Introduction to Exercise Physiology & Sports Performance

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Lecture - 05
Skeletal muscle & Exercise

Good morning ladies and gentlemen and welcome back to this course on exercise physiology and sports performance. This is lecture 5 of week 1 and today we will be discussing skeletal muscle and exercise and I am Colonel Dr. Anup Krishnan and I will be your instructor for this lecture. I will be covering this lecture under the following heads, Introduction, Muscle Contraction, Types of Muscle Fibres, Types of Muscle Contraction, Force Generation by the Muscles and Conclusion. Let us talk about what is a muscle contraction.

Our muscle contraction is a sequence of events that starts with a motor nerve impulse and results in a muscle contraction. This is also called an excitation-contraction coupling. The muscle contraction is initiated by a motor neuron impulse or action potential. At the level of the neuromuscular junction, The motor neuron releases ACH, which opens up the ion gates in the muscle cell membrane, allowing sodium to enter the muscle cell, a process called as depolarization.

If the cell is sufficiently depolarized, an action potential is generated and muscle contraction will occur. The action potential travels along the sarcolemma, enters the T-tubules and reaches up to the sarcoplasmic reticulum. Because when the action potential hits the sarcoplasmic reticulum, stored calcium ions are released from the sarcoplasmic reticulum, somewhere here. Calcium ions binds with the troponin which moves the tropomyosin molecules off the myosin binding sites on the actin molecules. Basically, there are some myosin binding sites on the actin filament which is covered by the tropomyosin.

When calcium molecules bind with troponin, troponin goes and hits the tropomyosin and moves them off the myosin binding sites. When the myosin binding sites are open, the myosin head will tilt and it will bond with the myosin binding site and pull the thin filament past the thick filament. We have already seen this in the previous lecture. A process called as sliding filament theory. The tilting of the myosin head is the power stroke.

And because the power is generated, energy is required for the muscle contraction to occur. This happens here. The end of the muscle contraction is signaled when the neural activity ceases at the neuromuscular junction. When there is no more impulse coming from the nerves, the end of the muscle contraction is signaled. Calcium is actively pumped out of the sarcoplasm and into the sarcoplasmic reticulum for storage.

Tropomyosin moves to cover the actin sites on the actin molecules and the myosin heads will relax and the binding sites will also relax. Because of this relaxation, muscle relaxation occurs. And because of tropomyosin activity, muscle relaxation also requires energy which is supplied by ATP. This is a diagram of the entire process. process and which I will leave for a couple of seconds in case you want to freeze it and save it.

There are different types of muscle fibers. A single skeletal muscle may have fibers having different speeds of shortening and different abilities to generate maximal force. They are generally called type 1 or slow twitch fibers and type 2 or fast twitch fibers. Type 1 fibers take approximately 110 milliseconds to reach peak tension when stimulated. Type 2 fibers, on the other hand, can reach peak tension in about 50 milliseconds.

In humans, there are two major forms of type 2 fibers called type 2a and type 2x. Type 2a fibers are believed to be the most frequently recruited. Most muscles are composed of roughly 50% type 1 fibers and 25% type 2A fibers. The remaining 25% are mostly type 2X with a rare type 2C making up only 1-3% of the muscle. If you look at the fiber classification, the classification type preferred is type 1, type 2, and type A, type 2A and type 2X.

They are also called slow twitch, fast twitch A, and fast twitch X. They may also be called slow oxidative, fast oxidative glycolytic, and fast glycolytic. The oxidative capacity of the type 1 fibers is high. the glycolytic capacity is low, the contractile speed is slow, the fatigue resistance is high, and the motor unit strength is low. In type IIa, Oxidative capacity is moderately high, glycolytic capacity is high, contractile speed is fast, the fatigue resistance is moderate, and the motor unit strength is high.

The Type IIx fibers, on the other hand, oxidative capacity is low, Glycolytic capacity is the highest. Contractile speed is fast. Fatigue resistance is low. And the motor unit strength is. Type 1 fibers have less than 300 fibers per motor neuron. The motor neuron size is smaller. The conduction velocity is slower. Contraction speed is 110 milliseconds. Type of myosin ATPase activity is slow. Sarcoplasmic reticulum development is slow.

Type 2a. Fibers per motor neuron is more than 300. Motor neuron size is larger. Conduction velocity is faster. Contraction speed is 50. Type of myosin ATPase is fast.

Sarcoplasmic reticulum development is high. The type 2 X fibers on the other hand, fibers per motor neuron are less than or equal to 300. Motor neuron size is larger. Motor neuron conduction velocity is faster. Contraction speed is around 50 milliseconds.

Type of myosin ATPase is fast. Sarcoplasmic reticulum development is high. Most skeletal muscles contain both type 1 and type 2 muscle fibers. Different fiber types have different myosin ATPase activity. We have already discussed the ATPase and type 2 fibers act faster than the ATPase in type 1 fibers.

Type 2 fibers have a more developed sarcoplasmic reticulum, enhancing the delivery of calcium needed for muscle contraction. Alpha motor neurons innervating type II motor neurons are larger and innervate more fibers than the alpha motor neurons for type I units. Thus, type II units have more and larger fibers to contract and can produce more force than type I motor units. The proportion of type 1 and type 2 fibers in a person's arm and leg muscles are usually similar. Type 1 fibers have higher aerobic endurance and are well suited to low-intensity endurance activities.

Type 2 fibers are better suited for anaerobic activities. Type IIa fibers play a major role in high-intensity exercise. Type IIx fibers are activated when the force demanded of the muscles is Type I and Type II fibers of the same diameter generate about the same force. Type II fibers tend to be larger than Type I fibers, and Type II motor units tend to have more muscle fibers than do the Type I motor fibers. Generally, motor units give an all-or-none response.

Activating more motor units produces more force. In low-intensity activity, most muscle force is generated by Type I fibers. As the intensity increases, Type IIa fibers are recruited, and at even higher intensity, Type IIx fibers are activated. The same pattern of recruitment is followed during events of long duration. World champion marathoners possess 93-99% type 1 fibers in their gastrocnemius muscles.

However, world class sprinters have only 25% type 1 fibers in their gastrocnemius muscles. Muscle movements generally can be categorized into three types of muscle contractions, concentric isometric or static, and eccentric. In many activities such as running or jumping, all three muscle fibers, in many activities such as running or jumping, all three types of contraction may occur in the execution of a smooth, coordinated action. Let's talk about concentric contraction. A muscle's principal action, shortening, is referred to as concentric contraction.

And this is the most familiar type of contraction. In a concentric contraction, the thin filaments are pulled towards the center of the sarcomere. Because joint movement is produced, concentric contractions are called dynamic contractions also. Isometric contractions. Muscles may also act without moving.

When this happens, the muscle generates force, but the length remains static. This is called a static or isometric muscle contraction because the joint angle does not change. It happens if you are trying to lift a heavy weight which is beyond the force which can be generated by the muscle. This weight will cause the muscle to contract and produce force but there will be no movement.

Eccentric contraction. Muscles can exert force even while lengthening. This movement is called eccentric contraction. Because joint movement occurs, this is also called a dynamic. If I try to lift or hold a heavy weight, but the weight is much more than what my biceps can lift, slowly the muscles will start to contract. relax but at the same time the force is also being produced.

This type of contraction is called an eccentric muscle contraction. You are extending the muscle to lower a heavy weight but the muscle is lengthening and there is force also being produced. In this case, the thin filaments are pulled farther away from the center of the sarcomere, essentially stretching it and producing a muscle force. Force generation. Whenever muscle contracts, the force developed must be graded to meet the needs of the task or the activity.

For example, If you need to tap a 1 meter putt in golf, the force needed is less. However, if you need to drive that same ball 250 meters from the tee, the force generated is much more. The amount of muscle force developed is dependent on the number and types of muscle units activated, the frequency of stimulation of the motor unit, The size of the muscle, the muscle fiber and the sarcomere length and the speed of the muscle contraction. Let's take each in detail.

Motor units and muscle size. More force can be generated when more motor units are activated. Type 2 motor units generate more force than type 1 motor units because of the large number of muscle fibers. Larger muscles having more muscle fibers can produce more force than smaller muscles. Frequency of stimulation. A single motor unit can exert varying levels of force depending upon the frequency at which it is stimulated.

A process called rate coding. There is an optimal length of each muscle fiber related to its ability to generate force. When the sarcomere is fully stretched or fully shortened, little or no force can be generated because there is little cross bridge interaction. Speed of contraction. The ability to develop force also depends on the speed of muscle contraction.

During concentric contractions, maximal force is developed, but it decreases progressively as the speeds increase. A fast eccentric contraction will allow maximal application of force on the other end of the spectrum. Let's talk about the take-home messages, what we have learned in this lecture. Muscle fiber type and composition differs by sport and event. Speed and strength athletes have higher percentages of type 2 fibers and endurance athletes have higher percentages of type 1 fibers.

The three main types of muscle contractions are concentric, static, and eccentric. Force production can be increased by the recruitment of more motor units and by increase in the frequency of stimulation of the motor units. Force production is maximized at the muscle's optimal length. That means a muscle has to be at an optimal length to produce maximal force. Speed of contraction also affects the amount of force produced.

For concentric contraction, maximal force is achieved with slower contractions. For eccentric contractions, faster movement allows more force production. These are the references which I have used to prepare this lecture. Strongly urge you to go through them in the interest of better understanding and more learning of the subject.

I thank you for your time, ladies and gentlemen. We will be very happy to take questions and answer any queries or comments which you may have. You may write to us on the mentioned email. Thank you for your time, ladies and gentlemen. and Jai Hind.