Exercise & Sports Biomechanics
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Week 01
Lecture 02

Basics of Biomechanics Research

Hello everyone, welcome back to this course. Today, we are going to talk about the basics of biomechanics research. As we discussed before, the main goal of biomechanics research is very simple. It is about improving performance and reducing the risk of injuries for athletes.

 Biomechanics help us to understand how the human body moves and interacts with the different forces in all sporting movements. By understanding this, we can identify which key performance indicators facilitate the athlete's performance. Sports biomechanics play a crucial role in helping athletes and coaches by conducting research and providing valuable support services. They will identify errors in technique, suggest corrections and even provide insights into the causes of the injuries**.**

We will explore the different research techniques applied in sports biomechanics. In modern biomechanical research, we rely on advanced technology like motion capture systems, force plates and electromyography to gather precise data. Can you imagine that? How they would have done biomechanical research in 100 years or 500 years back? Let us start from there:

Around 300 BC, Aristotle, the great scientist, was the first person to analyze the human movement of walking. He demonstrated that when we walk, our body do not move in a straight line. He conducted a very simple experiment using a stick and ink. He dipped the stick in ink and placed it on his head, and he started walking alongside the wall. When he analyzed the traces of the lines, he found that those lines were not straight. It was zigzag. To cross-verify that, I have replicated the same experiment in the motion capture technology, which is the gold standard method for doing biomechanical research. So, I have done the walking gait and plotted the one-head marker, and you can notice that the same zigzag pattern was followed.

In 1600, Alfonso Borelli performed the first experiment in gait analysis. He placed two poles similar to the kho kho court and tried to walk towards one pole. He found that when the person is walking towards the pole, it appears that the person is moving to the left and right. And from here, he proved that there is mediolateral movement in the body.

Next, Muybridge used multiple cameras to take a series of photos to prove that the horse was in the air for a fraction of a second. He also studied human motion, like walking and running, and he applied the same. To visualize this, he developed a tool called Zoopraxiscope. What is meant by that? It is a kind of projector.

When Muybridge displayed a sequence of photographs, we were able to visualize it as it was exactly moving. He is the first person to give the life to the picture. Following Muybridge, Jules Marey developed a technique called chronophotography, which captured movements in a series of images but on only one frame which helps us to understand how the muscles and joints work during the motion.

Next is Rotoscoping-

I hope everyone would have enjoyed the Cartoon Network in your childhood days, right? Rotoscoping is a process of converting the video into animation. In 1985, the Sun One computer took 17 hours to compute, the three-second trial from the four cameras. Imagine the amount of time we need to spend on those days. But nowadays you can do it instantly on your WhatsApp video call. It identifies your face, and it will animate immediately. The technology is going so fast.

Now, we will look into different examples of research techniques and methods used in biomechanics. The first one, a long-distance runner, came with the complaint of right lateral calf tightness. We have to address what would be the cause of this pain. We have done both the qualitative and quantitative analysis. If you look at the video normally, it is very hard to observe the information because it is like observing the athlete running in line.

If you slow down the video, then you can see the details of it, and later, you can use any tool for the qualitative analysis. So, I will pause the video, and I can control the movements and I can able to see the details of the running kinematics. First, I will draw a midline, and from here, you can notice that the knee is going away from the midline, which means the knee is getting abducted and moving away from the midline; watch the movements very carefully. After landing, you can see there is a pronation movement in the right foot and in addition, you can see the foot is averted little bit. And if you notice the hand, it is clearly visible from the posterior view.

If we can see the hand from the posterior view of the camera, it means the body is rotated towards the right side. And that is why if you notice the knee of the left leg, it compensates by moving towards the medial side, which is moving towards the centre line. So, I will play the video again so you can able to visualize it. You see, the left knee is moving towards medially, and then it is getting normal. So, this is the information that we can retrieve from the qualitative analysis.

Now, we move on to quantitative analysis.

We have conducted gait analysis using a motion capture system and analyzed it using visual 3D software. Here are the basic results of the gait parameters like step length, stride length, stance time and flight time. We tested the athlete at 8 km per hour, 10 and 14 km per hour, you can notice that there is no difference in any of these parameters.

If you cross-check the step length, it is 1.38, and for the left leg, it is like 1.37, 2.74, and 2.73. It was so consistent in both legs, so the problem is not because of the asymmetry of the basic parameters. Let us go into the depth of joint angles and let us identify what would be the real cause of this pain. Before going into the analysis of the knee angle, we should

understand how to interpret this graph. You can able to see this graph. It starts from 0 to 100 from right foot strike to right foot strike. And that is written the line is left foot strike.

The entire gait cycle is divided into a percentage. The first one is the right foot strike, and you can see the three lines, which are the right toe-off.

This line is considered a left-foot strike and left toe off, and there is an imaginary line, which is the right-foot strike; so, that is why the event starts from the right-foot strike and ends with the right-foot strike. Now, let us see the knee angle. This is written as 0 degrees, which is the anatomical position where the entire body is stretched, and if there is any bend, the angle between these two segments decreases, which is known as flexion. It is a flexion of the knee. In the graph, it is clearly mentioned that as and when the speed of the treadmill increases, the flexion angle also increases. Both the left and right knee do not show much asymmetry here.

The next one is, the Adduction and Abduction.

First, I will draw a center line. If you notice that the graph itself, it has mentioned, that adduction is positive and abduction is negative, which means if your knee is moving towards the centre line, which is known as adduction, which is positive, and if it is moving away from the centre line, is abduction, which is negative. The problem that we notice in the qualitative analysis is the right knee angle, where the knee is abducted, right? It is moving away. So, in the image, it is very clearly seen it is going downward, which is the abducted movement from where the initial point, which is the right foot strike and right toe off, both the movement are the abducted movement. If you see on the left-hand side, it is adducted, and then it is abducting, which follows the pattern of the normative data. You can able to see these grey colour lines, which are considered normative data.

We are supposed to take our knee in the adductor position, and then it should come to the abduction movement. The real problem starts here for this athlete. Similarly, the same asymmetry was found in the shank rotation and in the ankle flexion. Ankle flexion means we have both dorsiflexion and plantar flexion. So, the athlete is having in the plantar flexion. You can see the asymmetry between the left and right foot on the plantar flexion. So, what is the reason for the right lateral calf tightness? The reason is that the shank rotation is averted, the knee is abducted, the foot is averted, and there is a pronation in the foot, which causes tightness in the lateral side of the muscle and weakness in the medial side of the muscle. That is the reason the athlete is getting pain and tightness on the right side of the leg, which is the lateral side of the leg.

The next one is that the badminton player came to us and said that he could not recover quickly from the lunging movement. Now, we need to identify what would be the reason preventing him from the retrieval action. For that, we have done the EMG analysis, which is the Electromyographical analysis, to check between the left leg and the right leg.

We can identify what would be the reason behind it. For example, if I am performing a lunging movement, what would be the primary muscle that is working? It is a quadriceps for the hip flexion to happen. The quadriceps will work eccentrically, control the

movement, and retrieve back. To retrieve back, the quadriceps will work concentrically. What is the movement here? The knee angle will increase, which means the athlete is extending the leg. The quadriceps will act as a prime mover. In the alternative leg, there will be a knee flexion where the gluteus and hamstring will act as the prime mover. Let us decode exactly what happens in the muscle:

We have placed the EMG sensor at the gluteus, hamstring and quadriceps. Further, we have calculated both the mean value and peak value of the muscle activity. In the retrieval movement, the prime mover is the quadriceps. If you notice that, the mean value of all the three muscles in both the right leg and the left leg are almost the same.

But, in the peak muscle activity, the left quadriceps activation was less when compared to the right leg. The peak EMG focuses on the most intense moment, initiating the lateral action in the lunging movement. To understand the cause of this, we have conducted the isokinetic test. In this, we asked the athlete to perform the isometric movement in three angles, which are 60 degrees, 45 degrees and 30 degrees angle. If you see the result of 60 degrees angle, the difference between the left leg and right leg of the peak torque is 30.7 Newton meter deficit is there in the left leg. When we conduct a similar test at the 45-degree angle, you can see the deficit is 68.4 Newton meters when compared to the left and right, which is very high, right?

We will take a look at the 30-degree angle; it is even worse, and the left and right leg can generate up to only 49.2 Newton meters, and the deficit is 69.6 Newton meters. So, exactly what happens is, when the athlete is performing at three different angles at the 30-degree angle, the athlete is unable to generate more strength when compared to at the 60-degree angle. Imagine that if the athlete is going to retrieve from the lunging position, at that moment, the athlete is unable to generate more strength, which is why the athlete cannot retrieve back to the normal position.

As a next step, we have recommended the strength training program specifically focusing on that 30-degree angle. After almost 8 weeks of training, we can see the difference in how fast the athlete can retrieve back. Here is the white one, which we did before training, and the green one, which we tested after the training program. So this result clearly shows that the green one can be retrieved faster when compared to the white one.

In this research, we need to identify the key factors contributing to elite jumping smash in badminton. For this research, we have collected data from 18 male elite players. The data was recorded using a motion capture system with 700 FPS.

FPS means frames per second. On the right side, if you notice, the markers are placed in the body to compute the advanced biomechanical calculation. Here, we used the shuttle launcher to feed the shuttle for the players to perform the jumping smash. The data was collected using the 25 Qualisys motion capture system with 700 FPS. You can able to see where the cameras are placed during this specific research.

On the floor, we placed three Kistler force plates to understand the jumping and landing movements. The next one is the shuttle launcher. You can see it; it was highlighted over here in this image. From there, the shuttle was feeded for the players.

Next is the target zone where the players need to smash over there. Now you see the target zone on the right for the right-handers, and on the left, you can see the target zone for the left-handers. After collecting the data from the motion capture system, the data was analyzed using the visual 3D software. This research was published in the Journal of Sports Biomechanics. Here, we are trying to compare what is the difference between the fastest and the slowest jumping smash at the elite level.

Can you identify the difference between the A image and B? Here, we have three takeaways. The first one is the greater shoulder internal rotation. The normal line is the slowest performer. The dotted line is the fastest jumping smash. You can see the internal rotation was greater among the fastest jumping smash players. The less shoulder elevation and less shoulder extension at contact were the most important factors between the fastest and the slowest jumping smash performance. You can see in this video that the orange model was the fastest one.

If you notice that the internal and external rotation is much faster when compared to the green one. The last one is research on the long bounce, which is a controversy here. The coaches are saying the players are not consistent in release, but the players are saying no, I am doing the same as before; it is very difficult for the coach to quantify it because the sport is purely a technical one. First of all, there are very few literature out there. Because of that, there is no such documentation of movement patterns. First, let us understand the sports. The objective is, that the player has to roll the ball to get it as close as possible to the target known as Jack. If you look at this ball, it is not perfectly round. They are weighted on one side, which facilitates the ball to take the curvy movement. Let's look into the video. The player makes a very simple lunging movement and releases the ball. If you notice that the ball is moving very slowly in a curvy path, and it reaches the jack, which is yellow in colour. This is the perfect example and objective of this sport- lawn bowls. We have to achieve this.

In the previous research, we have conducted in the laboratory setup, but now we have moved everything into the field to test the athlete in the actual game scenario. This is the complete setup for the data collection. You can see the multiple motion capture system and this is where the player will roll the ball from here. This is the data captured from the motion capture system.

We can see only the markers, not the human. Based on this, the model was developed using the Visual 3D software. We have computed all the joint angles and velocities in different phases to understand the movement pattern and why there is an inconsistency in the performance. In addition, we have calculated the score. We used a measuring tape to check how far the ball is from the jack. If it is closer is better. You can see the animation. One is the forehand, and the other one is the backhand. The white one is the forehand, and the orange one is the backhand.

If you compare both movement patterns, there is no significant difference between the forehand and backhand techniques. It is very difficult, even in the motion capture system; when we analyzed, we were not able to identify any asymmetry between the forehand and backhand. The shoulder velocity is a 4.67 per cent increase in the forehand technique when compared to the backhand, which resulted in the highest score, which means that it is a poor performance. Our goal is we have to take the ball closer to the jack. If it is moving away, that is known as the highest score.

Though, when we compare the data statistically, it is not significant. But when we look into the data bigger, even minor changes can impact the performance. In this video, we have covered both qualitative and quantitative analysis. And in addition, we have covered the different research techniques like video, motion capture system, EMG and isokinetic system. More importantly, this is the time we need to shift from laboratory to field-based research to better understand sporting movements and enhance the athlete's performance.