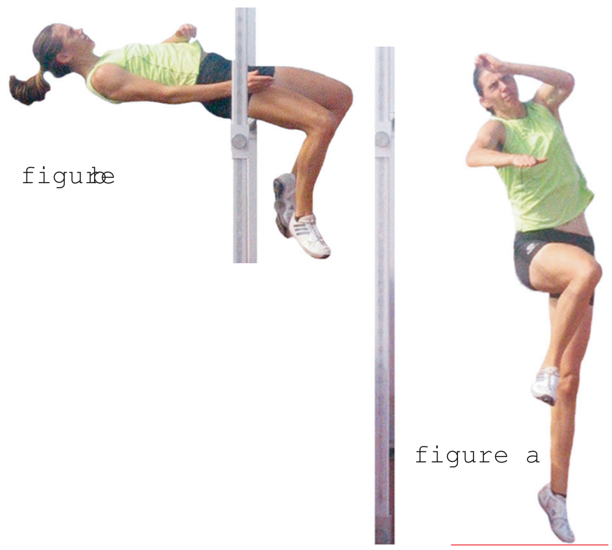


Table 5 – **the high jump**

After a continually accelerated run-up with a long penultimate stride, the jumper has a very fast last take-off stride before arriving at the position in figure 14 a.

physical activity	joint used	articulating bones	movement produced	agonist muscles	type of muscular contraction (isotonic)
high jump at take-off figure 14 a	ankle - take-off leg	talus, tibia, fibula	plantarflexion	**gastrocnemius**, soleus, tibialis posterior, peroneus, flexor digitorum longus	concentric
	knee - take-off leg	tibia, femur	extension	**quadriceps group:** rectus femoris/ vastus medialis/ vastus intermedius/ vastus lateralis	concentric
	shoulder girdle	clavicle, scapula	elevation	**upper fibres of trapezius**, levator scapulae, rhomboids	concentric
high jump in flight figure 14 b	hips	femur, acetabulum of pelvis	extension	**gluteus maximus**, adductor magnus, assisted by: **hamstring group:** biceps femoris/ semimembranosus/ semitendinosus	concentric
	spine	vertebrae	extension/ hyperextension	**erector spinae group**	concentric

Table 6 – **sprinting leg action**

figure 15 – sprint – a full stride

STUDENT NOTE

You **must** list all muscles in the quadriceps and hamstring groups when you analyse the actions of the knee and hips during physical activity.

physical activity	joint type	movement produced	agonist muscles	antagonist muscles	type of muscular contraction
leg action in sprinting – figure 15 a left leg	ankle/hinge	plantarflexion	**gastrocnemius**, flexor digitorum longus	**tibialis anterior**, extensor digitorum longus	concentric
	knee/hinge	extension	**quadriceps group**	**hamstring group**	concentric
action of hip joint figure 15 b - left leg	hip/ ball and socket	flexion	**iliopsoas**, rectus femoris, adductor longus / brevis	**gluteus maximus**, hamstring group, adductor magnus	concentric
action of the trunk - figure 15 c	spine/ cartilaginous	extension	**erector spinae group**	**rectus abdominus**	isometric

STUDENT NOTE

The main agonist muscle for each movement is in **red bold** font type. The main antagonist muscle for each movement is in **blue bold** font type in table 15 above.

figure 16 – over arm throw

Table 7 – **the arm action in an over arm throw**

STUDENT NOTE

The main agonist muscle for each movement is in **red bold** font type in tables 7 and 8 below.

figure a figure b figure c

physical activity	joint used	articulating bones	movement produced	agonist muscles	type of muscular contraction (isotonic)
arm action in over arm throw - figure 16	elbow	humerus, radius, ulna	elbow joint extends as movement progresses	**triceps brachii**, anconeus	concentric
	shoulder girdle	scapula, clavicle	elevation, upward rotation	**elevation:** **upper fibres of trapezius**, levator scapulae. **upward rotation:** **upper fibres of trapezius**, serratus anterior	concentric
	radio-ulnar (wrist)	carpals, radius, ulna	supination to pronation	**pronator teres**, pronator quadratus	concentric

Table 8 – **the full action of the squat - down then up**

figure 17 – squat – down then up

STUDENT NOTE

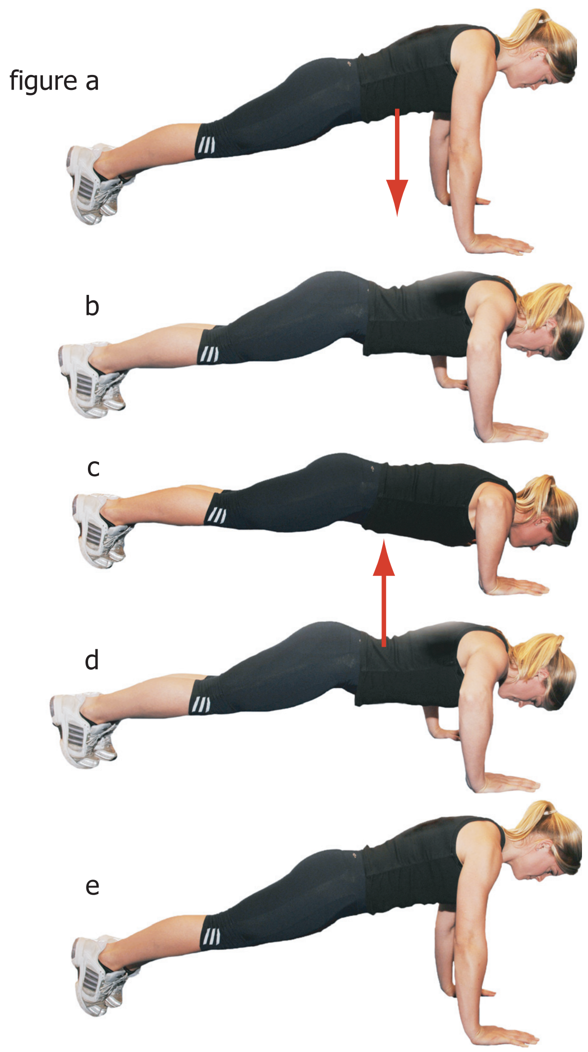
You **must** list all muscles in the quadriceps and hamstring groups when you analyse the actions of the knee and hips during physical activity.

figure a b c d e

physical activity	joint used	articulating bones	movement produced	agonist muscles	fixator muscles	type of muscular contraction (isotonic)
leg action in squat - figure 17	knee – figures a to c	tibia, femur	extension to flexion	**quadriceps group**	adductor magnus	eccentric
	hip – figures c to e	femur, acetabulum of pelvis	flexion to extension	**gluteus maximus**, hamstring group, adductor magnus	erector spinae, transversus abdominus, gracilis	concentric

Table 9 – **the full action of the push-up - down then up**

figure 18 – push-up – down then up



STUDENT NOTE

Note that during a very controlled downward phase in figures 18 a-c the **agonist** muscle at the elbow joint is the **triceps brachii** muscle. This is because the triceps brachii muscle is under extreme tension as it lengthens and so acts as a brake to control the downward phase of the action. The same explanation applies to the pectoralis major and anterior deltoid muscles, which act as the agonists at the shoulder joint.

physical activity	joint type	movement produced	agonist muscles	antagonist muscles	type of muscular contraction (isotonic)
arm action in push-up – down movement figure 18 a to c	elbow/hinge	flexion	**triceps brachii**, anconeus	**biceps brachii**, brachialis	eccentric
– up movement figure 18 c to e	shoulder/ ball and socket	horizontal flexion	**pectoralis major**, anterior deltoid	**trapezius**, posterior deltoid	concentric

STUDENT NOTE

The main agonist muscle for each movement is in **red bold** font type. The main antagonist muscle for each movement is in **blue bold** font type in table 9 above.

Table 10 – **leg action in a kick**

This sequence covers the strike phase only for the kick.

figure 19 – a kick

STUDENT NOTE

The main agonist muscle for each movement is in **red bold** font type in table 10 below.

physical activity	joint type	movement produced	agonist muscles	synergist muscles (many possible examples)	type of muscular contraction (isotonic)
leg action in kicking (right leg) – figure 19	ankle/hinge	plantarflexion	**tibialis anterior**	rectus abdominus	eccentric
	knee/hinge	extension	**quadriceps group**	rectus abdominus	concentric
	hip/ ball and socket	flexion	**iliopsoas**, rectus femoris, adductor longus / brevis	rectus abdominus	concentric

STUDENT NOTE

As the ankle plantarflexes, during the foot strike of the ball, the tibialis anterior lengthens and is under extreme tension. Then as the ball leaves the foot this muscle will shorten (contract) and the foot will dorsiflex.

Muscle fibre types in relation to choice of physical activity

Skeletal muscle tissue

Skeletal muscle (also called striated voluntary muscle in that microscopic bands or striations can be seen) attaches to bone and is responsible for the following functions:

- **Producing** movement.
- **Maintaining** body posture.
- **Generating** heat to keep us warm.
- **Storage** of glycogen for energy.

Muscle fibres

Not all skeletal muscle fibres have identical functional capabilities. Some muscle fibres contract quickly and fatigue quickly (known as **fast twitch** muscle fibres) whereas others contract more slowly and are resistant to fatigue (known as **slow twitch or type I or Slow Oxidative (SO)** fibres). Fast twitch fibres are classified into 2 groups – **fast twitch type IIa or Fast-Oxidative-Glycolytic (FOG)** and **fast twitch type IIb or Fast-Glycolytic (FG)** muscle fibres.

Table 11 - **major structural and functional differences** between **Slow-Oxidative (SO type I), Fast-Oxidative-Glycolytic (FOG type IIa), and Fast-Glycolytic (FG type IIb)** muscle fibre types.

	SO - type I	**FOG - type IIa**	**FG - type IIb**
structural differences			
colour	red	red to pink	white
fibre diameter	small	medium	large
fibres per motor unit	10-80	300-800	300-800
sarcoplasmic reticulum development	low	high	high
myoglobin content	high	high	low
capillary density	high	midway / high	low
mitochondrial density	many	midway	few
energy stores (phosphocreatine (PC) / glycogen / ATP content)	low	high	high
functional differences			
myosin ATP activity	low	high	high
glycolytic enzyme activity	low	high	high
oxidative enzyme activity	high	midway	low
motor unit strength	low	high	high
recruitment order	first	second	third
contractile strength	low	high	high
contractile time	long	midway	short
fatigue resistance	low	midway	high
aerobic capacity	high	moderate	low
anaerobic capacity	low	high	high
primary function	maintaining posture / endurance-based activities	running / sprinting	high intensity rapid activity

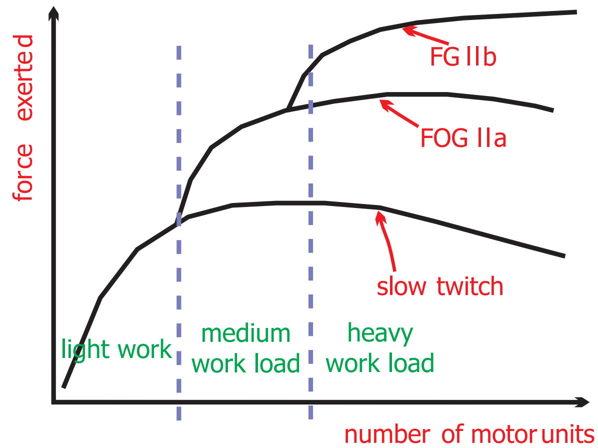
Fibre type and exercise

Fibre type usage (**recruitment**) is based on the intensity of exercise.

- **At low intensity, Slow Twitch or Slow Oxidative (SO)** motor units are recruited first.
- **At higher intensityFast-Oxidative-Glycolytic (FOG)** type **IIa** motor units are recruited.
- **At greatest intensity Fast-Glycolytic (FG)** type **IIb** motor units are recruited to produce powerful fast muscle contractions.

All available fibres are recruited for all power activities as seen in the graph – figure 20.

figure 20 – fibre type recruitment



Differences within individual muscles

The proportion of muscle fibre type differs within individual muscles. Most muscles have both fibre types, however the large postural muscles contain a high proportion of slow twitch fibres because postural muscles need to produce low forces over a long period of time.

The arms tend to consist of more fast twitch muscle fibres as they need to move quickly but over shorter periods of time. The percentage type of muscle fibres found in the legs determines whether the athlete is more suited to sprinting or endurance running.

Differences in fibre type distribution between different individuals

The average fibre type distribution within **sedentary** men and women and young children is between 45% and 55% slow twitch fibres, with fast twitch equally distributed between type IIa and IIb subdivisions. However individual variation is large.

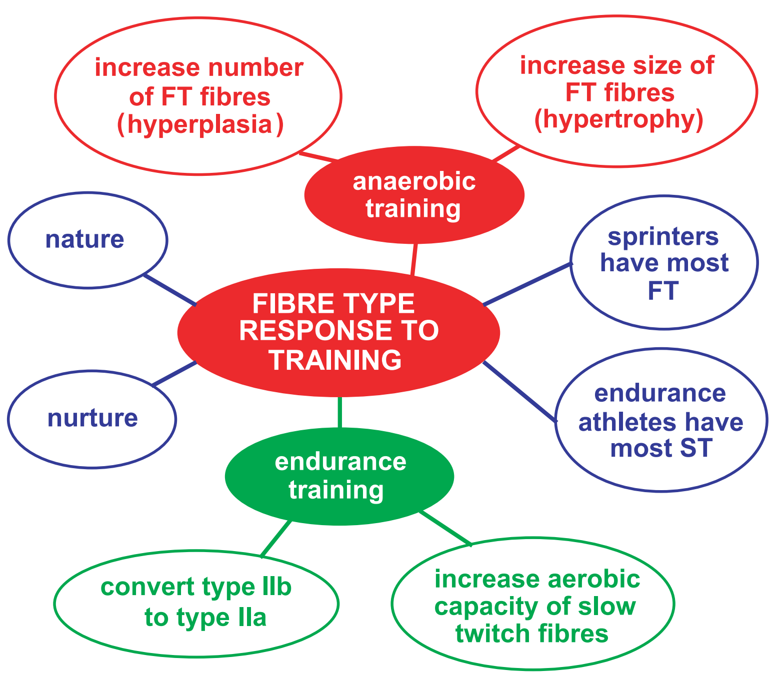
Elite sprinters have a greater percentage of fast twitch muscle fibres, whereas elite long-distance runners have a higher percentage of slow twitch muscle fibres in their leg muscles. As might be expected, elite men and women show similar trends.

Responses to training

Endurance training results in **type IIb** muscle fibres being converted to **type IIa**, and increases the aerobic capacity of **slow twitch** fibres. This explains why long steady training results in loss of speed.

High intensity anaerobic training causes increase in size of **fast twitch** muscle fibres (**hypertrophy**), and number of **fast twitch type IIb** fibres (**hyperplasia**). Lack of high intensity training causes atrophy (loss of size and function) of fast twitch muscle (figure 21).

figure 21 – fibre type response to training

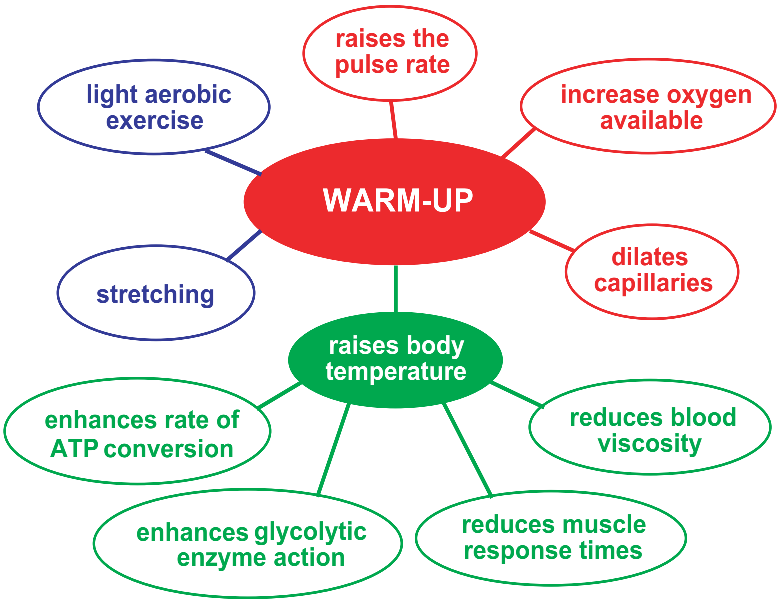


Nature or nurture?

- Proportions of fibre types are **genetically determined**, and this could account for specialisms of individuals such as whether a person becomes good at marathon running or weight lifting.
- On the other hand, researches have shown that a knowledge of a person's predominant fibre type is of limited value in predicting the outcome of specific exercise performances.
- This finding is not surprising because performance capacity is the end result of the blending of many physiological, biochemical, neurological and biomechanical 'support systems'- and is not simply determined by a single factor, such as muscle fibre type.

Warm-up and cool-down

figure 22 – warm-up



THE EFFECT OF WARM-UP ON SKELETAL MUSCLE

The need for oxygen

A **warm-up** (figure 22) is light **aerobic exercise** (such as jogging, stretching and skill drills relevant to the activity) that takes place prior to activity. **Anaerobic** exercise does not need oxygen and can theoretically be performed without warm-up. But replenishment of **ATP** and **muscle glycogen** depend on an efficient blood capillary system, and recovery of the oxygen debt requires oxygen and is therefore improved if **light aerobic exercise** is undertaken before exercise.

Warm-up:

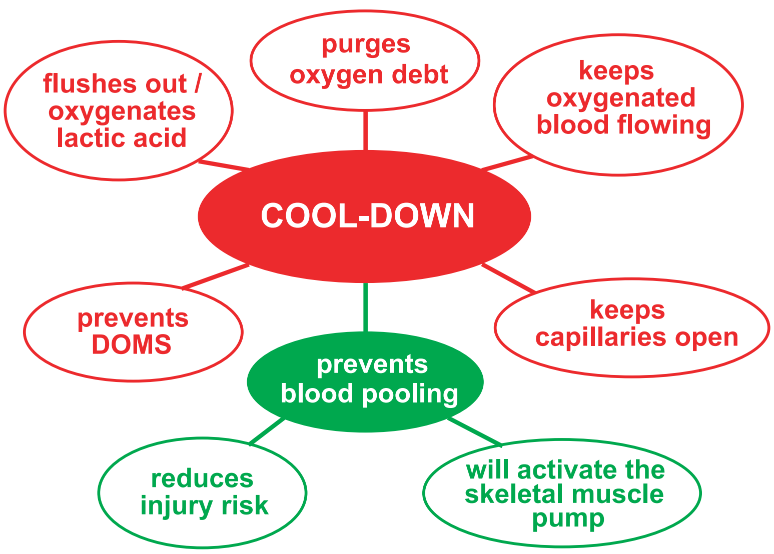
- Dilates capillaries.
- Raises the pulse rate.
- Therefore enabling more blood.
- Hence oxygen is available to working muscles.

Warm-up also **raises body temperature** which enhances the rate of ATP conversion, enhances glycolytic enzyme action and reduces muscle response times. This enables bigger forces to be exerted by muscle more quickly. Increased temperature also **reduces blood viscosity** so that blood flows slightly more quickly through muscle capillaries, and hence oxygen can be supplied slightly more quickly to muscle.

Stretching during warm-up prepares muscle to operate over its full range reducing the risk of injury.

Cool-down after exercise

figure 23 – cool-down



Cool-down (figure 23) is continuation of light aerobic exercise after exercise which:

- Keeps **capillaries open** longer.
- Therefore keeps **oxygenated blood** flowing to muscles.
- This assists the purging of an **oxygen debt**.
- Flushes out **lactic acid**.
- Helps **oxidise lactic acid**.
- Therefore prevents **Delayed Onset Muscle Soreness – DOMS**.

Cool-down also prevents **blood pooling** (blood will remain in limbs if muscle action is stopped suddenly) by keeping muscles active until the **need for oxygenated blood** has reduced. This is necessary since active muscles will activate the **skeletal muscle pump** for venous return of blood to the heart. Cool-down therefore **reduces injury** risk.

Stretches during cool-down can **increase flexibility** of joints, because the body is still very warm after full-effort exercise.

Impact of different types of physical activity on the skeletal and muscular systems

Repeated collisions between players of contact sports can cause injury to soft and hard tissue of the human body. Soft tissue injury (commonly known as a **muscle strain**) is usually temporary, haematoma (which is internal bleeding causing bruising within a muscle bed) are common in contact sports such as soccer, rugby and hockey. **Sprains** of ankles, wrists, fingers or toes (the overstretching of connective tissue surrounding a joint) are the most common.

But **repeated** injury to the same area can cause long-term dysfunction of the muscle or joint affected (the term **strain** is generally applied to muscle and tendon injuries and denotes that damage has occurred in the muscle or tendon fibres).

Injury to hard tissue is often bone breakage (to thighs, shins, ankles, fingers, arms, ribs and occasionally skull) for which immediate medical treatment and at least 6 weeks rest from exercise will be necessary.

Examples of trauma

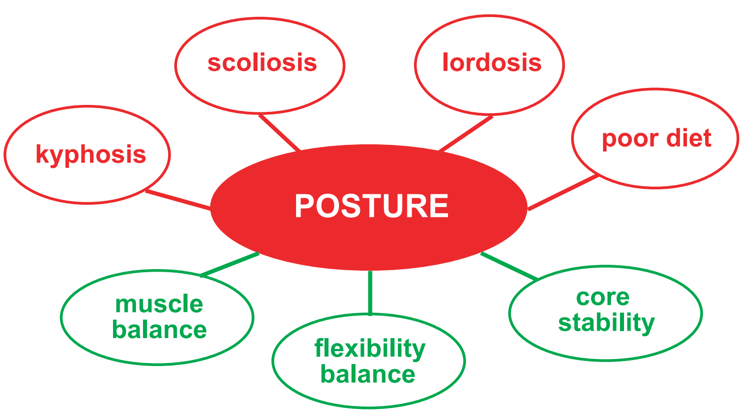
Examples of repeated trauma resulting from over-training in high impact sports (figure 24):

figure 24 – repeated injury / overtraining

- **Achilles tendinosis** is predominantly a condition of wear and tear caused by overuse or incorrect training. Over time tears and weaknesses create a thickened, painful and stiff tendon that often responds positively to a good warm-up. Shoe heel supports can off-load the achilles a little, but the mainstay of treatment is an exercise programme which involves eccentric heel drops. For example, double and single calf raise over the edge of step, slowly forcing heel from dorsi to plantar flexion. Where forces are too large and are applied too rapidly the achilles tendon can rupture (when 95% of fibres are damaged it is diagnosed as a rupture). For most people the best option for recovery is surgical repair followed by a rehabilitation programme.
- **Jumper's knee** – called patellar tendinosis – is inflammation of the bottom of patella where the patella tendon inserts into the bone. This condition is often related to biomechanics (the fact that jumping is often done with the joint not moving through the anatomically correct range and plane of movement during a jump).
- **Tennis elbow** – is inflammation of the tendons which connect wrist and finger extensors to the outer part of arm just above the elbow.
- **Shin splints** – is irritation of the muscle insertion in front of the shin bone (tibia), caused by repeated foot impact on a hard surface.

Also, any long-term unbalanced repetitive trauma to the skeletal system can cause **stress fractures** to spine, hands or feet. This trauma can be caused by activities as simple as jogging or as fierce as hopping or jumping. Such activities can also cause long-term postural problems by gradually damaging the spine, and hence changing its shape and functional capability.

figure 25 – posture



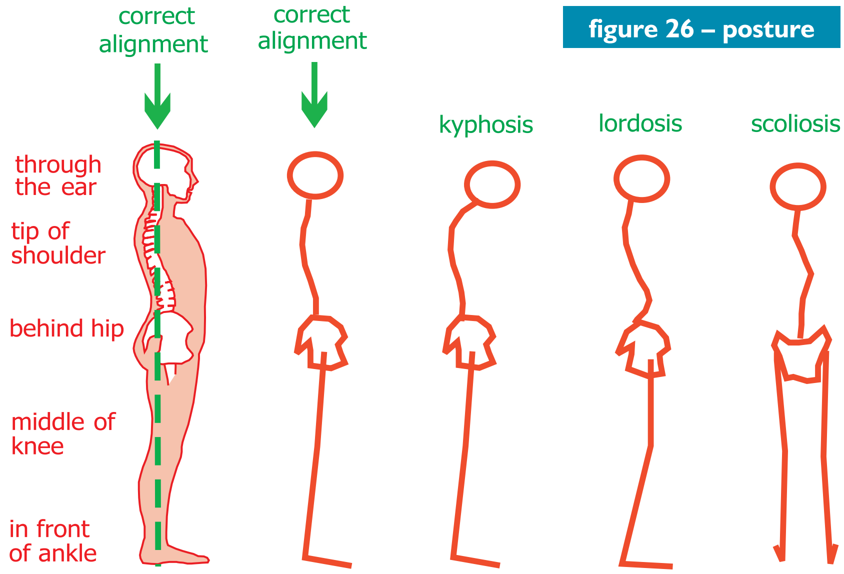
Posture

Posture (figure 25) is a position or **attitude** of the body as a whole which is maintained as a result of **muscle tone** (muscle tone refers to the constant tension produced by muscles of the body for long periods of time). In the correct standing posture, there is an alignment through the ear, tip of shoulder, behind the hip, through the middle of the knee joint to the front of the ankle, as illustrated in figure 26 (see next page). This enables the person's weight to be most efficiently carried by his or her skeleton. When viewed from the behind, the vertebral column should be straight. When viewed from the side, the vertebral column should present four distinct curves: the **kyphotic** curves (convex curvature of the thoracic and sacral regions) and **lordotic** curves (concave curvature of the cervical and lumbar regions). These curves assist in absorbing shock and give the back its normal posture. But excessive or decreased curvature can cause unnecessary stress to the vertebral structures.

Common postural defects are:

- **Kyphosis** (hunchback) which is dorsally exaggerated spinal curvature of thoracic region.
- **Lordosis** which is an accentuated, convex forward spinal curvature of the lumbar region.
- **Scoliosis** which is the abnormal lateral (sideways) curvature of the spine normally in the thoracic region.

figure 26 – posture



Causes of poor posture are:

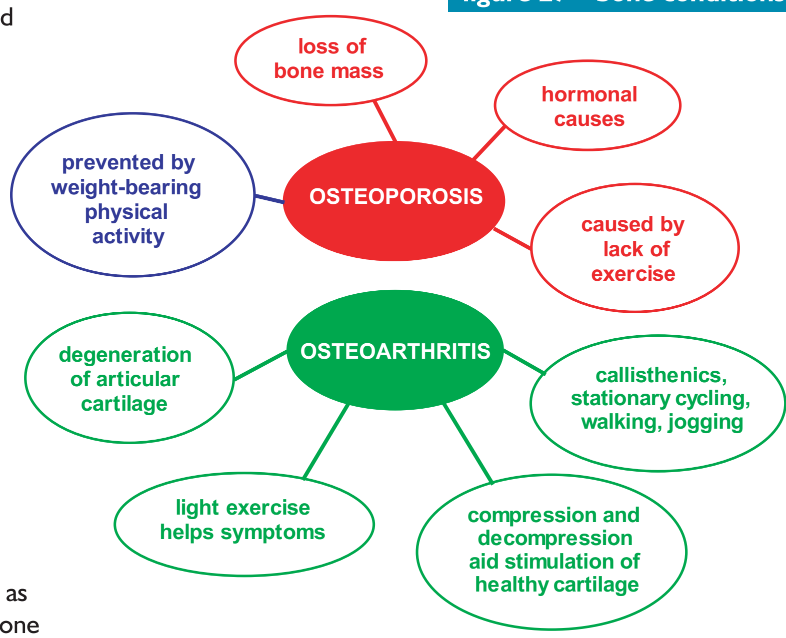
- Poor diet due to **lack of vitamin D** (rickets).
- Osteoporosis.
- Weaknesses in and between **muscle** groups.

This latter cause is due to **front or back dominance** (stronger back muscles than abdominal muscles) which would then create **muscular** and **flexibility** imbalances. Particular attention should be given to the role of the **core stability** musculature. For example, the strengthening of the **transversus abdominus** and **multifidus** (part of the erector spinae group of muscles) will improve abdominal and lumbar tension respectively. It is important that **balanced** exercise is taken that stresses different muscle groups on and around the torso region.

Osteoporosis

Osteoporosis (figure 27) means bone (osteo) that is porous (porosis). And so osteoporosis causes loss of bone mass as **calcium minerals are dissipated** around the rest of the body, making bones brittle and liable to break. This is caused in the elderly by change in hormone quantity and balance (thin-boned women are particularly at risk following menopause).

figure 27 – bone conditions

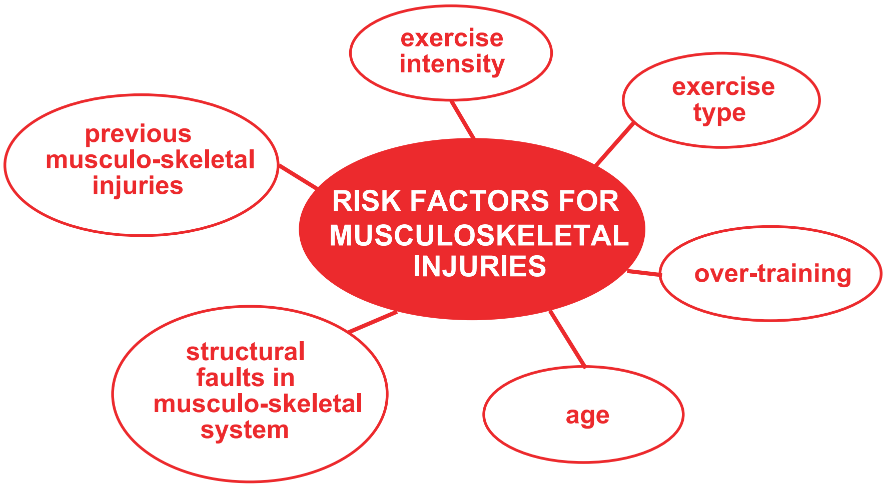


However, osteoporosis can also be caused by lack of exercise. This happens because bone has a tendency to strengthen itself if it is exposed to forces (which can be applied during the exercise process). This is part of most biological systems reaction to being placed under stress. For example, muscles grow bigger and stronger when exposed to force in the form of intense exercise, and bone reacts in a similar way. Hence bones must be **mechanically loaded** so that when you use muscles that cross a joint, the two surfaces of the joint are compressed against each other.

On the other hand, non-weight bearing activities, such as swimming and biking, are less effective in stimulating bone mass. Astronauts exposed to gravity-free conditions for 3 months have shown a bone mass loss of 60%. This was due to the fact that their skeletons did not have to support their weight for this period, and hence their bones reduced in strength as an adaptation to this fact.

The key point here is that **weight-bearing physical activity helps prevent osteoporosis by increasing bone strength and mass.**

figure 28 – risk factors for musculo-skeletal injuries



Osteoarthritis

Osteoarthritis is a joint disease characterised by the degeneration of articular cartilage in the joint. This restricts joint flexibility and capability in the individual for doing exercise. It is important to do whatever light exercise is possible, since it has been shown that the **symptoms** of osteoarthritis are considerably reduced if regular aerobic exercise is taken. This is because the cycles of compression (as muscle contracts) and decompression (as muscle relaxes) aid the stimulation of healthy articular cartilage. Exercise types such as callisthenics, stationary cycling, walking and jogging are recommended.

In **high impact sports**, compression forces on one area of a joint surface can cause irritation within the joint. This is a form of repeated stress that can lead to osteoarthritis.

The **Growth Plate** or epiphyseal disc is where the increase in the length of a bone takes place. Bone growth starts prior to birth and normally ceases in late adolescence. **High impact sports,** such as elite gymnastics, can **stunt** bone growth within the young growing skeleton, and hence reduce the potential height of the individual.

In **summary** (figure 28), the risk factors for **musculo-skeletal injuries** whilst engaging in physical activity are:

- Exercise intensity.
- Exercise type.
- Over-training.
- Age.
- Structural faults in the musculo-skeletal system.
- Previous musculo-skeletal injuries.

However, well-planned, reasonable weight-bearing **physical activity** can help improve **physical health**. Hence we should encourage an active lifestyle throughout a person's life (figure 29).

figure 29 – exercise while ageing

Summary of the benefits of regular physical activity on the skeletal and muscular systems

Skeletal system adaptations

- Strengthening of bone tissue due to increased deposition of calcium.
- Thickening of articular cartilage provides greater cushioning and protection of bone ends from wear and tear.
- Increased range of movement at a joint.
- These adaptations enable an athlete to progress to higher intensity impact work within training programmes such as in plyometrics, weight lifting and gymnastics.

Muscular system adaptations

- Increased thickening of tendons to withstand increased muscular forces.
- Strengthening of ligaments to give improved joint stability.
- Increased muscle mass due to muscle hypertrophy.
- Therefore increased force of muscular contractions.
- Improved ability to maintain power output for longer, due to increased tolerance to muscle fatigue.
- Improved elasticity of muscle fibres and therefore increased flexibility.
- Increased muscle cell stores such as glycogen to support improved performance in endurance-based activities such as marathon running.
- Reduced risk of injury during physical activity.

Practice questions

Warm-up question 1)
Hockey involves movement at many joints in the body. Identify which bones articulate at each of the following joints: shoulder, elbow, radio-ulnar, hip, knee, and ankle. 6 marks

Warm-up question 2)
Complete the missing gaps in table 12 by naming the main agonist and antagonist muscles for each of the actions: elevating the shoulder girdle, extending the elbow joint, flexing the hip joint, flexing the knee joint, dorsiflexing the ankle joint, and flexing the trunk. 12 marks

Table 12 – **agonist and antagonist muscles**

action	main agonist	main antagonist
elevating the shoulders		
extending the elbow joint		
flexing the hip joint		
flexing the knee joint		
dorsiflexing the ankle joint		
flexing the trunk		

3) Figure 30 a-c shows the final stride, take-off and flight phase of a long jump.

Use these three pictures to help you complete the following joint analysis.

a) Name the type of muscle contraction occurring in the left leg (foot in contact with the ground) in figure 30 a, name an agonist muscle responsible for this muscle contraction and explain why you have selected this muscle. 3 marks

b) Complete the following joint analysis below in table 13 for figure 30 b. 9 marks

figure 30 – long jump take-off and flight

Table 13 – **joint table**

joint	joint type	articulating bones	main agonist muscle
left ankle			
left knee			
left hip			

c) Describe the changes in movement patterns in the left ankle, knee, hip and trunk from figures 30 b to c. 4 marks

d) Suggest two factors which could affect the range of movement at the hip joint. 2 marks

e) Identify the predominant fibre type stressed during the take-off and give two reasons why this fibre type would be used. Identify the type of muscle contraction occurring during the take-off phase of the long jump. 4 marks

f) Why is it important to warm-up muscle tissue prior to long jumping? 2 marks

4) Figure 31 shows a tennis player completing a forehand drive. Use the figure to help you complete the following joint analysis.

figure 31 – tennis forehand

a) For the shoulder joint during horizontal flexion, identify the type of joint, the articulating bones, an agonist muscle, and the type of contraction for the agonist. 4 marks

b) Using the muscles that create flexion of the elbow during the forehand drive, explain what is meant by antagonistic muscle action. 4 marks

c) Identify the movement pattern produced and an agonist muscle responsible for the action on the right hand side of the trunk. 2 marks

d) For the right wrist, identify the articulating bones, an agonist muscle, and the movement pattern at the completion of the forehand drive. 3 marks

5) The athlete in figure 32 is holding a plank bridge position. Use the photograph to help you complete the following joint analysis.

a) Identify the joint type, articulating bones, agonist (prime mover), and type of muscle contraction at the hip joint. Explain why the muscle contraction is of this type. 5 marks

b) Identify a core stability muscle that is supporting the trunk position and explain the role of this muscle in relation to the plank bridge position. 2 marks

figure 32 – athlete holding a plank position

5) c) There are four rotator cuff muscles that are inserted around the cuff or cap over the proximal humerus. Name one of these muscles and explain how these muscles provide range of movement and yet collectively protect the shoulder joint. 4 marks

6) Skeletal muscle contains both slow and fast twitch muscle fibres but the proportion of each depends upon the function of a muscle as a whole. Table 14 lists some of the differences between slow and fast twitch muscle fibres.

Table 14 – muscle fibre type characteristics

characteristic	slow twitch type	fast twitch type
contractile time / ms	110	40
mitochondrial density	high	low
glycogen store	low	high
phosphocreatine stores	low	high
capillary density	high	low
sarcoplasmic reticulum	poorly developed	well developed
oxidative enzyme activity	high	low

a) Suggest why the muscles concerned in maintaining the trunk posture of the body of the sprinter might be expected to have a larger percentage of slow twitch muscle fibres.
Using table 14 explain why fast twitch muscle fibres may build up an oxygen debt during a 400m sprint. 5 marks

b) Account for the difference in the speed of contraction between slow and fast twitch fibre types.
Fast twitch fibres are divided into two types, IIa and IIb. Identify a major functional characteristic between these sub groups. In what sporting activities would the adaptation of fast twitch type IIb to type IIa fibres be relevant to a sportsperson? 6 marks

c) Discuss the role of genetics in determining the proportion of muscle fibre types and potential for success in athletic performance. 4 marks

7) What is meant by a cool-down and explain the importance of cooling down skeletal muscle following a sprint training session? 4 marks

8) Osteoporosis refers to a loss of bone mass that occurs with ageing.
Identify two major contributing factors common to post-menopausal females.
What is the most desirable form of exercise that would slow down the rate of skeletal ageing and why? 4 marks

9) Critically evaluate the positive and negative impacts of participating in different types of physical activity on the joints and muscles of the human body. 10 marks

This question will assess quality of written communication – the answer must be written in prose (essay) form. Marks will be awarded for spelling, punctuation and grammar, use of appropriate form and style of writing, and for organising work clearly and coherently.