

**Exercise & Sports Biomechanics**  
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**Week 05**  
**Lecture 22**  
**Linear Kinematics**

[Hello, everyone! Welcome back to this course. So, now we are going to discuss the branches of biomechanics].

**Branches of biomechanics:**

The branches of biomechanics can be categorized into statics and dynamics.

**What is statics?**

Statics is the study of objects that are at rest or moving at a constant speed. So, the examples of statics are when a ball is lying on the ground. When we study the ball which is at complete rest, it is called statics. Further, when an object is moving at a constant velocity or constant speed, an example is in a 100-meter sprint, where the athletes run the middle of the race, say, for example, after 40 to 60 meters. They reach the maximum velocity, which means maximum acceleration, and they maintain the maximum acceleration from, for example, 50 to 80 meters or sometimes 60 to 80 meters, it differs.

So, the distance that they maintain at a constant speed comes under statics. So, whenever as a biomechanist, when you study an object that is at rest or moving at a constant speed that is called statics.

**What do we measure in statics?**

Statics is subclassified into kinematics and kinetics. As far as this lesson is concerned, we will discuss kinematics. So, in kinematics, we study linear and angular motion. So, we have already discussed motion or movement. We have studied linear motion as well as angular motion.

The combination of linear and angular motion is called general motion. So, when you analyze an object that is moving in a linear direction at a constant speed, its position, distance, time travelled, and velocity and acceleration, it is called linear kinematics.

[Here, we also discuss the angular motion].

When an object is moving in angular motion, as a biomechanist, when you study or analyze the angular motion, the angular position, time taken, angular distance, angular displacement, angular velocity, and angular acceleration are studied.

We will also study kinetics, which means the forces that cause motion. So, in **linear kinetics**, the cause of movement is force. When it comes to **angular kinetics**, the cause of movement is torque.

[So, the details of linear kinetics and angular kinetics will be discussed next week. That is week 6. Here, our topic of discussion is linear and angular kinematics].

### **What is dynamics?**

Dynamics is the study of objects that are in acceleration or deceleration. Acceleration is speeding up, and deceleration is slowing down.

In a basketball match, the players speed up to receive the ball, and the ball is passed in advance. They accelerate to go and reach the ball. The moment they go nearer to the ball, they slow down. This is the difference in team games and sprint events. In sprint, the athletes start accelerating. For example, 100 meters. They start accelerating soon after the gunfire. On your mark, set, gun is fired.

The athlete starts accelerating in each 10 meters, subsequent 10 meters. Somewhere between 40 and 60 meters, the 100-meter sprinter reaches his maximum acceleration. Further, the same speed is maintained till 80 or 85 meters. In the last 15 to 20 meters, the athletes decelerate, slowing down from the maximum acceleration they achieved. This is happening due to reasons like fatigue or any other reason or psychological conditions. But, when it comes to team games like basketball, Handball., Hockey and Football, the players accelerate to reach the ball. The moment they get closer to the ball, they decelerate to gain control to receive the ball and gain the position of the ball.

In sports, the sports biomechanist should always understand that most of the time, we analyze acceleration and deceleration because we assess movements that are in dynamic mode. So, in dynamics, we study kinematics.

When the object is accelerating or decelerating, that comes under dynamics and linear kinematics, which measures the object's position, the distance it travelled, displacement, velocity, and acceleration. At the same time, when it comes to angular motion, the angular position, the time taken to move the angular distance and angular displacement, then comes angular speed, angular velocity, and acceleration. And when it comes to kinetics, as we discussed, linear kinetics, as well as angular kinetics, and this is how the branches of biomechanics are divided into subdivisions. When a biomechanist analyzes a movement, either linear or angular motion, you need to segregate which phases of the movement are in statics and which phases are in dynamics. At the same time, you have to go for the segregation of kinematics and kinetics.

In kinematics, you need to understand which segments are moving in linear, rectilinear, and curvilinear motions, as well as which segments are moving in angular motions. So, we need to quantify and assess in all respects: linear, angular, rectilinear, curvilinear, statics, and dynamics. So, these sub-branches have to be carefully analyzed in order to prepare a result and report of an athlete. So, with this, we move on to the next component. That means, yes, we use different technologies to quantify any movement in biomechanics.

But, if you want to be a better biomechanist, what are the basic subject knowledge you must have? Like a car mechanic who needs to understand the parts of the car, the biomechanist is a human engineer. He applies the principles of physics to human movement to optimize it, whether it is an exercise or a sport. So, a biomechanist should have a thorough knowledge of anatomy and physiology, because we need to understand the basic structure and function of the body.

Next comes kinesiology, the study of human movement. What are the joints responsible for a particular movement? What are the movements that occur during each phase of the movement? And what are the roles of the muscles, and how a movement happens with respect to the nervous, muscular, and skeletal systems? Furthermore, a better biomechanist should understand the basic principles of mechanics, a branch of physics, and the basic mathematical concepts like vector addition, vector resolution, basic trigonometry, and algebra. Apart from this, biomechanics needs technology, because technology helps us to reduce time and ensures accuracy. So, computers come into the picture, along with movement analysis software. The basics of computers should be understood, and knowledge of computers is essential for a biomechanist.

Are these five components enough to be a better biomechanist?

No. I know about anatomy and physiology. I know about kinesiology. I know the physics principles because I am going to apply them to human anatomy and kinesiology, human structure and movement, and I know basic mathematics. Then I will know how technology can be used correctly by computers, but this knowledge will be very vital. Still, a biomechanist should have basic knowledge about the technique of any movement or skill. And phases and techniques of any movement or skill. Say, for example, if you want to assess a half squat, you should know the phases of the half squat. If you want to assess the 100-meter sprint, you should know the phases of the 100-meter sprint. Right from the start, the position of the athlete's body at the start, the technique of the start, then the drive phase, then the acceleration phase, then the speed maintenance phase, and then the deceleration phase.

So, these are all the skills which are easy to understand. But when it comes to complex skills like a tennis serve, when it comes to a field hockey drag flick, when it comes to shot put, either glide or rotation style. So, these are all complex movements where the biomechanist should understand the basic phases of any technique and skill. So, it is essential to understand the nature and technique of any movement to be a better biomechanist.

### **Branches of kinematics and kinematic variables:**

First, the meaning of kinematics, then its branches, then kinematic variables will be discussed.

### **What do you mean by kinematics?**

Kinematics is a Greek word derived from the Greek word kinesis. Kinesis means movement or motion. Kinematics means the description of motion without force or the

geometry of motion without force. So, here kinematics is the study of any movement With respect to distance and time without force.

Only with these two metrics, distance and time, how far an object moved and how much time it took. These are the two metrics we get based on this. We arrive and derive the rest of the components. Here, we can see the branches of kinematics. One is linear kinematics, and the other is angular kinematics. So, we have already discussed linear motion.

### **What are the examples of linear motion?**

In linear motion, we have two subclassifications. One is rectilinear, and the other is curvilinear. In this aspect, when it comes to rectilinear motion, an example is the 100-meter sprint. So, in the 100-meter sprint, how much distance does an athlete run? Obviously, it is known; the name itself is 100 meters. So, the athlete in a 100-meter sprint runs 100 meters in total.

### **What is the displacement?**

The displacement and distance are the same when the object is moving in rectilinear motion. The 100-meter sprint is an example of rectilinear motion. So, whenever an object is moving in rectilinear motion, that means straight, so both distance and displacement will be the same.

### **What is distance?**

Distance is the difference between the initial position and the final position.

### **Speed:**

When we have the distance and time, we can calculate speed, velocity, and acceleration. These are all the metrics we measure in linear kinematics. So, whether it is rectilinear or curvilinear. Time is the common component in both linear kinematics and angular kinematics.

### **What do you mean by angular kinematics?**

When you describe an angular motion with respect to time and distance without force, it is called angular kinematics. Similar to linear kinematics, we measure angular distance, angular displacement, angular speed, angular velocity, and angular acceleration. So, these are all the branches of kinematics and metrics we measure in studying an object that is moving in linear motion or angular motion. So, in summary, I can say you should know about the nature of motion.

If it is linear motion, you are applying linear kinematics. Kinematic analysis of a 100-meter sprint comes under linear kinematics. But the same 100-meter sprinter moves his arms, meaning his elbow joint, knee joint, and hip joint move in an angular direction. So, the segments are undergoing angular motion. So, any movement is a combination of both linear and angular motion, which is generally called general motion.

### **What is linear distance?**

In this picture, you see an ice hockey player start and finish the path, or the movement direction is mentioned in the dotted line. The trajectory or the movement path of the ice hockey player is shown in this picture.

There is one more straight line with an arrow mark from start to finish, given in this picture, which means we need to discuss a component called scalar.

### **What is scalar?**

Scalar is a quantity that describes only the magnitude, the size.

### **What is vector?**

Vector is a quantity that describes both magnitudes as well as direction, and here the total distance travelled by this ice hockey player is 30 meters, and the displacement is 18 meters north, so the total distance is shown by the dotted line, and the displacement of 18 meters is shown with a straight line with an arrow marker.

### **What is the difference between distance and displacement?**

The difference between the initial position and final position is the distance, but when the initial position and final position are connected by a straight line, the straight line is called displacement. So, what is the necessity to find out distance and displacement? Because distance comes with only the magnitude. It does not have direction, which is why distance is called a scalar quantity. But when it comes to displacement, displacement comes with magnitude and direction. That means the ice hockey player has a displacement of 18 meters, towards the north direction. So, the vector quantity will always come with direction. So, obviously, displacement speed is a vector quantity.

### **What is linear speed and velocity?**

Linear speed is a scalar quantity because it comes with only the magnitude, and velocity is a vector quantity because it comes with magnitude as well as direction. Let us see how the linear speed and velocity of this ice hockey player are measured. So, the time taken, as we discussed in linear kinematics. What are the metrics or parameters we measure? Position, distance, displacement, speed, velocity, acceleration, and then time. So, the time taken by this ice hockey player from start to finish is six meters, as we have already discussed. The distance is 30 meters. The formula to find out speed is known to everyone.

$$\frac{\text{distance}}{\text{time}}$$

So, distance is 30 meters, time is 6 seconds. What is the average speed? You can easily find out

$$\frac{30 \text{ m}}{6 \text{ s}}$$

$$= 5 \text{ m/s}$$

The speed of the ice hockey player. Particularly, if I want to mention the average speed of the ice hockey player, it is 5 meters per second. Then comes the displacement. We already know the value of displacement: 18 meters. The time taken is 6 seconds.

### **What is the formula to find out velocity?**

The formula to find out velocity is,  $\frac{\text{displacement}}{\text{time}}$

So, here we have two values: displacement and time. So, obviously, yes, it is 18 by 6 in the north direction.

Whenever you discuss velocity, you should mention the direction. So, the rate of change of position or the rate of change of displacement is called velocity. So, here the speed is 5 meters per second, and the velocity is 3 meters per second north.

$$\frac{18 \text{ m}}{6 \text{ s}}$$

$$= 3 \text{ m/s north}$$

Then comes acceleration.

### **What is linear acceleration?**

The rate of change of velocity, linear velocity, is called linear acceleration. So, the definition is given in common. The rate of change of velocity is called acceleration.

But as far as linear kinematics is concerned, the rate of change of linear velocity is called linear acceleration, particularly average acceleration. If you look at the 100-meter sprinters, you will see that they move in a linear direction. Particularly rectilinear directions, right from the start till the point they reach the maximum acceleration. So, some athletes may reach a distance of 40, some athletes may reach a distance of 50, some sprinters may reach a distance of 60, and until the maximum point of acceleration is reached. Athletes keep on accelerating. That means the rate of velocity is being altered or changed.

### **What is the formula used to find linear acceleration?**

The formula to find out linear acceleration is  $\frac{\text{final velocity} - \text{initial velocity}}{\text{final time} - \text{initial time}}$

The unit of measurement of linear acceleration is a meter per second squared. And here you can see the picture in slow motion. The 100-meter finals of the 2024 Olympics. And you can see the athlete right from the start to the finish. And the first red-lined zone is an approximate area where the athlete keeps on accelerating. The yellow mark shows that this is the zone, the approximate zone where the athlete maintains their maximum acceleration. Because their velocity is constant and acceleration is zero. They maintain the maximum acceleration. They do not further accelerate. That means their acceleration is zero during this phase. And the final phase, say for example, 20 meters. This is the deceleration phase where the athlete slows down.

[So far, we have discussed only the average values: average speed, velocity, and acceleration].

**What is instantaneous speed, instantaneous velocity, and instantaneous acceleration?**

When you measure right from the start to the finish, say for example, a 100-meter sprinter runs the 100 meters in 10 seconds, what is the speed of the athlete? The average speed of the athlete is the distance run by the athlete divided by the time taken to complete the distance. So, we know the distance, 100 meters, divided by the time taken, 10 seconds, that means 10 meters per second is the average speed. And the average speed and the average velocity of any rectilinear motion are the same when the start and finish are different, and both the average speed and average velocity are measured in meters per second. The unit of measurement for speed and velocity is meters per second.

But here, if you want to measure the speed of the athlete at any instant point in time or point of distance, say for example, what is the speed of an athlete at the 7th second? What is the speed of an athlete at the 60th meter? So, when you want to measure an athlete's speed either at one point in time or a particular point of distance, it is called instantaneous speed. So, when we want to measure the instantaneous speed, it should be either at a particular time or a particular distance.

[So, I hope you understand what average speed and instantaneous speed are. It depends on the coach's need to ask for either average or instantaneous speed].

[Thank you, and I will meet you in the next video].