Exercise & Sports Biomechanics
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Week 04
Lecture 17
Measurement Issues & Data Collection

[Hello, everyone! Welcome back to this course].

In this video, you will explore the different measurement issues and data collection procedures. Now, we are entering into the **quantitative analysis from the qualitative approach**. In the qualitative analysis, we have analyzed movement using visual observation and cameras.

In the cameras, there is no set of rules for where we have to record the video, from which angle, or how far the camera needs to be placed. But when it comes to quantitative analysis, we are going to describe the movements based on numbers. For that, we need to choose a highly accurate and reliable tool for measuring the movement. For example, video cameras, motion capture systems, force plates, EMG, etc.

[Next, we move on to different methods to analyze human movement].

Different methods to analyze human movement:

The first one is two-dimensional analysis. It is a simple and cost-effective method to record and analyze movement. The limitation of this method is that we need to record the video perpendicular to the plane of motion.

In addition, you cannot even pan the video for the two-dimensional analysis. If you wish to do that in two-dimensional analysis, then you need to apply the two-DLT method. What is meant by DLT? DLT is the Direct Linear Transformation. It helps to reconstruct the data for accuracy. If the movements are out of the plane, it may cause errors in kinematic calculations. The major errors are perspective error and parallax error. The second one is the 3D analysis, which requires a minimum of two cameras to record the movement from the two different perspectives. If you are using two different video cameras, then we will be using the 3DLT method, which is the Direct Linear Transformation method for computing the data. Currently, all over the world, 3D motion capture systems are considered the gold standard to analyze sports movements in 3D. So, what is the difference between two-dimensional and three-dimensional analysis? In 2D, it captures the movement in two dimensions, where you will have only the height and width. In 3D, it captures movement in three dimensions: height, width, and depth. In the image, it is X, Y, and Z.

[Next, let us understand what the different types of errors are and how to minimize them].

What are the different types of errors, and how can we minimize them?

The first one is the perspective error. What is meant by that? When the size and shape of an object appear disordered due to the distance between the object and the camera,

specifically within the plane of motion, it is known as a **perspective error**. If you look at the image in the middle, the subject is standing in line with the plane of motion. Where the calibration frame is fixed and the subject stands in line with that. So, the height of the subject is 1.85 meters.

When the subject moves away from the plane of motion, either forward or backwards, you notice that the values change from 1.85 to 1.37, and on the right-hand side, it is 3.06 meters. In addition, if you notice that when the subject is standing closer to the camera, the object or the subject appears to be larger, and as and when he is moving away from the camera, The subject looks very small. To minimize this, we need to make sure the athlete should perform any activity in line with the plane of motion.

Let us practically identify the perspective error and see how the values are changing. For that, open the Dartfish software and import the video. Here, I will introduce two different tools for the quantitative analysis. The first step is to calibrate the video.

For that, there is an option in the drawing pane. Click on the calibration tool and identify the known information. For example, you can see the two markers which are pasted on the floor. For better visualization, I will zoom in on the video so that you can see the marker much more clearly.

Draw a calibration line from point A to point B, and if you notice that the reference frame is showing as 1 meter, If I right-click that, it will ask to set it as a reference. Click on that. You need to provide the actual value from point A to point B. In this example, we have placed the marker at a distance of 5 meters. And then press OK. This is the distance tool.

The next tool is the angle tool. Click on that. We need three points to define the angle. I will click the elbow joint first and move on to the wrist, and the last one is the shoulder.

For the perspective error, we will use both the distance tool and the angle tool. In this example, the athlete will perform squats in three different regions. Number one, number two, and number three. So, you can notice here there is a marker over here.

This is the last marker, and this is the second one. This is the first one we have already calibrated. The calibration frame and the size of the number are a bit big. So, if you see the property selection, you can reduce the size of the font, and if you right-click, we can make it fade out immediately. So, that we can do further drawings. So, I press immediate, I will play the video here. I am going to measure the hip marker to the knee marker. Click on the distance tool and draw a line from the hip marker to the knee marker. So, as a reference, I will give a Text, which is 0.80 meters.

I will move this and play the video. Now, the athlete has moved to the second position. Again, I am clicking the distance tool to measure the distance between the hip and the knee marker. You can notice that the values are less when compared to the first one. So, I am using the text 0.60 meters for our reference.

I will move this and play again. Now, the subject has moved to the last position. I have selected the distance tool and am again drawing a distance between the two markers. Again, I am using the text 0.47 meters. You know that this is the plane of motion.

On the plane of motion, the distance between the hip and the knee marker is 0.80 meters. As the athlete moves away from the camera, the values are decreasing. So, I hope that you have understood this perspective error very clearly. The subject has to perform in line with the plane of motion. To cross-check that, I will change the plane of motion.

The first step is to right-click the calibration frame, which we have done before, and delete it. Again, go to the distance tool and select the second position markers from point A to point B. Now, the video is already calibrated from the first position of the plane of motion. To change that, right-click the number in the distance tool, and it will again ask to set it as a reference. Click on that and change it to 5, then press OK. Now, the video is calibrated again.

The plane of motion is changed from the first position to the second position. I will go to the property tools, minimize the size of the font, and right-click on that fade-out immediately. I will choose the distance tool again to measure the length between the hip and knee joint. So, it is very clear that even if you change the plane of motion, the length of the segment remains the same.

When it comes to angle measurement, imagine that if this angle is 90 degrees from the first plane of motion. Even if you move towards the second and third positions and if you perform a squat and measure a joint angle, it will show exactly the same value. This means even when the subject is moving away from the plane of motion, the angle data will remain unchanged.

[Next, we move on to parallax error].

Parallax error:

It occurs when the apparent position of an object changes due to the observer's viewpoint, which causes measurement inaccuracy in two-dimensional analysis only. It happens especially when the observer or a camera is not aligned perpendicular to the plane of motion. If you look at the image, the person is holding the same object. Only the camera perspective is different. On the left-hand side, the angle was 90 degrees. When the perspective was changed, the angle was changed to 39 degrees. Let us practically identify the parallax error and see how the values are changing. The first step is to calibrate the video. I will choose the distance tool and draw a line from point A to point B. Right-click on that.

Set as a reference and change to 5 meters, then press OK. The video is calibrated, and I am minimizing the size of the font. I will press the play button. I will identify the lowest position of the squat and use the angle tool for the knee angle. The first marker is at the knee joint, the second one is at the ankle, and the third one is at the heel joint. So, the value is 86.3 degrees. Now, I will import another video from a different perspective.

I will zoom in again, calibrate the video first using the distance tool, right-click on that, set as reference 5 meters, and click OK. Again, I need to use the lowest position of the squat. I will check the angle tool. The first point is on the knee, ankle, and hip. Now you can notice that as the perspective of the camera changes, the angle is totally different. This is known as the parallax error.

Let us take an example from sports. Imagine that now we have kept the camera perpendicular to the plane of motion where the athlete is performing a set shot. You can measure the elbow angle because this movement is performed in line with the plane of motion. But if you notice that the knee angles of both athletes are slightly rotated, then we need to change the orientation of the camera and keep it exactly perpendicular to the plane of motion. Even in a single technique, the movement will take place in different planes of motion. This means we need to place different cameras for each plane of motion. That is why there are so many limitations to 2D analysis.

Now, let us explore the step-by-step procedure for collecting data in 2D analysis. First, we need to find a space with sufficient light where the athlete can perform the movement comfortably. For example, walking, running, or even gymnastics movements. Then, we need to define the plane of motion where the movement will occur.

In this example, since the camera is over here, the plane of motion will be either in this direction or the opposite direction towards the left and right side of the camera. Next, draw a straight line on the ground that should match the movement of the plane. We can either use these existing lines or if that is not available, use tape to mark alignment.

[Next, we move on to the camera position].

Camera position:

The camera must be placed exactly 90 degrees to the plane of motion. To make sure it is perfectly aligned, we use the 3-4-5 method. For example, if this is the plane of motion. First, mark a 3-meter line along the plane of motion. From this point, I am taking the 3-meter mark. From this point, I will draw another 4-meter mark perpendicular to the plane of motion, which is 4 meters. From the 3-meter mark, I will draw another line that intersects at the 4-meter line with a distance of 5 meters. This one is 5 meters. Then the lines are perfectly perpendicular. If not, adjust until the 3-4-5 rule is met. Once this is done, leave a small mark on the floor for future analysis. Before recording, make sure the background is clear, non-reflective, and provides good contrast with the athlete. The ideal option is that you can use a plain wall, a curtain, or a movable screen to minimize distractions in the recording.

Next, mount the camera on a tripod to prevent shaking, which will reduce the chances of errors. Once the camera is mounted on the tripod, we need to use a plumb line to ensure the camera is directly above the perpendicular line to the plane of motion. This helps us prevent misalignment issues that could distort movement analysis.

The next important factor is the height of the camera. The camera height always depends on the activity the athlete is performing. In most cases, the camera should be positioned at the midpoint of the movement. For example, if the athlete is performing a walking gait analysis, the camera should be set at hip height.

In this example, if a subject is going to perform walking or running, the camera is placed In line with the hip joint, so that we can have a better field of view to record specific human movements. Now it is time to capture your first biomechanics video in action. Once you have recorded, import the video into Dartfish and analyze the movement.

In the next video, we are going to explore the open-source software **known as Kinovea.** For that, go to Google and type Kinovea. There is a link called **kinovea.org**. Open the website. On the homepage, you can see the download for 2023.1. If not, you can go to Downloads.

There is an option to download the **Kinovea software**. Make sure you meet the minimum hardware requirements. The operating system works from Windows 7 to 11. It can work on either Intel or AMD with 64-bit, and the screen resolution is 1024 x 600 pixels. The good thing here is they have provided the source code on GitHub. If you wish to develop new biomechanical analysis software, you can use the source code to develop a new one. So, try to install it.

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