Exercise & Sports Biomechanics
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Week 07
Lecture 31
Introduction to Lever System

[Hello friends! Let us discuss the concept of lever system in sports biomechanics].

The concept of Lever system in sports biomechanics:

The skeletal and the muscular system works together to move your body parts. Some of this body parts can be thought of a simple machines or lever.

A lever is a simple machine consists of a plank or a beam that can rotate freely about a fixed point. It is used for moving, lifting, or propelling objects. In sports biomechanics, the concept of lever is fundamental to understanding how athletes generate forces, optimize movement efficiency and enhance the performance.

A lever is a rigid structure such as a bone in the body that rotates about a fixed point called fulcrum, and that is nothing but the joint in our body and when a force, a muscular force is applied, the human moves through a system of lever. The lever cannot be changed but they can be utilized more efficiently.

By definition, a lever is a mechanical device which produces turning action about an axis. The key components of lever includes a rigid bar which rotates about an axis called fulcrum or the axis or you can call it as a pivot point. This is a fixed point around which the lever rotates. Example, joints in the human body. The load or the resistance it is the object or the body parts being moved. And on the other hand, there is effort or the force, applied force, the force exerted by the muscle to move a load.

So, these are the three integral part of the lever system. Along with that, if I talk about the distance from the load to the axis is called the load arm or the resistance arm and the distance from axis to the effort is called force arm or the effort arm.

There are total five main part of the lever:

The first is the axis or the fulcrum, the effort or the force, the load or the resistance and the fourth one is the load arm and the fifth one is the effort arm. So, the fulcrum is the pivot point, the fixed point around which the lever rotates. The role is basically act as the axis of movement, determining how force is applied and transferred.

The effort is the force applied to move the load. It determines how much force is needed for movement. The load is the object of resistance that needs to be moved or lifted. It affects the effort required for the movement. So, we have already discussed that there are five main parts of a lever. The importance of levers in human movement and sports mechanics is the foundation of human movement. Levers, like bones, and fulcrums, like joints, facilitate movements, allowing efficient force application in daily activities and sports.

Force amplification: levers help in magnifying force, enabling athletes to lift heavier weights or generate powerful movements with less effort. Speed and range of motion, different lever classes influence the speed and extent of movement, crucial for sprinting, jumping, and striking motions in sports. Energy efficiency: proper lever mechanics reduce energy expenditure, allowing athletes to perform longer without fatigue.

Biomechanical advantages: understanding levers helps in optimizing technique, reducing the risk, injury risk, and enhancing performance in various sports. Application in strength training: exercises leverage biomechanical principles to maximize muscle engagement and strength development. Role in injury prevention: proper alignment and lever use reduce stress on joints, preventing overuse injuries in athletes. Sports-specific movements, Different sports rely on specific lever advantages, such as longer limbs aiding powerful throws or kicks.

Equipment design and Performance: sports equipment like bats, racquets, or prosthetics are designed based on lever principles to enhance performance.

Functioning of a lever:

A lever works by reducing the force applied to move a heavy object. A beam is placed on a fulcrum, and the object is positioned on the beam. The force is applied somewhere on the beam. The beam pivots around the fulcrum and lifts the object. The relative positions of the fulcrum and the load are adjusted to minimize the applied force. The beam rotates above the pivot point. A torque is necessary to rotate the beam and lift the object. The basic principle is that the applied torque manifests at the load. The functioning of lever depends on the relative position of force, axis and the resistance. And it is governed by a formula

$F \times FA = R \times RA$.

Where F is the force applied or the effort, FA is the force arm or the effort arm, R is the resistance or the load and the RA is the resistance arm or the load arm. So, this is the formula on which any lever works. So, if this is the case where the two objects, so this is the case where on one side there is a resistance, another side there is a force and which is being, the plank is being pivoting on a particular fulcrum. So, this lever can function on the formula

$F \times FA = R \times RA$.

There are three kinds of lever: first order lever, second order lever and the third order lever.

The first order lever is also called first class lever or the type 1 lever. The second order lever can be called as the second order lever or the type 2 order lever. And the third order lever is also known as the third class lever or the type 3 levers. Based on the relative position of the fulcrum, load and the effort, there are three different types of lever. They are known as the first, second, and third class levers respectively.

Coming to the first-order lever, also known as class one or first-class lever. The load is at one end of the beam, and the effort is at the other end of the beam. The fulcrum is between the load and the effort. Depending on the position of the fulcrum, the effort can be high or low.

If the fulcrum is closer to the load than the effort, the effort is low. And the effort is high if the fulcrum is closer to the effort than the load. So, in short, just to remember, in a first-class lever, the fulcrum comes between the load and the effort. For example, a seesaw is a good example. In the human body, if we extend the neck or the nodding movement, you can see that the axis of rotation is nothing but the atlanto-occipital joint, which is here.

The force is applied by the posterior muscles of the neck, and the resistance we feel is basically the weight of the skull on the front side. So that is why, in this case, the fulcrum comes in between. So, this is a first-class lever. A few more examples in sports, like heading a football: the neck acts as a fulcrum with muscles applying effort on one side and the weight of the head or the ball on the other side. The seesaw motion in gymnastics, where the athlete uses their arms and legs as effort forces around the hip to control their landing. The elbow extension in triceps exercises. The elbow is the fulcrum with the triceps providing effort and the resistance is provided by the machine.

The **second order lever** also known as class 2 and **second class lever**. The fulcrum is at one end of the beam and the effort is at another end. The load is located between the fulcrum and the effort. The position of the load affects the effort. If the load is closer to the fulcrum, then the effort is low. If the effort is high, if the load is closer to the effort, then the fulcrum. So in short, just to remember, in second order lever, the load comes in between the effort and the fulcrum.

You can see the examples. See here the load is coming into the between then the fulcrum and the effort. The same is happening here in this example as well. The anatomical example includes the calf raise. The toe acts as a fulcrum. The body weight is the load, and that is in the middle, and the calf muscle provides the effort to heel the raise. In rowing, the oar lock is the fulcrum, the water resistance is the load, and the rower's hand applies force at the end of the oar. In the push-off in speed skating, the skate acts as a fulcrum, the body weight is the load, and the leg muscle provides the effort to push forward.

The **third-order lever** also known as the class 3 or the **third-class lever**. The fulcrum is at one end of the beam, and the load is at the other end of the beam. The effort is located between the fulcrum and the load. The effort depends upon its position. The effort is high if it is close to the load rather than the fulcrum, and the effort is high if it is close to the fulcrum rather than the load. In short, just to remember, in a 3rd-class lever, the effort comes between the load and the fulcrum.

You can see the examples here. You can see the effort is coming in between the fulcrum and the load. The same thing is happening here with the tong as well. The effort is coming in between the fulcrum and the load. Some sporting examples include throws like a javelin throw. So the shoulder is the fulcrum, the arm muscle applies the effort, and the javelin is the load. Allows for a high-velocity release. Assuming a tennis racquet, the wrist is the fulcrum, the forearm muscle applies the effort, and the racquet is the load.

When kicking a football, the hip joint is the fulcrum, the quadriceps provide the effort, and the ball is the load. Talking about the lever, we should also discuss mechanical advantage. The mechanical advantage measures how much a lever can multiply the force applied to lift or move the load. The relative positions of the fulcrum, load, and effort determine the mechanical advantage value. It is mathematically given by the ratio of the load and the effort, as proven by the Greek mathematician and physician Archimedes. The mechanical advantage is given by the force arm divided by the resistance arm.

mechanical advantage = $\frac{\text{force arm}}{\text{resistance arm}}$, or I can say, MA = $\frac{FA}{RA}$

Suppose the distance from the effort to the fulcrum is greater than that of the load; in that case, the mechanical advantage is greater than 1.

Force arm > Resistance arm = MA is >1

Force arm < Resistance arm = MA is <1

In other words, the further the effort is from the fulcrum, the easier it is to displace the load since less effort is required. Therefore, placing the fulcrum close to the load is advantageous to minimize the effort. Levers are designed such that their mechanical advantage is greater than one, which makes them ideal as a simple machine. So, in some scenarios, if the force arm is bigger than the resistance arm, the lever favors force.

The lever provides some mechanical advantage meaning it favours force over the speed and the range of motion. This setup allows an athlete to move heavier load with less effort. Here are some sporting examples. Like the calf raise, a second class lever example, jumping and sprinting, the ball of the foot acts as a fulcrum and the body weight is the resistance and the fulcrum and the effort, the ball of the foot acts as a fulcrum. The body weight is between the fulcrum and the effort, that is the calf muscle. Since the force arm, that is the Achilles tendon attachment, is longer than the resistance arm, this setup allows powerful jumping and sprinting motions with less muscular effort. The wheelbarrow lift, the robust the wheel borrow lift, in that case also the force arm is bigger than the resistance arm so they offer the more force than the speed. The push-offs in speed skating or cycling, the skates or the paddle or fulcrum, the athlete's body or weight is in middle and the leg muscle applies the effort further away.

This provides the force advantage for efficient propulsion. In shot put also, this is a modified first class lever with a favorable FA by RA ratio. So, the shoulder acts as the fulcrum, the shot that is the load is positioned closer and the effort that is by the deltoid and the arm muscle and the body muscle is applied further away. So, this allows maximum force generation with maintaining the control.

The second scenario is if the resistance arm is bigger than the force arm, this lever favors speed and the range of motion rather than the force. The setup allows for rapid and powerful movement which are crucial in many sports like throwing a baseball which is a 3rd class lever right. So, the fulcrum is the shoulder joint, the effort is basically from the biceps, triceps and the shoulder muscle, the load is provided by the baseball in the hand. So, the long resistance arm enables high speed throws despite requiring more muscle force.

Kicking a soccer ball, again a third class lever, so you can see that the fulcrum is the hip joint and the effort is from the quadriceps and the hamstring muscles and the load is the ball at the foot. So, the longer resistance arm, distance from hip to foot definitely that increases the ball's velocity. Same is happening with the tennis forehand shot or the golf swing. The resistance arm is getting increasing so that they get the higher velocity than the force.

To summarize the lever in sports, just look at this particular table which is having the first class, second class and the third class lever. The example of first class are the soccer header, the triceps dips and the advantage is they are balanced in force and speed because the fulcrum is coming into the middle. In the second class lever, the examples are the calf raise, rowing, speed skating and they are having greater force advantages over the speed because in this case the force arm is bigger than the resistance arm. And the third class lever is where the examples are the baseball pitch, golf swing, soccer kick and here they are having the advantages of greater speed over the force because resistance arm is bigger than the force arm.

[Thank you and see you in the next video].