Exercise & Sports Biomechanics
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Week 06
Lecture 26
Introduction to Kinetics in Exercise and Sports Science

[Hello friends! Welcome to this course on Exercise and Sports Biomechanics. I am Dr Rahul Tiwari, High-Performance Analyst at the Sports Authority of India, Netaji Subhash National Institute of Sports, Patiala. Hello friends, so this week we will be discussing kinetics].

We all know that under the umbrella term biomechanics, there are two key components. One is **kinematics**, and the other **is kinetics.**

What is kinetics?

Kinetics is basically the study of forces that cause motion. In this category, we will be talking about both **linear kinetics and angular kinetics**. In linear kinetics, we will be talking about key concepts like mass, weight, force, inertia, momentum, and impulse.

On the other hand, in **angular kinetics**, we will be talking about concepts like eccentric force, couple force, angular inertia, moment of inertia, torque, angular momentum, and so on. Apart from this, we will be talking about certain key principles as well, like Newton's laws of motion. In both, we will be discussing the linear aspect as well as the angular aspect, including work, power, energy, conservation of angular momentum, equilibrium, and stability.

Linear kinetics:

Linear kinetics is basically the study of the causes of linear motion and how forces overcome inertia.

Angular kinetics:

Angular kinetics is the study of the causes of rotatory motion and how torque creates rotation.

So, to summarize these two in one table, I can say that linear kinetics is defined as the study of forces causing motion along a straight line. On the other hand, angular kinetics is the study of motion causing rotational motion around an axis. So, the key quantities that I just told you, which we will be discussing regarding force, mass, inertia, momentum, and impulse, are in linear kinetics. In angular kinetics, we are going to discuss torque, which is denoted by tau, eccentric force, couple force, moment of inertia, and angular momentum.

When talking about Newton's laws with respect to linear kinetics, we all know that there are three laws: Newton's first law, Newton's second law, and Newton's third law. The first law of inertia with respect to linear kinetics is basically that an object stays at rest or in motion unless acted on by a force. On the other hand, in angular kinetics, it becomes like a rotating object remains in constant rotation unless acted on by torque. The second law of inertia in linear kinetics is F= ma, where m is the mass and a is the acceleration.

On the other hand, in angular kinetics, the second law becomes tau (T), that is, Torque = Iα, I - is basically the moment of inertia, and alpha - is the angular acceleration. The third law of motion in terms of linear kinetics is that action equals reaction. In angular kinetics, it becomes a reaction equal to the reaction in rotation. The unit that we will be using for force in linear kinetics is Newton, and for torque in angular kinetics is Newton meter.

[So, let us begin the week. Hello, friends. So, in this section, we will be talking about mass, weight, and force. Let us begin with mass].

What is mass?

Mass is the amount of matter present in a body. Now, what is matter? So, anything that occupies some space and has some mass. What is the unit of mass? The unit of mass is kg.

Mass measures the amount of matter present in a body. For example, if we have two cups, the first cup has 2 kg of sugar while the other one has 5 kg of sugar. We know that 5 kg of sugar is greater than 2 kg of sugar. Or we can say that the amount of sugar in the first cup is 2 kg, and the amount of sugar in the second cup is 5 kg. So, the amount of sugar in 5 kg is greater than the amount of sugar in 2 kg.

In physics, we consider sugar as matter because sugar occupies some space and has some sort of mass. So, sugar is matter. Therefore, we can say that the amount of sugar or the amount of matter in this 5 kg cup is greater than the amount of sugar or the amount of matter in this 2 kg cup. Simply remember here Mass measures the amount of matter or the amount of sugar in these two cups. Let us consider some more examples. So, we have four objects here. The first is a car, an apple, a boy, and a pen. So, if we consider the first example, the car.

The car contains the maximum amount of matter among these four. So, the mass of the car is the greatest among these four. Followed by the man because he has the second highest amount of matter. Followed by the apple and then the pen. Remember, the SI unit of mass is the kilogram.

We use various types of balances to measure the mass of an object. Mass is constant everywhere. For example, if Raju's mass is 70 kg on Earth and he goes to the Moon, Raju's mass will again be 70 kg. Also, remember that mass is a scalar quantity. I mean, 70 kg has only magnitude or size with a suitable unit like kg.

Here, kg has no proper direction, which is why we call mass a scalar quantity. You cannot say whether the 70 kg mass is upward or downward. Weight. What is weight? Weight is one type of force, or I can say, weight is the force exerted by gravity.

So, considering this as mass, the weight is basically the force with which the particular mass is attracted toward the center of the Earth. The weight can be expressed as weight equals mass times gravity, or it can be mathematically expressed as W = m*g, where m equals mass and g is the acceleration due to gravity. And remember, the value for g under the gravitational limit of the Earth is $9.81 m/s^2$. The SI unit of weight is Newton because it is a force. Firstly, remember that weight is the force of the Earth due to which an object falls toward the Earth.

For example, if you release an object from a certain height above the earth, the object falls or accelerates towards the earth. You may be wondering why things fall towards the earth. It is due to the force between the object and the earth, and in physics, this downward force towards the earth is called weight. Let me ask you a question:

Why does the heavy object fall faster than the lighter object?

In order to understand this concept, you have to look into Newton's second law of motion, which is F = ma, where F is the force, m is the mass of an object, and a is the acceleration due to gravity. Now let us consider that the mass of the lighter object is m_1 and the mass of the heavier object is m_2.

The force or the weight between the lighter object and the earth is W_1, and the weight between the heavy object and the earth is W_2. Here, Newton's second law is F = ma, which means if you exert a force on mass m, then mass m will accelerate with a in the direction of the force. Thus, heavy or light objects accelerate towards the earth due to the force or weight W. So here, instead of F, can we write W? We also know that in the absence of air, all bodies fall towards the earth with the gravitational acceleration 'g', which is equal to $9.81 m/s^2$.

Thus, in Newton's second law, instead of 'a', we can put 'g'. So, the weight of the lighter object is $m_1 = m_1 g$, while the weight of the heavy object is $w_2 = m_2 g$. We know that g is constant in both cases. So $w_1 \propto m_1$. On the other hand, $w_2 \propto m_2$.

Hence, the force on the Earth depends on the mass of an object. That is why a heavy object falls faster towards the Earth than a lighter object. One more thing to note is that weight is a vector quantity because it has direction along with magnitude, and the direction is always towards the Earth. Now, we all know that weight depends on mass. As gravitational acceleration is constant at a given point. But you need to remember this as well: the value of g is 9.81 meters per second squared for the Earth ($g = 9.81 m/s^2$). And if we consider the Moon, for example, the gravitational acceleration is 6 times lower than that of the Earth. Now, calculate the weight of Raju on Earth as well as on the Moon.

The mass of Raju is 70 kg. So, the weight on Earth is mass times gravitational acceleration, which is 70 times 9.81, coming out to be 686.7 Newtons.

Mass – 70 kg, Weight = m * g

= 70*9.81

= 686.7 N

While on the Moon, the mass will remain the same as it is the amount of matter, but the value of g changes to 9.81 divided by 6, which is 1.63 Newtons.

$g = 9.81/6\ m/s^2$

$= 1.63$ N

So, the weight of Raju on the Moon would be 70 times 1.63, which is 114.45 Newtons.

Weight = 70 * 1.63

= 114.45 N

This means the same person weighs differently under different gravitational fields. The gravitational field of the Earth is greater than that of the Moon, and the mass of the Earth is greater than that of the Moon.

Just summarize what mass and weight are. So, we all know the definition that mass is the amount of matter in an object. On the other hand, weight is the force exerted on an object due to gravity. Mass is represented by the symbol m. On the other hand, weight is represented by the symbol w. The unit of mass is kilogram.

The unit of weight is the Newton. Mass is a scalar quantity. Weight is a vector quantity. Mass depends on the amount of matter present in the object. Weight depends on the mass and the local gravitational field strength.

The mass value remains constant everywhere, but the weight value depends on the gravitational field.

What is force?

A force is a **push or pull** upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects.

When the interaction ceases, the two objects no longer experience the force. The force only exists as a result of an interaction. The SI unit of force is Newton, and 1 Newton means 1 kilogram meter per second squared ($1N = 1kg\ m/s^2$). A force is a vector quantity. It has magnitude and direction.

To fully describe the force acting upon an object, you must describe both the magnitude, the size or the numerical value, and the direction. Remember one thing: force is the only thing that can start the motion, stop the motion, accelerate or decelerate the motion, change the direction of the motion, or change the shape of an object. All the forces that interact between two objects can be placed into two broad categories. These are the **contact force** and the **non-contact force**.

The **contact force** results when the two interacting objects are perceived to be physically contacting each other. For example, the frictional force, tensional force, normal force, air resistance force, and the applied force. On the other hand, the **non-contact force** is the force that results when the two interacting objects are not in physical contact with each other yet are able to exert a push or pull despite their physical separation, including gravitational force, magnetic force, electrostatic force, etc. But in sports, when we have to categorize the force, we can categorize it into internal force or external force.

Internal force is generated within the body, mainly by muscles, tendons, and ligaments. These forces are responsible for creating movements or maintaining posture. The external force, on the other hand, acts on the body from the external environment, such as gravity, friction, or air resistance. These forces influence the body's motion or stability. Some examples of internal forces are the muscular force generated by the contraction of muscles to create movement or stabilize the joint.

An example is the contraction of the biceps during pull-ups or during the curl of the biceps. The joint reaction force is the force generated when the muscle shortens during contraction. For example, the knee joint during a squat. The shoulder joint during a baseball pitch. The ligamentous force or the tendon force.

So, the tendon force is transmitted from muscle to the bone via the tendon to create movement. For example, the Achilles tendon transmits calf muscle force during running. The ligament force. The force exerted by ligaments stabilizes the joint and limits excessive motion. An example is the anterior cruciate ligament, or ACL, stabilizing the knee during a sprint.

The abdominal force, or intra-abdominal force, is the force generated within the abdominal cavity to stabilize the spine and torso. For example, core stabilization during heavy lifting maintains posture in gymnasts. Bone-to-bone force or bone-on-bone force. That is a compressive force acting within the bone to support loads and maintain stability. For example, the force on the vertebrae during a deadlift.

Impact force on leg bones during a long jump. Coming to the external force. The first example is obviously the gravitational force. The force of gravity pulls objects towards the centre of the Earth. An example is a basketball falling into a hoop or a gymnast landing after a flip.

The ground reaction forces. The forces exerted by the ground to support the body react to the forces applied by the body. For example, the upward force during a vertical jump and the push force during a sprint.

The **air resistance** is the force of air opposing the motion of a moving object.

A cyclist reduces drag with an **aerodynamic** posture. A javelin experiences drag during its flight. The frictional force. The force that opposes motion between two surfaces in contact. For example, the grip between a runner's shoes and the track, sliding a hockey puck on ice. And the buoyant force. The upward force exerted by a fluid on an object submerged in it. For example, a swimmer floating in the water. A water polo player treading water.

[Thank you. See you in the next video]