

Exercise & Sports Biomechanics
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Lecture 07

Muscular System

[Hello, everyone! Welcome back to this course. In this video, we will dive into the muscular system]

Muscular system:

The muscular system is primarily responsible for movement in the body. In addition, it helps us maintain posture and perform important functions like breathing and pumping blood to all parts of the body. If you calculate it all together, these muscles make up approximately 42% of the total body weight.

The muscles in our body are divided into three main types of tissue:

- Skeletal muscle
- Smooth muscle
- Cardiac muscle.

Skeletal muscle:

The skeletal muscles are voluntary muscles, which means you can control them consciously. If you look at the microscopic level, you will see the striped appearance in the muscle cells. That is why the skeletal muscle is also known as striated muscles. These skeletal muscles are attached to the bones by tendons and are purely responsible for body movements.

Smooth muscle:

Smooth muscles are involuntary in nature, which means they work automatically without our conscious control. Unlike skeletal muscle, smooth muscles are not striated. They do not have a striped appearance under a microscope. These smooth muscles are found in the walls of internal organs such as the stomach, intestines, and blood vessels. That is why smooth muscles are also known as visceral muscles.

Cardiac muscle:

This muscle is found only in the heart, and it is responsible for keeping your heart beating and pumping blood throughout your body. Like smooth muscles, cardiac muscles are also involuntary in nature. However, cardiac muscle is striated, meaning it has a striped appearance similar to skeletal muscle.

What are the properties of muscles?

Skeletal muscle tissue has four main properties which help us move, exercise, or play efficiently:

Excitability:

It is the muscle's ability to receive and respond to electrical stimuli from the nervous system. When you decide to lift a glass of water, your brain sends an electrical signal to the arm. These muscles then receive the signal and contract, allowing you to lift the glass. I will give another example: when a soccer player needs to kick the ball, the brain sends electrical signals to the leg muscles, and these signals travel quickly through the nervous system. By stimulating the muscle to contract, it produces a powerful kick.

Simply put, it is the muscle's ability to receive and respond to electrical stimuli. This is known as excitability.

Contractility:

It is the ability of the muscle to contract and generate force when stimulated. This ability to contract is a unique property not found in any other body tissues. For example, you can see the animation. To perform an elbow flexion, the biceps muscle must contract and generate force. This is known as contractility.

Extensibility:

Extensibility is the ability of the muscle to stretch or extend beyond its normal resting length without damage. This allows the muscle to lengthen when an opposing force is applied to achieve full range of motion. For example, the triceps muscle demonstrates extensibility when it stretches beyond its normal length as the biceps to achieve full range of motion.

Elasticity:

This is the muscle's ability to return to its original length after being stretched. In the animation, you can notice that. When the model is jumping, the gastrocnemius stretches and then returns back to its original length. We will take the previous example again. We have discussed the elbow flexion. Again, here the triceps muscle shows elasticity by returning to its normal resting length when the elbow extension movement occurs.

Types of muscle contraction

There are two types of muscular contractions. One is isotonic contraction, and another one is isometric contraction.

Isotonic contraction:

So, what is meant by isotonic contraction?

Iso means same, and tonic means tension. It is going to be the same tension throughout the movement. There will be a change in length, which facilitates movement at all the joints. This type of contraction is responsible for most movements in exercise and sports.

Isotonic contraction is further divided into two types: concentric contraction and eccentric contraction.

Concentric contraction

when a muscle shortens while generating enough force to overcome the resistance. These contractions are like moving against gravity or resistance, and they are often called positive contractions. When you look into this model, The biceps curl is moving in an upward direction, which is the positive contraction. For example, in this model, the person is performing a dumbbell biceps curl.

The force that your muscle creates is always greater than the weight you are lifting. This means the biceps muscle force is always greater than the resistance you are lifting. This is the reason the muscle shortens, which facilitates the joint to move. This is known as a concentric contraction.

The roles of the muscles in this movement are:

First, we have the **Agonist muscle**, also known as the prime mover. This is the main muscle responsible for creating movement and contracting concentrically. This means they shorten to generate force. These muscles are considered the main workers to generate the majority of force for a motion. For example, during a biceps curl, the biceps brachii is the agonist. It is the primary muscle that contracts to flex the elbow and lift the weight. Without the agonist, there is no movement.

Next is **Antagonist muscle**. These muscles work opposite to the agonist, which is the triceps. Their job is to relax or lengthen so that the agonist can perform the entire action efficiently. These are all called opposers. For example, in the biceps curl, the triceps brachii is the antagonist. While the biceps contracts to flex the elbow, the triceps relaxes to allow the movement. Now, if you reverse the action and extend your elbow, the triceps become the agonist and the biceps become the antagonist. They switch roles depending on the movement.

Eccentric contraction:

Eccentric contraction happens when a muscle lengthens and still produces tension in the muscle. It is known as eccentric contraction. This occurs when the muscle gradually reduces its force to control the movement, like when you slowly lower the weight. In this case, the resistance or weight is stronger when compared to the muscle force. But the muscle still controls the movement. The eccentric contraction works with gravity or the resistance and is often called negative contraction. It is moving away from the body. For example, when you bring a dumbbell down in the biceps curl, the muscle lengthens to control the motion. This is known as eccentric contraction. In simple terms, if the muscle shortens, it is known as concentric contraction. If the muscle lengthens, it is known as eccentric contraction. It occurs in both the biceps and triceps.

Isometric contraction:

An isometric contraction occurs when tension is developed within the muscle, but the joint angles remain constant. There will not be any movement in the joint. For example, holding a plank position, in this case, your core muscles are contracting without any visible movement to maintain the plank posture.

Another example is pushing against a wall, where the muscle generates force but there is no movement. These are the types of muscle contraction.

There is a **misconception** that isokinetic is part of muscle contraction. **Isokinetic** is a unique exercise method and not a separate type of muscle contraction. It involves dynamic movements, often using both concentric and eccentric contractions. But the key feature is that the speed of the movement remains constant throughout the exercise. This means the muscle works consistently and contracts maximally during the entire range of motion. There are machines like Biodex and Humac that are specifically designed to perform these isokinetic exercises.

[The next one is stabilizers, also called fixators].

Stabilizers:

These stabilizers do not directly cause movement, but they are crucial because they provide support and keep the joint steady. This stability allows other muscles to perform their movements effectively. For example, during a biceps curl, the muscles around the scapula, like the rhomboids, act as stabilizers. They hold the shoulder in place so that the biceps can focus on only lifting the weight. Think of stabilizers as the anchor that provides a stable base, which facilitates the movement efficiently.

[Next, we move on to synergists]

Synergists:

Synergists, also known as helpers, that assist the agonist in creating movements. Synergists can add extra force or refine the motion by preventing undesired movements.

There are two types of synergists:

One is helping synergist and true synergist. The helping synergist assists the agonist muscle and also prevents unwanted motion. The true synergist does not directly help in the motion but prevents the unwanted joint actions. For example, In the biceps curl, the brachioradialis acts as a synergist.

[Finally, we have neutralizers]

Neutralizers:

These muscles cancel out unwanted actions of the agonist muscle, ensuring that the desired movement happens very smoothly. For instance, if you look into the animation very

carefully, During the biceps curl, the biceps brachii tends to flex the elbow and also supinate the forearm. If you want only the elbow flexion without supination, as in this animation, the pronator teres acts as the neutralizer.

It contracts to prevent the supination action of the biceps, allowing only the elbow flexion to occur. These neutralizers act like characters that keep the movement focused.

[So far, we have covered a few important concepts like properties of muscles, types of muscles, and their roles. Do you think this is really important?]

Why do coaches sports scientists or professionals in physical education need to study this. Understanding these properties of muscles helps us to grasp the concepts like reaction time, response time, and movement time. For example, the reaction time is the interval from the stimulus to the initiation of the movement, which is closely linked to the property of excitability in muscles, right?

Reaction time:

Reaction time is the time taken from the moment of stimulus to the initiation of the movement.

The movement time:

The movement time, on the other hand, refers to the time taken to complete the movement after it has been initiated.

The response time:

The response time is the total time taken to respond to the stimulus, which includes both the reaction time and movement time.

These concepts are crucial in sports, as they help in understanding how quickly and efficiently an athlete can react and execute a movement during competition. When it comes to the type of muscle action, as a sports biomechanist, it is essential to know whether the exercise involves isometric, concentric, or eccentric contraction. For instance, based on research, eccentric training is effective for increasing muscle mass and strength compared to concentric training.

By studying the roles of muscles, we learn that even if you want to focus on the biceps brachii, it is not just about the single muscle. You need to focus on surrounding muscles like the rhomboid, which is a stabilizer, and the brachioradialis, which is a synergist, also plays a crucial role. These smaller supporting muscles have a significant impact on the performance of the main muscle, which is the biceps brachii.

As a coach and sports scientist, we must understand that even the smallest muscle can influence overall performance in a significant way. This is why it is crucial for the sports biomechanist to understand these basics and apply them effectively in real-world situations and to design a better training program and improve athletic performance,

[we next move on to two-joint muscles]

Two-joint muscles:

two-joint muscles, also known as bi-articular muscles. These muscles are found in both the upper and lower parts of the body. They cross two joints and can generate movements at both joints. For example, the rectus femoris, which is part of the quadriceps, crosses both the hip and knee joints. It performs two functions: hip flexion and knee extension.

In comparison, single-joint muscles only cross one joint and can create movement at that single joint. But, two-joint muscles have the advantage of producing movement at two joints, making them more efficient for many human movements. However, two-joint muscles can sometimes become inefficient when trying to perform full movement at both joints simultaneously. This is due to two concepts known as active insufficiency and passive insufficiency.

Active insufficiency occurs when a muscle cannot shorten enough to produce full movement at both joints it crosses. For example, you can fully flex the knee on one leg while simultaneously trying to swing that leg back to achieve full hip extension. At this moment, the hip extension will be restricted because the hamstrings are unable to shorten enough to produce the full range of motion. A kind of cramping in the hamstring muscle can occur during this movement.

Passive insufficiency happens when a muscle cannot stretch far enough to allow full movement at the joint it crosses. For example, lie on your back and try to bring one leg forward toward your shoulder while keeping the knee straight. You will feel the hamstring fully stretched. At some point, you will not be able to bring it closer because the hamstring cannot stretch enough to allow full hip flexion and full knee extension at the same time. However, if you bend your knee, you will notice that your leg can move closer toward your shoulder.

This shows how muscle length affects the range of motion in two-joint muscles. By understanding these two-joint muscles and knowing about active and passive insufficiency is key to improving performance and protecting the body during any sporting activity.

[We move on to the next one, which is the stretch-shortening cycle].

Stretch-shortening cycle

In the name itself, it is very clear: in the stretch-shortening cycle, the muscle first stretches and then immediately shortens to produce movement, like in a sprint. You stretch it, and then when you release it, it recoils and produces energy. The research found that athletes jump higher, up to 4 cm, when they perform a countermovement jump compared to a squat jump. This is simply because the countermovement jump incorporates a pre-stretch, which is lowering down, but the squat jump initiates the movement from a static position without a pre-stretch. This pre-stretch or countermovement is the stretch-shortening cycle.

The stretch-shortening cycle has three phases.

The first one is the **eccentric phase or stretch phase**. This is when the muscle lengthens as it absorbs force. Think of it as stretching a spring. We will take the counter-movement

jump as an example. When you squat down before jumping, your quadriceps and calf muscles lengthen to store energy.

The second one is the **amortization phase or transition phase**. This is the short period between the stretch and the shortening phases. A shorter amortization phase, means less energy is lost and more power can be produced. The last one is the concentric phase or shortening phase.

This is when the muscle shortens and releases the stored energy to produce force and movement. It is like the spring recoiling effect. For example, when you push off the ground, the quadriceps and calf muscles shorten to propel you upward. This concept is the basis of plyometric training, which improves power and enhances the performance of the athlete.

[The next most important concept is Line of pull and angle of pull]

What is a line of pull?

The line of pull is an imaginary straight line that runs along the long axis of the muscle. If this is the origin of a muscle and at the end it is an insertion, it is an imaginary line which runs straight along the long axis of the muscle.

It represents the direction in which the muscle exerts force when it contracts. For example, in the biceps brachii, the line of pull runs along the length of the muscle. What is the angle of pull? The angle of pull is the angle formed between the long axis of the bone, which acts as a lever, and the line of pull of the muscle. This is the angle between the line of pull and the long axis of the bone.

As a joint moves through its range of motion, this angle changes, and it significantly affects how the muscle produces force.

[The next one is the moment arm.]

Moment arm:

The moment arm is the distance between the joint axis and the line of pull of the muscle. So, we know this is the line of pull of the muscle, and the distance between the joint axis and the line of pull is the moment arm.

The maximum amount of torque is produced when the angle of pull of the muscle is 90 degrees. So, this is at 90 degrees. So, in this position, the maximum amount of torque is produced in the muscle. And in addition, the moment arm is at the greatest distance. In this position, all the muscle force is directed to produce only rotational movement.

As the angle of pull increases or decreases from 90 degrees, the muscle's ability to produce torque decreases. Why? Because part of the muscle force is no longer directed towards the rotation. It is instead directed parallel to the bone, either pulling the joint together, which is the stabilizing component, or pulling it apart, which is the destabilizing component.

When the angle of pull is less than 90 degrees, the part of the muscle force acts to stabilize the joint by pulling the bones closer together. This is called the stabilizing component.

When the angle of pull is greater than 90 degrees, the part of the muscle force acts to destabilize the joint by pulling the bones apart. This is called Destabilizing component. For example, if you are using a biceps curl, exactly 90 degrees is the rotatory component, and the angle of pull of the biceps is less than 90 degrees, which helps to stabilize the elbow joint. As we move past 90 degrees, Some of the biceps force may destabilize the joint slightly, which reduces the efficiency in creating the rotational motion. When it comes to practical implications, if athletes are using free weights, the maximal resistance occurs when the pull of the weight is perpendicular to the ground, regardless of the position.

In this position, the line of pull of the weight is 90 degrees. For example, when an athlete is in a supine position and performs elbow flexion with the weight, the greatest resistance is at the start of the motion when the athlete's elbow moves from full extension to flexion. If the athlete is standing or sitting, however, the maximal resistance from the weight is when the elbow is at exactly 90 degrees. That is why, in rehabilitation, the choice of exercise is very crucial, and we should avoid activities that destabilize the joint. This knowledge is essential for creating effective exercises that help to enhance performance and minimize injury.

[So, thank you, and see you in the next video.]