CHAPTER 3

3.1 Effect of Exercise

Physical exercise is important for maintaining physical fitness and can contribute to maintaining a healthy weight, regulating digestive health, building and maintaining healthy bone density, muscle strength, and joint mobility, promoting physiological well-being, reducing surgical risks, and strengthening the immune system. Some studies indicate that exercise may increase life expectancy and the overall quality of life. People who participate in moderate to high levels of physical exercise have a lower mortality rate compared to individuals who by comparison are not physically active. Moderate levels of exercise have been correlated with preventing aging by reducing inflammatory potential. The majority of the benefits from exercise are achieved with around 3500 metabolic equivalent (MET) minutes per week. For example, climbing stairs 10 minutes, vacuuming 15 minutes, gardening 20 minutes, running 20 minutes, and walking or bicycling for transportation 25 minutes on a daily basis would together achieve about 3000 MET minutes a week. A lack of physical activity causes approximately 6% of the burden of disease from coronary heart disease, 7% of type 2 diabetes, 10% of breast cancer and 10% of colon cancer worldwide. Overall, physical inactivity causes 9% of premature mortality worldwide.

3.2 Exercise and Systems of Human Body

1. Muscular System

a. Types of Muscles

- **Skeletal muscle**

Skeletal Muscles are those which attach to bones and have the main function of contracting to facilitate movement of our skeletons. They are also sometimes known as striated muscles due to their appearance. The cause of this 'stripy' appearance is the bands of Actin and Myosin which form the Sarcomere, found within the Myofibrils.

Skeletal muscles are also sometimes called voluntary muscles, because we have direct control over them through nervous impulses from our brains sending messages to the muscle. Contractions can vary to produce powerful, fast movements or small precision actions. Skeletal muscles also have the ability to stretch or contract and still return to their original shape.

- **Skeletal muscle fibre type**

Not all fibres within Skeletal muscles are the same. Different fibre types contract at different speeds, are suited to different types of activity and vary in colour depending on their Myoglobin (an oxygen carrying protein) content.

- **Smooth muscle**

Smooth muscle is also sometimes known as Involuntary muscle due to our inability to control its movements, or unstriated as it does not have the stripy appearance of Skeletal muscle. Smooth muscle is found in the walls of hollow organs such as the Stomach, Oesophagus, Bronchi and in the walls of blood vessels. This muscle type is stimulated by involuntary neurogenic impulses and has slow, rhythmical contractions used in controlling internal organs, for example, moving food along the Oesophagus or contracting blood vessels during Vasoconstriction.

- **Cardiac muscle (heart muscle)**

This type of muscle is found solely in the walls of the heart. It has similarities with skeletal muscles in that it is striated and with smooth muscles in that its contractions are not under conscious control. However, this type of muscle is highly specialised. It is under the control of the autonomic nervous system, however, even without a nervous impute contractions can occur due to cells called pacemaker cells. Cardiac muscle is highly resistant to fatigue due to the presence of many mitochondria, myoglobin and a good blood supply allowing continuous aerobic metabolism.

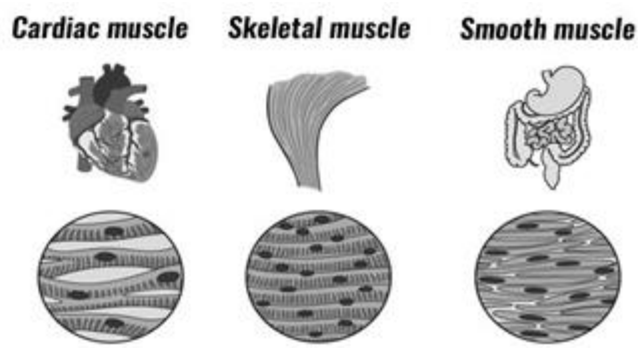

Figure 6

b. Functions of the Muscular System

- *Voluntary and Reflexive Movement*

Gross movement refers to large coordinated movements such as walking, running, jumping, sitting down, standing up, lifting large objects, swimming, and swinging a bat or racket. Gross movements rely primarily on large skeletal muscles. Fine motor skills refer to smaller, more intricate body movements. Examples include speaking, writing and playing a musical instrument. Fine motor skills typically involve small skeletal muscles of hands, face or feet. Although most skeletal muscles are under voluntary control, they can also contract reflexively – such as blinking when an insect flies toward face or pulling hand away from a hot surface.

- *Skeletal Stability and Organ Protection*

Bones provide the frame for body. Skeleton, however, lacks structural stability without the skeletal muscles and their associated tendons that hold bones together and keep them in place. Even in a static posture, such as when we're standing still, numerous skeletal muscles of the trunk, neck and legs must remain in a contracted state to support body and head. The axial skeletal muscles are particularly important for maintaining an upright position and enabling to twist head and body.

- *Blood Circulation*

Smooth muscle cells in the walls of arteries and veins also contribute to blood circulation by altering the diameter of these blood vessels in different situations. For example, arteries supplying exercising skeletal muscles relax to enable increased blood flow to meet the increased metabolic demand. Conversely, if we're dehydrated or suffer a significant blood loss, the smooth muscle of blood vessels contracts to help maintain blood pressure and ensure continued circulation to brain and other vital organs.

- *Internal Organ Function*

Several internal organs contain smooth muscle tissue, which contracts automatically to support their normal function. For example, smooth muscle tissue in the walls of esophagus, stomach, and small and large intestines produce rhythmic contractions that propel food through digestive tract. Similarly, smooth muscle in the wall of bladder enables to expel urine. Uterine smooth muscle tissue, called the myometrium, proliferates during pregnancy and provides the strong propulsive force that enables a vaginal delivery. Other internal organs and structures that rely on smooth muscle to support some of their functions include the gallbladder, male reproductive ducts and glands, and the irises of the eyes.

- *Body Temperature Regulation*

A normal body temperature of roughly 98.6 F is generally lower than the environmental temperature. Since body heat is lost to the environment in typical conditions, body must generate heat to maintain a normal temperature. Most of this needed heat is generated by skeletal muscles. When body temperature decreases, skeletal muscle activity automatically increases to generate heat. Shivering is the most obvious manifestation of this response. Smooth muscle in the blood vessels supplying skin also automatically constricts in cold conditions to conserve heat by limiting loss at body surface. The opposite effect occurs when exercising or otherwise overheated. Smooth muscle cells in surface blood vessels relax, increasing blood flow and heat release through skin.

c. Types of Muscle Fibers

The body's diverse requirements of its skeletal muscles, e.g. to generate rapid movements in some cases but to maintain high levels of tension (without fatigue) in the cases of other muscles, are such that the muscle fibres forming some muscles have different properties than muscle fibres forming other muscles whose main function and activity is significantly different.

Muscles that need to be able to perform effectively in both respects consist of a combination of both slow- *and* fast-contracting muscle fibres.

Slow-contracting muscle fibres are called **Type I**. Fast-contracting muscle fibres are called **Type II**.

There are two main types of fast-contracting muscle fibres (that is, **Type II** muscle fibres are divided into **Type IIa** and **Type IIb**), which have **different resistance to fatigue**. This relates to how effectively the muscle fibres can access the energy they need to contract. As explained on supply of energy for muscle contraction, the immediate source of (chemical) energy for muscle contraction is the molecule adenosine triphosphate (ATP), which releases energy when it breaks down: ATP $\rightarrow$ ADP + P_i + Energy. As ATP is used-up by muscles as they contract, an important aspect of the supply of energy for muscle contraction is *how* the muscle fibres produce ATP.

In order to describe and compare the different types of skeletal muscle fibres it is useful to know that:

- In general, the myosin heads (within the thick filaments of muscle fibres) include an enzyme called **ATPase** that **catalyzes**, i.e. it acts as a catalyst for (=increases the rate of) the reaction ATP $\rightarrow$ ADP + P_i + Energy, in which ATP decomposes into ADP and a free phosphate ion.
- **Oxidative phosphorylation** is the final series of chemical reactions in the synthesis of ATP by **aerobic cellular respiration**, which is a very efficient method of production of ATP and a method of ATP production that can be sustained for long periods of time, e.g. when running a race that takes several hours to complete. However, this process of ATP synthesis requires oxygen.

Oxidative phosphorylation takes place in the mitochondria within cells, so cells that contain many mitochondria are better adapted for production of ATP *via aerobic cellular respiration*, of which the final steps that yield most of the ATP are known as **oxidative phosphorylation**, than cells that contain fewer mitochondria.

Properties	Properties	Red / Fast (Type II a)	White / Fast (Type II b)
Another Name	Slow twitch fibers	Fast oxidative fibers	Fast glycolytic fibers
Colour	Red - due to the respiratory pigment myoglobin which, in common with the haemoglobin (Am.Sp. hemoglobin) in red blood cells, stores O_2 by loosely binding it.	Red - due to the respiratory pigment myoglobin which, in common with the haemoglobin (Am.Sp. hemoglobin) in red blood cells, stores O_2 by loosely binding it.	White - due to the absence of pigmentation, e.g. the respiratory pigment myoglobin or hemoglobin (as present in red blood cells)
Contraction time	Slow	Fast	Very Fast
Oxidative capacity	High	High	Low
Resistance to fatigue	High	Medium (Intermediate)	Low
Diameter (of muscle fibre)	Small	Medium (Intermediate)	Large

Capillary density	High	Medium (Intermediate)	Low
Mitochondrial density	High	High	Low
Glycogen reserves	Low	Intermediate	High
Main (metabolic) pathway for production of ATP	Aerobic cellular respiration - final stage: oxidative phosphorylation	Both aerobic and anaerobic metabolic pathways	Only anaerobic metabolism, esp. anaerobic glycosis
Force production (i.e. force produced by muscle)	Low	Medium-High	Very High
Example of typical use	Repeated low-level contractions e.g. walking or low intensity cycling for 30 mins.	Activities involving speed, strength and power, e.g. moderately weight training and fast running e.g. 400 metres.	Short, fast, bursts of power (but rapid fatigue) e.g. heavy weight training, power lifting, and 100 metre sprints

Examples of muscles or locations of skeletal muscles with this type of fibre	Postural muscles, e.g. of the neck and spine, & leg muscles (which have Type I & Type II a fibres).	Leg muscles have large quantities of both Type I and Type II a fibres.	*Arm muscles.* *N.B. Type IIb fibres can be converted into II a fibres by resistance training.*

a. The Effects of Exercise on Muscular System

Exercise involves a series of sustained muscle contractions, of either long or short duration, depending on the nature of the physical activity. Effects of exercise on muscles can be considered short-term or immediate, both during and shortly after exercise; as well as long-term, lasting effects.

✓ **Short term effects such as**

- **Blood flow** – after exercise muscle tissue (warm muscle) is bigger than cold muscle, because of blood flow into them. It can increase by up to 25 times, because muscle requires more energy and oxygen.
- **Muscle fatigue** – is the decline in ability of a muscle to generate force. It can be a result of intense exercise, but abnormal fatigue may be caused by barriers to or interference with the different stages of muscle contraction. There are two main causes of muscle fatigue. The limitations of a nerve's ability to generate a sustained signal (neural fatigue) and the reduced ability of the muscle fibre to contract (metabolic fatigue).

- **Muscle exhaustion –** general exhaustion often occurs after have done too much activity at one time, such as by taking an extra-long hike. It may feel weak and tired, or the muscles may be sore. These sensations usually go away within a few days. In rare cases, generalized muscle weakness may be caused by another health problem, such as problems with body regulating the distribution of energy to muscles and organs.
- **Muscle damage –** any effort beyond muscle ability level or accident can tear the fibres and cause muscle damage. When a muscle fibre is damaged, the body immediately starts to repair it at the cellular level. Muscles most of the time repairs by themselves (if body is functioning properly) through time. If damage or injury is critical, surgery might be needed.
- **Cramp –** because of over-exercise, lack of nutrients like magnesium or bad blood circulation when muscles don't receive enough oxygen. It is very painful and can be dangerous if doing exercise that involves heavy weights alone.

✓ **Long-term effects of exercise**

- **Muscle size** – is mostly determined by persons genetics but can be affected with life choices like anabolic steroids, exercise, and healthy food. Exercising specific muscles regularly can increase their size by up to 60%. This increase in muscle size is mainly due to increased diameter of individual muscle fibres.
- **Muscle coordination** – It trains muscles to work more

efficient and effectively by working together. E.g.: when the prime mover contracts more rapidly the antagonist (muscle) must also relax as quickly to prevent blocking the movement.

- **Blood supply** – As a result of frequent exercise over a sustained period of time both the quantity of blood vessels and the extent of the capillary beds increases.
- Effects of exercise on muscular system would benefit by increasing size and number of mitochondria, improved perception of muscle tone and also overall improved.

- Coordination
- Power
- Balance
- Speed
- Agility
- Body composition
- Reaction time
- Muscular endurance
- Flexibility

2. Effect of Exercise on Nervous System

The nervous system is largely comprised of nerves and the brain. The brain is the control centre for the system and resides inside the skull. In addition, the spinal column which contains the most imperative nerves resides in the spine.

The nervous system consists of brain, spinal cord, nerve fibers that transmit messages from the brain throughout the body

Function

The nervous system is responsible for all physical reactions and telling each body part to move when and where. The nerves are also responsible for feeling pain and reaction time to stimuli. Additionally, the brain is responsible for all emotions and feelings.

System Importance

The nervous system is important for proper functioning of the body in that it ensures that reactions occur efficiently and directs signals through the body that result in every bodily function.

Potential Health Issues

Some of the many potential health issues associated with the nervous system are paralysis due to nerve damage, all psychological disorders, and epilepsy.

a. Exercise can affect the Nervous System

Short Term Effects

The immediate effects of exercise are on the neurotransmitters. It causes complex signals to pass through the neurons in the brain. This alerts the brain for learning and makes information easier to retain.

Long Term Effects

Exercise stresses the muscles which creates growth factors. This contributes to brand new brain cells and it increases the number of pathways for oxygen, energy, and to remove waste from the brain.

Aerobic Exercise

Aerobic exercise is the more beneficial type of exercise on the nervous system. It improves cognition for all people, but the cognitive abilities of aerobically active children particularly stand out against those who are not aerobically active.

Anaerobic Exercise

Anaerobic exercise has no proven effect on the nervous system, but it still is a very important part of a balanced exercise plan and positively affects other body systems.

Inactivity's Effect

Inactivity makes the nerve cells reduce growth, as depicted. It reduces the effectiveness of the areas of the brain associated with motor skills and learning.

3. **Circulatory system**

Exercise places an increased demand on the cardiovascular system. Oxygen demand by the muscles increases sharply. Metabolic processes speed up and more waste is created. More nutrients are used and body temperature rises.

- ✓ Delivers oxygen to working muscles
- ✓ Oxygenates blood by returning it to the lungs
- ✓ Transports heat (a by-product of activity) from the core to the skin
- ✓ Delivers nutrients and fuel to active tissues
- ✓ Transports hormones
- ✓ Reduction in bad (LDL and total) cholesterol

- ✓ Increase in good (HDL) cholesterol

To perform as efficiently as possible the cardiovascular system must regulate these changes and meet the body increasing demands.

The acute or immediate response to exercise and the long-term adaptations that take place in the cardiovascular system with repeated exercise. The most important aspects of the cardiovascular system to examine include:

- Heart rate
- Stroke volume
- Cardiac output
- Blood flow
- Blood pressure
- Blood

4. Digestive system

Digestive system is responsible for breaking down food and providing energy to the rest of the body. The digestive system is made up of the esophagus, the stomach, the pancreas, liver, gallbladder, small intestine and the large intestine. Exercise can help to improve the efficiency of the digestive process and helps to maintain a healthy weight. Regular exercise and conscious breathing (pranayama), which works on the digestive system as a gentle massage, have a favourable effect on the digestion. They activate the digestive enzymes and the bowel movement. Regular exercise is good for circulation, and it stimulates and energizes the nervous, endocrine, and muscular systems.

- ✓ **Increased Metabolism**
- ✓ **Internal Massage**
- ✓ **Strengthens the Muscles**
- ✓ **Increased Blood Flow**

5. Endocrine system

Endorphins can help reduce tension and anxiety and facilitate the proverbial “runner's high.” endocrine response to exercise can increase organ function, physical appearance and state of mind. Conversely, low testosterone levels might inhibit motivation, self-confidence, concentration and memory. Pituitary gland may produce a large increase in blood endorphin levels shortly after exercise begins. Endorphins block sensitivity to pain and can reduce tension or anxiety by inducing a sense of euphoria.

- ✓ **Pituitary Gland-**During exercise, the pituitary gland releases human growth hormone, which tells the body to increase bone, muscle and tissue production.
- ✓ **Thyroid Gland-** sends out hormones that regulate the body’s temperature, heart rate and blood pressure. It also regulates the alertness and focus that are needed to work at a high intensity.
- ✓ **Adrenal Gland -** Located at the top of the kidneys, the adrenal glands are responsible for the release of cortisol into the bloodstream. Cortisol levels control blood pressure, glucose and acts as an anti-inflammatory agent. The adrenal glands also release aldosterone, a hormone that regulates hydration levels, the speed of the heart and the strength of contractions.

It also turns stored carbohydrates into energy.

- ✓ **Pancreas -** Insulin regulates glucose, or blood sugar, by transporting it to the muscles and tissue that use glucose for energy. Excessive insulin in the blood reduces sensitivity to insulin and can cause diabetes, which is also connected to overweight and obesity. Exercise improves insulin sensitivity and reduces the reliance on insulin injections.

6. Exocrine system

The Exocrine System is a system of glands that produce and secrete substances that may either protect or lubricate the body. Combining exercise with proper amounts of sleep, relaxation techniques, and positive thinking will help reduce stress and keep hormone levels balanced. One of the main functions of some glands is to secrete hormones which will help the body respond to stressful situations; however, that is intended to be short-term. When stress lasts longer than a few hours, higher energy demands are placed on the body. They tend to weaken the body's defences, leaving the body open to infection.

Exocrine glands include:

- **Sweat:** secretes sweat and is in the dermis of the skin
- **salivary**: discharges a fluid secretion into the mouth cavity
- **mammary**: the milk-producing gland of women
- **prostate**: the semen-producing gland of men
- **gastric**: produces acids in the stomach to help with digestion
- **bile-producing glands of the liver**

- **ceruminous**: a special kind of sweat gland
- **lacrimal**: secretes tears
- **sebaceous**: a small gland in the skin which secretes an oily substance to lubricate the skin and hair
- **Mucous**: a slimy substance used for lubrication and protection.

These are all travel through ducts. They usually deposit their substances onto epithelial surfaces which line the cavities and surfaces of blood vessels and organs throughout the body. They are in three distinct shapes:

- squamous (very thin and flat)
- columnar (like a column)
- cuboidal (many sides)

2.3 Muscular Contraction

For voluntary muscles, all contraction (excluding reflexes) occurs as a result of conscious effort originating in the brain. The brain sends signals, in the form of action potentials, through the nervous system to the motor neuron that innervates several muscle fibers. In the case of some reflexes, the signal to contract can originate in the spinal cord through a feedback loop with the grey matter. Involuntary muscles such as the heart or smooth muscles in the gut and vascular system contract as a result of non-conscious brain activity or stimuli endogenous to the muscle itself. Other actions such as locomotion, breathing, and chewing have a reflex aspect to them: the contractions can be initiated either consciously or unconsciously.

There are three general types of muscle tissues:

- Skeletal muscle responsible for movement
- Cardiac muscle responsible for pumping blood
- Smooth muscle responsible for sustained contractions in the vascular system, gastrointestinal tract, and other areas in the body.

Skeletal and cardiac muscles are called striated muscle because of their striped appearance under a microscope, which is due to the highly organized alternating pattern of A band and I band.

While nerve impulse profiles are, for the most part, always the same, skeletal muscles can produce varying levels of contractile force. This phenomenon can be best explained by Force Summation. Force precis describes the addition of individual twitch contractions to increase the intensity of overall muscle contraction. This can be achieved in two ways: by increasing the number and size of contractile units simultaneously, called *multiple fibres summation*, and by increasing the frequency at which action potentials are sent to muscle fibers called *frequency summation*.

- **Multiple fiber summation** – When a weak signal is sent by the CNS to contract a muscle, the smaller motor units, being more excitable than the larger ones, are stimulated first. As the strength of the signal increases, more motor units are excited in addition to larger ones, with the largest motor units having as much as 50 times the contractile strength as the smaller ones. As more and larger motor units are activated, the force of muscle contraction becomes progressively stronger. A concept known as the size principle, allows for a gradation of muscle force during weak contraction to occur in small steps, which then become progressively larger when greater amounts of force are required.

- **Frequency summation** – For skeletal muscles, the force exerted by the muscle is controlled by varying the frequency at which action potentials are sent to muscle fibers. Action potentials do not arrive at muscles synchronously, and, during a contraction, some fraction of the fibers in the muscle will be firing at any given time. In a typical circumstance, when a human is exerting a muscle as hard as he/she is deliberately able to roughly one-third of the fibers in that muscle will be firing at once, though this ratio can be affected by various physiological and psychological factors (including Golgi tendon organs and Renshaw cells). This 'low' level of contraction is a protective mechanism to prevent avulsion of the tendon the force generated by a 95% contraction of all fibers is sufficient to damage the body.

A. Types of Muscular Contraction

Muscle fiber generates tension through the action of actin and myosin cross-bridge cycling. While under tension, the muscle may lengthen, shorten, or remain the same. Although the term contraction implies shortening, when referring to the muscular system, it means muscle fibers generating tension with the help of motor neurons. Several types of muscle contractions occur, they are defined by the changes in the length of the muscle during contraction.

1. Isotonic Contractions

Isotonic contractions maintain constant tension in the muscle as the muscle changes length. This can occur only when a muscle's maximal force of contraction exceeds the total load on the muscle. Isotonic muscle contractions can be either concentric (muscle shortens) or eccentric (muscle lengthens).

i. Concentric Contractions

A concentric contraction is a type of muscle contraction in which the muscles shorten while generating force. This is typical of muscles that contract due to the sliding filament mechanism, and it occurs throughout the muscle. Such contractions also alter the angle of the joints to which the muscles are attached, as they are stimulated to contract according to the sliding filament mechanism.

This occurs throughout the length of the muscle, generating force at the musculo-tendinous junction; causing the muscle to shorten and the angle of the joint to change. For instance, a concentric contraction of the biceps would cause the arm to bend at the elbow as the hand moves from near to the leg to close to the shoulder (a biceps curl). A concentric contraction of the triceps would change the angle of the joint in the opposite direction, straightening the arm and moving the hand toward the leg.

ii. Eccentric Contractions

An eccentric contraction results in the elongation of a muscle. Such contractions decelerate the muscle joints (acting as "brakes" to concentric contractions) and can alter the position of the load force. These contractions can be both voluntary and involuntary. During an eccentric contraction, the muscle elongates while under tension due to an opposing force which is greater than the force generated by the muscle. Rather than working to pull a joint in the direction of the muscle contraction, the muscle acts to decelerate the joint at the end of a movement or otherwise control the repositioning of a load.

This can occur involuntarily (when attempting to move a weight too heavy for the muscle to lift) or voluntarily (when the muscle is "smoothing out" a movement). Over the short-term, strength training involving both eccentric and concentric contractions appear to increase muscular strength more than training with concentric contractions alone.

2. Isometric Contractions

In contrast to isotonic contractions, isometric contractions generate force without changing the length of the muscle. This is typical of muscles found in the hands and forearm: the muscles do not change length, and joints are not moved, so force for grip is sufficient. An example is when the muscles of the hand and forearm grip an object; the joints of the hand do not move, but muscles generate enough force to prevent the object from being dropped.

3. Isokinetic Contractions

Isokinetic contractions are like Isotonic in that the muscle changes length during the contraction, where they differ is that Isokinetic contractions produce movements of a constant speed. To measure this a special piece of equipment known as an Isokinetic dynamometer is required. Examples of using Isokinetic contractions in day-to-day and sporting activities are rare. The best is breaststroke in swimming, where the water provides a constant, even resistance to the movement of adduction.

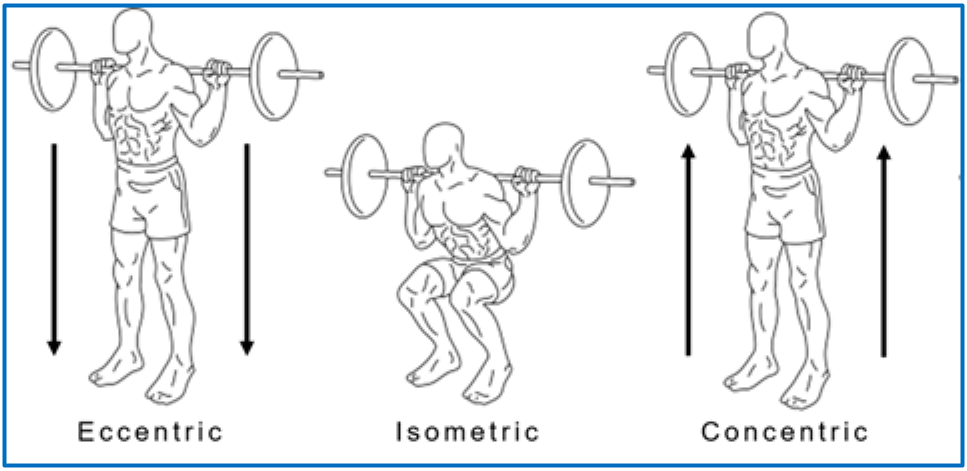

Figure 7