Exercise & Sports Biomechanics
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Week 05
Lecture 21
Introduction to Linear and Angular Kinematics

[Hello, everyone! This is Dr. Rajinikumar Palaniyappan, Associate Professor and Head, Department of Sports Biomechanics and Kinesiology, Tamil Nadu Physical Education and Sports University, Chennai. Greetings from Tamil Nadu Physical Education and Sports University, especially the Centre of Excellence in Biomechanics from the High-Performance Centre for Sports.]

Today, we are going to learn about linear and angular kinematics. Before we discuss linear and angular kinematics, let us discuss sports and exercise movement and its concepts.

What is sports and exercise biomechanics?

Sports and exercise biomechanics is a science concerned with the analysis of the mechanics of human movement. What is the purpose of studying sports and exercise biomechanics? Sports and exercise biomechanics is used to enhance the performance of athletes and reduce the risk of injury. And finally, to optimize the performance of athletes.

Whenever we study sports biomechanics or movement analysis, the center of mass plays a vital role. Before we discuss what the center of mass is, let us discuss what mass is. Mass is the matter of an object, or mass is nothing but the quantity of matter contained in a body. When it comes to the center of mass, the center of mass is the point where the whole-body mass is said to be concentrated.

The center of mass is always the same, whether a person is on the Earth or on the Moon. But when it comes to the center of gravity, it differs between the Earth and the Moon, and exercise and sports biomechanics should always focus on the center of mass whenever we do some assessment or movement analysis because whenever we perform some linear or angular motion, the center of mass plays a vital role.

[Furthermore, we discuss the anatomical position and fundamental position].

Anatomical position and Fundamental position:

Most movement professionals, whether physiotherapists, biomechanists, or exercise professionals, refer to the anatomical position as the fundamental reference position, and some movement professionals refer to the fundamental starting position. These anatomical and fundamental positions have already been discussed in previous lessons.

[And I move on to the next topic]:

The planes.

Movement is the aspect that we must take utmost importance in, where the body is intersected into two equal halves.

First is the frontal plane, which divides the body into anterior and posterior parts. Examples of frontal planes are abduction and adduction.

The next one is the **transverse plane**, which divides the body into superior and inferior halves and upper and lower halves, and the axis for the transverse plane is the longitudinal axis. All rotary movements occur in the transverse plane, and next comes the sagittal plane.

The **sagittal plane** divides the body into right and left equal halves. The movements of flexion and extension occur in the sagittal plane. The axis for the sagittal plane is the transverse axis. This is vital information that every movement professional should understand.

Whenever there is movement, when you analyze any movement, you need to focus on which plane the movement is occurring in. Sometimes, the movement will occur in only one plane, for example, flexion and extension, which occur in the sagittal plane. Sometimes, movement occurs in the frontal plane, such as jumping jacks, abduction, and adduction of the shoulder and hip, and sometimes, only rotational movements occur. But when it comes to sports and exercise, it is a combination of either two or all three planes in the movement will occur, and it is the utmost duty of the exercise and sports biomechanist to segregate and simplify which plane the movement is occurring in, and we have to analyze it.

Then, before we analyze anything, we need to create a free-body diagram. So, a free-body diagram is the one we draw to identify the variables we will measure. For example, a runner is running on a track, and we measure the body weight, the direction it applies, air resistance, force applied, and ground reaction force. So, these are all the variables we are going to measure. Before we analyze or start the analysis, we need to create the free body diagram, which will help us establish a focused and simplified workflow to achieve optimal results.

[Next comes absolute and relative angles]

What is an absolute angle?

An absolute angle is the one where the joint center is intersected by the x and y axes or x and y straight lines and the angle is measured. When it comes to a relative angle, it is the intersection of the lines between two segments. Most exercise and sports biomechanics measure the relative angles.

What is the advantage of measuring an absolute angle?

An absolute angle is the one where we have the reference. Because we previously discussed the anatomical position. In the anatomical position, all the joints are in an extended position. That means all the joints are at zero. For example, when you perform a biceps curl. So, in a biceps curl, when you move the arm to 90 degrees, that means from the

extended position of zero, your arm moves to 90 degrees. So that is an example of an absolute angle.

Relative angles:

But when it comes to relative angles, very limited references are available. We cannot do the interpretation, but we need to have some insight to explain and interpret the relative angles. So, here we discuss the joint range of motion, degrees of freedom, and kinematic chain. So, in the joint range of motion, if you see, as we discussed in the previous slide, in the anatomical position, all the joints are in the extended position, which means it starts from zero when we want to measure the absolute angle. If you see the shoulder joint range of motion, elbow, wrist, and then hip, knee, and ankle, this is the range given to measure only the absolute angle, whereas when it comes to the **relative angle**, it is the angle between two segments, and after the range of motion, what we need to discuss is degrees of freedom.

What is degrees of freedom?

How many planes a joint can move decides the degrees of freedom. For example, we can discuss the knee joint. The knee joint can move in the sagittal plane. In the sagittal plane, it can move in flexion and extension. And when the knee is flexed, it can go into rotation. That means the knee joint can perform two degrees of freedom. Similarly, if you see the elbow. In the elbow, we have only one degree of freedom. That is flexion and extension. But pronation and supination happen in the radial-ulnar joint. And you can see it here. The shoulder joint can perform movement in all three planes of motion. Flexion, extension, abduction, adduction, internal rotation, and external rotation. So the number of movements and the number of planes decide the degrees of freedom. And when it comes to the kinematic chain.

What is a kinematic chain?

If you are performing a half squat. The number of joints which are involved are the knee, ankle, and hip, and the movements that are happening in the ankle, for example, are plantar flexion and dorsiflexion; in the knee, flexion and extension; in the hip, flexion and extension. So, the cumulative number of movements occurring in one joint decides the kinematic chain. As movement professionals, we should understand the movement of the joint, the range of motion, and the degrees of freedom. This is the foundation for any movement analyst to understand the movement.

Then, whenever we do any movement, we have to quantify, quantitatively assess, and measure the person's movement. So, when the movement happens in two or three planes, we measure it by having a reference system called the Cartesian coordinate system. In the Cartesian coordinate system, we have x and y axes, positive and minus, and we have an origin. If any person is moving either forward or backwards, say, for example, as we discussed in any of the planes, how far a person has travelled from the origin and how fast they have moved. So, these are all the pieces of information we can arrive at and derive by using a reference system called the Cartesian coordinate system, and this is how we can measure how far a limb or a person moved in the x direction as well as the y direction. This is a two-dimensional analysis. When it comes to three-dimensional analysis, we also add

one more value, z. Here, with the Cartesian coordinate system, I would like to differentiate between two-dimensional movement and three-dimensional movement analysis. So, when it comes to two-dimensional analysis, we move in the x and y directions; only the x and y directions are being analyzed when we have limited infrastructure, say for example, only one camera.

When you capture the movement of an individual, you measure how much length they move and how much height they move when you are keeping the camera in the sagittal plane. The same camera can be kept in the frontal plane to assess how far they move and how wide they move.

When it comes to three dimensions, we can measure the subjective plane movement: lengthwise, widthwise, and heightwise. So here we have three dimensions. Any limb or the whole body, when it moves lengthwise, how far it has moved lengthwise, how far it has moved widthwise, and how far it has moved heightwise. So, this information we get when we go for three-dimensional analysis.

Here, we need to use a sophisticated mockup system to quantify an object's movement in three dimensions. But whether it is two dimensions or three dimensions, we need to have a basic understanding of Cartesian coordinate systems to further analyze either 2D or 3D in movement analysis. Then, when it comes to the polar reference system, the polar reference system is used when there is angular movement. If you look at this picture, you will see when the joints are moving in angular motion or when the body or the subject is moving in angular motion. So, how far from the centre has the object been positioned? Or the object moves; that is one aspect and to what degree.

So, the polar reference system gives you the value of how far an object moved from the starting position, which is the origin, and at which angle. So, we get two metrics from the polar reference system. Here, I can further explain how the polar coordinate system is used to quantify an object's position. From the origin, how far it moves and at which angle it moves. That is how you can see a football field here. You can see from the center how far each player is positioned and at which degree. So, this is how we can analyze and position the players by using the polar reference system.

So, both Cartesian and Cartesian coordinate systems and polar reference systems are used to quantify or to position an object's movement in linear as well as angular motion. And when it comes to sports and exercise movements and techniques, we have to understand the pattern of movement. For example, a cyclist is moving in a linear direction, which means sometimes it is a single planar movement. But the second picture you see here is telling you about the multi-planar movement. So, the tennis serve and baseball pitching are all multi-planar, whereas when you are running, it is uni-planar, uni-directional. Cycling is uni-directional.

When it comes to analyzing multi-planar movements, we have to be very careful because they are complex. To break the complexity, we need to break the planar and analyze sagittal plane movement separately and frontal plane movement separately when it comes to 2D analysis.

[Now, we are going to discuss the forms of motion].

What are the types or forms of motion?

In forms of motion, we have linear motion or translation. Then, the subcategories of linear motion are rectilinear and curvilinear, and further, we have angular motion.

What do you mean by linear motion?

Linear motion is the movement in which all parts of the body travel the same distance in the same direction and at the same time. When it comes to angular motion or rotation, all parts of an object travel through the same angle in the same time in the same direction about the axis of rotation.

So, we can easily understand that linear motion means the object moves in a line, all the body parts are moving in the same direction, same distance, and same time. When it comes to angular motion, the movement is happening around an axis. So, the human body movement, particularly in sports, is a combination of linear and angular. The combination of linear and angular motion is collectively termed as **general motion**. And here are the examples of linear motion, particularly the subcategories of linear motion are rectilinear motion.

What is rectilinear motion?

Rectilinear motion is nothing but when an object is moving in a straight line, when all the body parts or the center of mass is moving in a straight line, it is called rectilinear motion. Recti means straight, so examples for rectilinear motion are the 100-meter sprint, the approach run in long jump, the approach run in triple jump, so these are all examples of rectilinear motion because the whole body is moving in a straight line, and a cyclist who is moving on a cycle track, so he is moving the whole body and the cycle is moving in a straight line, which is termed as rectilinear motion.

Curvilinear motion:

When it comes to curvilinear motion, the object is moving in a curved path. So, the basketball which is released from the hands of a basketball player to the ring is following a trajectory which is a curved path. So, it comes under curvilinear motion. So, the basketball release follows a trajectory, and it comes under curvilinear motion. And further, when the long jumper travels from the takeoff board to the landing point, the whole body is moving in a curvilinear nature. So, the other examples of curvilinear motion are the shot put, which is released from the hand of the shot putter. The trajectory it follows is termed as curvilinear motion.

Similarly, the javelin throw, from the release to landing, and when it comes to a football that is kicked in the air, from the release to landing, follows a curvilinear motion. So, sometimes, the object that is released from the athlete's body, either hand or leg, follows a curvilinear motion. Sometimes, the athlete's body follows a curvilinear motion.

[And next come the angular motion examples].

What are the examples of angular motion?

As we already discussed, angular motion means a motion that is happening around an axis. So, here, a hammer thrower accelerates her body by the rotation of her body and then releases it. The whole body is moving around an axis, and this comes under angular motion. And if you see a swimming diver, a swimmer who undergoes diving, she undergoes a lot of rotations, three rotations, three and a half rotations after they take off.

The picture is shown here. So, this is also an example of angular motion. However, when the cyclist is moving, though we said the cyclist is moving in a linear direction, the joints undergo angular motion. So, we come to understand the fact that any motion is a combination of linear and angular motion, and combined, it is termed a general motion. When it comes to angular motion, we can see the axis. In this example, when a person runs, the joints undergo angular motion. The whole body is moving in a linear direction, particularly a rectilinear direction, when it comes to a 100-meter sprint. The joint axes are imaginary axes, and the joints move in angular motion. At the same time, if you see a gymnast who is doing a somersault, the centre of mass is acting as the axis of rotation.

The third one is an external axis when a gymnast is rotating her body on the horizontal bar. The horizontal bar, which is held by the gymnast, is acting as an external axis. So, the angular motion can be categorized based on the axis of rotation. So, when it comes to joint angular motion, it is an imaginary axis; joints are undergoing angular motion, and in all the exercises, biomechanics professionals should understand that all joint movements are angular in nature. That is why we measure the angle of the joint in degrees, which is the unit of measurement of the angle of the joint. At the same time, we use a goniometer to measure the range of motion of the joint. At the same time, when you see here when it comes to angular motion, the number of rotations a swimmer makes before she enters the water, so one complete rotation is called a revolution. So, one revolution is equal to 360 degrees.

So finally, everyone should understand the forms of motion, in other words, types of motion. So, to summarize, the motion can be either Linear, angular, or a combination of both. Linear motion means the body is moving in a line, and there are subcategories of linear motion: one is rectilinear motion, and the other is curvilinear motion. Rectilinear motion is when the subject is moving in a straight line, and curvilinear motion is when the subject is moving in a curved path. The examples have already been discussed. The next type of motion is angular motion. Angular motion is the motion that moves around an axis.

[We have just discussed the three types of axes and how angular motion occurs].

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