Relationship between skeletal and muscular system

Locomotion of the human body is a result from the alternate contractions and expansion of the muscles[1]. These contractions are generally caused by conversion of chemical energy to forces and moments therefore creating[1]. Based on the properties of muscles (structural and contractile), the muscular system of the human body is classified into three categories ; skeletal muscle, smooth muscle and cardiac muscle.[1 & 2]. In this essay the anatomical structure, contraction mechanism and also a disease of the skeletal muscle is explained. Generally in the human body nearly 40-45% of the total body weight comprises of the skeletal muscles and the rest 10% is made up of the of smooth muscles[2]. These muscles help keeping the skeleton intact by distributing the external or internal loads evenly across the joints which are held by tendons that help in the transmission of force muscles to the bones or joints, thus providing strength for human motion[1].

Skeletal muscle is surrounded by a membrane called the epimysium, which consists of bundles of fascicles enveloped by a dense tissue called the perimysium[1&2]. These fascicles are made up of individual structural units that are long, cylindrically shaped multinucleated cells called muscle fibres[2]. The diameter of the muscle fibres varies from 1- 100Î¼m and has average length of 20cm[2]. Each muscle fibre is subdivided into thousands of myofibrils that are packed together in the form of cylindrical bundles by a thin membrane called sarcolemma[1, 2 &3]. Skeletal Muscles cannot be repaired in case of any damage but satellite cells which are located beneath the basal lamina of the myofibers have the ability to form new muscle fibres however the strength will not be same as the old skeletal muscle[4]. The myofibrils consists of many repeating units along its length called

sarcomeres which is made up of thick and thin filaments of varying size having contractile proteins called actin and myosin respectively[1, 2 &3]. According to nuclear magnetic resonance studies the structure of the actin was found to be Î±-helical in shape but certain other experiments using scanning transmission electron microscopy(STEM) prove that actin appears to be double helical in structure[5]. Thick filaments on the other hand is made up of protein molecules called myosin with an average molecular weight 200, 000[6]. The thick and the thin filaments are arranged in a parallel pattern in a sarcomere as given in figure 2 this gives to the rise of dark bands called the A-bands which lie in the central region of the sarcomere[1&2]. The darkness in this band is because of the presence of the thick filaments and the overlapping of the thin filaments. The thin filaments are connected to the Z line, which is made up of complex and dense protein structures. These Z lines have an unique property of not allowing easily the passage of light. Another set of bands is the I – bands, these are generally light bands because of the presence of thin filaments and they lie generally between the A band and the Z line. Titin molecules are polypeptide chains that link the Z line with the myosin filaments in this region and center them in a sarcomere[1, 2&7]. These titin molecules is responsible for generation of a passive force upon application of any load [7]. The striated appearance of the skeletal muscle is because of the presence of these bands. Some additional structures that are present are the H zone and the M line. The H zone lies in the centre of the A band and this region consists of only thick filaments. This zone is bisected by a relatively narrow band called the M line which is a result of the cross linking of proteins with the central region of the thick filaments. Recent studies which used electron micrographs to

determine the ultrastructure of the M line it was found that the M line had a width of 750 A and the thickness of the M line was large as a result the opacity of this line was high[8].

The Neuromuscular junction

The neuromuscular junction is the site of action of motor neuron (somatic efferent neurons) with respect to the muscle fibres. The axon terminal of the motor neuron bifurcates into several smaller branches, each of which forms a junction with the muscle fibre. Thus by this manner a single neuron is able to excite several muscle fibres at the site. The motor neuron and the muscle fibres at the site of the action are together known as the motor unit. The neural impulses from the axon branches are received by the muscle fibre at a site known as the motor end plate. The junction comprising of the axon terminal and the motor end plate together form the neuromuscular junction.

The axon terminal contains a neurotransmitters (acetylcholine (ACh)) in vesicles similar to those found at synaptic junctions. The nerve plasma membrane is triggered by an action thereby opening the voltage sensitive calcium channels and allowing the calcium ions to diffuse into the axon terminal. The calcium ions bind to proteins and cause the release of ACh from the axon terminals into the muscle fibers. The diffusing ACh binds to the receptors located in the motor end plate and causes the opening of the ionic channels. The opening of the ionic channels causes the movement of sodium and potassium ions, due to the differential electrochemical gradient there is a higher influx of sodium than the efflux of potassium causing a local depolarization of the motor end plate which is called as end plate potential.

The motor end plate has an enzyme known as acetylcholinestrase which causes the breakdown of ACh. The ACh bound in the receptors is in equilibrium with the free Ach present in cleft between the axon terminal and the skeletal muscle fibre. Acetylcholinestrase causes the fall in concentration of free ACh by breakdown, thus less amount of ACh is there to bind with receptors. The moment the receptors do not contain bound ACh the ion channels in the end plate close. Thus causing the depolarised end plate to return to its resting potential so that it can respond the arrival of Ach which would be released by the next nerve action potential. The axon terminals are located at the centre of the muscle fibre and thus with the generation of muscle action potential the wave of excitation travels bidirectionally towards the end of the fibre.

Sliding Filament Mechanism

Actin is globular in structure and hence when these single polypeptide chain polymerizes with other actin molecules forms a helical structure with a myosin binding site. Hence along with tropomyosin and troponin regulatory proteins these molecules together form a thin filament (see fig. 4).

Myosin molecules on the other hand comprises of two golf club like structures that are facing in the opposite direction hence these club heads are called myosin cross bridges (see Fig. 5). During shortening of the length these myosin cross bridges hook on to the myosin binding sites in the actin molecules and pull the thin filaments towards the M line of each sarcomere.

These filaments upon overlapping form arcs around the fixed poistion of the sarcomer. The length of I bands and the H zones keeps decreasing and

finally reaches the minimum during the sliding of the filaments . During contraction the length of the sarcomere depends on the movement of these molecules hence the length of the sarcomere decreases with the increase in contraction. This process of filament sliding is repeated many times to complete contraction of the muscle. The following figure (see Fig. 6) shows the overlapping of the thick and thin filaments in a sarcomere.

According to the sliding filament theory the muscle contraction process is due to the release of calcium ions. These ions are released by the lateral sacs in the sarcoplasmic reticulum when an action potential triggers the transverse T- tubules. Troponin and tropomyosin molecules prevent the overlapping of the actin and the myosin molecules before the release of the calcium ion. Upon release the calcium ions bind on to troponin complex to causing a shift and exposing the active site so that myosin cross bridges can be formed. Now the myosin is activated by the release of the calcium ions and breaks down in to ATP (adenosine triphosphate) , ADP (adenosine diphosphate), inorganic element (Pi) releases energy. This energy is used by myosin heads to pull the actin myofilaments along so that these filaments slide over each other thus cross bridges break at on site and attach at the other causing the muscle to contract. The contraction cycle ends when there is no action potential propagating through the T-tubules. As a result of which the calcium release channels are closed and the remaining calcium ions are pumped out of the sarcoplasemic reticulum. The troponin-tropomyosin complex returns to it original position and blocks the myosin binding site on actin. Thus the cross bridge movement ceases and the muscle relaxes. The

above process is explained in figure 7 which gives the sequence of operations that are involved in muscle contraction.

Skeletal Muscle Disease- Muscular Dystrophy

Skeletal muscle diseases are of many types which affect the normal movement and posture of the human body. This may be because of the loss of contractile properties of the muscle (myopathy) or the nervous system that is involved in contraction of the muscle (neuropathy). This disease taken into consideration here is muscular dystrophy.

Muscular dystrophy is the name given to a group of genetic muscle related disorder, characterized typically by muscle fibre degeneration. Generally about 1 in 3500 boys are affected and in the UK nearly around 100 boys are born of these disease[A, C] The most common among the group of disorders is the ‘ Duchenne muscular dystrophy’ and the ‘ myotonic muscular dystrophy’ . Usually it is more common in males since the disorder is carried on the recessive sex chromosome (X chromosome). The sex chromosomes in males is made up of X and Y chromosomes, hence a disorder in anyone of the two would cause the genetic disorder to appear. However in females the sex chromosomes comprise of a pair of X chromosomes, thus a genetic disorder would not appear unless both the X chromosomes carry a disorder. The most common symptoms seen in muscular dystrophy are Scoliosis (the bending of the spine in a S pattern), inability to walk hence the balancing of the body is not proper, calf pain and improper gait. The following figure (Fig. 8) shows the symptoms of muscular dystrophy. These symptoms are diagnosed by measuring the high level of a certain enzyme called creatine kinase in the blood. Some other techniques include DNA testing and muscle

biopsy. According to the recent findings it was found that certain biochemicals like dystrophin, merosin and adhalin were found deficient when diagnosed for muscular dystrophy[B]. Duchenne muscular dystrophy is the most serious and the most common type of dystrophies. In this dystrophy the Xp21 position part of the X chromosome arm carries the disorder and the gene that is encoded is dystrophin,. This protein is either absent or non functional in this disease. Normally patients suffering from this disease have a life expectancy of 25 years which can improve depending on the quality of treatment received so as to reduce the development of respiratory problems which may lead eventually to death. Most of the patients die at an early age because of the cardiacmyopathy. According to certain statistical studies done on the survival rate of duschenne muscular dystrphy it was found that the survival rate has increased from 14. 4 years in the 1960’s to 25. 3 years in the 1990’s but the occurrence of cardiacmyopathy has decreased the years to 16. 9. Its also found that a drastic increase in percentage of survival rate from 0% in 1960’s to 53% in 1990’s upon good quality treatment.