Exercise & Sports Biomechanics
Dr. Rajinikumar Palaniyappan
Centre of Excellence in Biomechanics Cum High Performance Centre for Sports
Department of Sport Biomechanics & Kinesiology
Tamil Nadu Physical Education & Sports University, Chennai (TN)
Week 10
Lecture 48
Practical application of force plates

[Hi, everyone! Here you see a beautiful tennis court].

Application of force plate in Tennis: What does the force plate have to do with a tennis court?

In tennis, there are so many skills. But the game starts with only the serve. We have different rallies. So many skills are performed in tennis. But the most unique and exclusive skill is the serve. Every tennis player has the chance to serve twice each time during the match.

Different phases of tennis serve:

The moment he or she goes for the first serve, it takes utmost importance because the speed matters. When we have a tennis serve, the tennis serve has different phases, right from the grip, ball toss, backswing, forward swing, ball contact, follow-through, and recovery. So, these are all the sub-phases of a tennis serve. And there are different types of tennis serves, Spin and kick serve. The first serve always goes with the fastest speed, and all tennis players tend to serve with maximum speed. So, when we want to send the ball with maximum speed to the desired location, we need to generate more force. As we usually discuss, the force is generated right from the bottom—from the foot, ankle, knee, hip, trunk, shoulder, elbow, and wrist. So, in this kinetic chain, that force is accumulated, summed up, and then it helps us generate more power so that the ball will go to the desired location at maximum speed.

[See in the video, where we have the second-year B.Sc. Sports Biomechanics and Kinesiology student Sudarman, who is a tennis player]. So, we have a tennis service zone and we have a force plate underneath the tennis service zone. But the player cannot know where the force plates are. But we have created an indirect map that mimics the real-time situation. And if you see here, the force plates are there, and I can show you where the force plates are placed, as we have already discussed.

You can see the force plates here, which is underneath the ground and there are two force plates on the right side which is the time, which is in the dimension of 900 mm by 900 mm which is square and we have the top layer. So, this will help you to identifying the ground reaction force in three dimensions as well as the moment and COP, center of pressure of the tennis player when he performs the tennis serve.

Here we are going to measure the tennis serve and how the ground reaction force from the foot from each sequence when Sudarmanan performs. And in tennis when he starts tossing

the ball when he goes for the backward acceleration and forward acceleration with ball contact and follow through after the ball is hit. At the time of ball is hit he is airborne and the moment he lands, so more amount of force is the reaction force acting on the body. So, when he lands when the tennis player after the jump after the airborne contact, when he lands, almost 1.52 times the body weight is the reaction force acting on the body. When it happens, it is asynchronous, asymmetry because the joints are loaded on one side.

[Now, we are going to see and we are going to capture the movement of tennis service performance of Sudarman].

You can see the whole area, it is actual tennis zone and we can find the competitive environment and that is how we are going to see the Sudarman's performance.

[See the video]

You can take the ball. Now he is going to serve from his left. So, when the subject is ready or when the player is ready, we should get ready with the system because the force plate has to be switched on. So, now it is switched on and I have to ask the operators whether the force plate is on or not.

Now the force plate is on and now the subject can perform the test. See, whenever we do some assessment, there are team of experts should be there to conduct the test. Now, we have four, five people who are well trained. So, who are working behind our assessment.

[So, now the subject is ready].

[Now, Sudarmanan performs the moments where he gets the command through the operator – Ready - Start. So, the first serve is done and no matter, so we can ask the subject to perform. So, when he performs, he can start running and easily perform].

When the subject performs the test, the force vectors are being recorded. And the same thing can be integrated, the force plates can be integrated with motion capture system. So, that will help us to find out all the kinematic parameters. At the same time, even EMG can be integrated. So, as we already discussed, so the force plate can be integrated with motion capture system and the EMG.

What can we assess from this?

We can assess all the kinematic and kinetic parameters. Kinematic parameters can be measured when the motion capture system is integrated. But now we are assessing only the kinetic parameters by having the force plate.

[And now we can make the player to serve].

We can assess the technique of the player. At the same time, how joints are loaded. And the third one is when we integrate with the motion capture system, we can perfectly assess the technique and all the kinematic parameters combining the kinetic parameters.

Now, what else we can see apart from the technique? Yes, we can create a pre-conditioned computer situation. So, where we can play for half an hour one hour. So, when he is tired,

so when he is fatigue, we can identify the loading pattern of or force loading pattern of the player doing the serve. Whether the force generation from the foot is same when he is starting the game or when he goes for second set, third set or fourth set, so it depends.

We can identify the fatigue level too. So, what are the other uses of these data, right? It would help a coach, a player, or a sports scientist to provide a better remedy for a tennis player. So, when the player is asynchronous or has asymmetry in loading, it will also be ideal data.

For example, as I said, the reaction force is 1.5 to 2 times the body weight when he lands after the serve. So, after the serve, when he lands, he must get ready for recovery to face the return ball from the opponent. So, it will be good data when we measure the loading or the ground reaction force on the joints. So, it will be good data for strength and conditioning professionals to design and optimize training intensity for tennis players. Also, it will help us prevent injuries.

So, sometimes the players may have better shoulder power but poor lower extremity power. On the other hand, they may have better lower extremity power but may not deliver it effectively during the serve due to a weak core. So, this type of data will help us when we integrate the force plate with a motion capture system and collectively gather kinematic and kinetic data. This is the beauty of this force plate.

Application of Force plate in Boxing:

We are going to see how Akshay Kadam is going to make punches. To identify the fatigue level, we are going to ask Akshay Kadam to go for each punch continuously. So, he will be starting with the jab. Continuously he will be performing jab. And the other one is cross. Then hook, then uppercut, followed by the sequence of cyclic of punches.

The purpose why we ask is that each boxing bout lasts for 3 minutes. It is completely anaerobic in nature. So, at what point he gets fatigued. So, the lactic acid accumulation point we can identify by this force plate, we can just we will be able to estimate it. But the other way is, okay, fine, we can take the blood sample and we can identify the lactic acid accumulation from the blood samples. So, that is the other way. But here, through the force vector, the pink punching force, we can identify.

[Now, I invite Akshay Kadam to start with].

You can see here, he is continuously punching starting with one punch and second he goes for thrust. So, the continuous jab force is measured and we can see from the graph that how consistent the punching force is. One is to identify how perfect his technique is. And second one is the consistency will tell you, right, he is not still tired, he is consistent in technique. And the moment the drop in peak punching force is an indication of the fatigue level of boxer.

[So, now he starts with the other technique].

So, this is how we can make the boxers to go for different punches and you will be seeing on the graph how each punch that will be shown here, and so now he is gasping and he is

somehow getting tired. So, we asked him to go for the other punch. So, now we can achieve the performing the combination of punches. So, we will be performing according to his choice. He can continuously do the choice of punches. So, it is his choice. But only thing is we need to identify, so how consistent the punches are.

This is very comfortable for the boxers right and the machinist mimicking the I mean the human and so that gives them better skill learning apart from the training, so the better skill learning is happening and neurological learning is happening.

Now, Akshay Kadam has gone for different types of punches continuously and we have seen him punching on the force plate and the force plate recorded the forces for each punch in three dimension X, Y, Z and when it comes to different types of punches the cross punch had the highest value it is more than 1000 Newton.

We can measure these types of forces, ground reaction force or the reaction force may be in Newtons or times the body weight. So, 1.5 to 2 times the body weight when it goes to cross punch. So of course, all the punches and the cross punch had the highest value in its movement and what we can do with this. So, he is gasping now and somehow, yes. So, we make the athlete or boxer to understand at which point he gets tired, we can make the strategy out of it.

This is one point, and only the force plate is the equipment which gives you these metrics. Now we can measure in combination. For example, these force plates can be integrated with the motion capture system. So, the motion capture system will help us to find out the punching velocity. For each punch velocity, we can find out the forces along with it. And impulse, the punching impulse, is the one measured by the force plate. And then, if we want to identify each individual muscle activation pattern, we can also integrate EMG, electromyography. So, these three components we can integrate to identify the boxer's key performance indicators, optimize performance, and determine at which level fatigue sets in to further improve performance. Also, sometimes when the technique is poor or incorrect, we can identify it through the motion capture system and suggest remedies.

These force plates can be integrated with motion capture systems and electromyography to obtain better key performance indicators, which will be more helpful to coaches as well as boxers.

Application of Force Plate in Block Start:

About the sprint start—usually, the sprinters, the 100-meter, 200-meter, and 400-meter sprinters, use starting blocks. So, if you know the history of starting blocks, they were only introduced in the Olympics in 1948. So, when Jesse Owens ran in the 1936 Olympics, winning four gold medals in the 100, 200, long jump, and 4x100 meters. During the sprint events, he used to dig a pit to place his legs to achieve better push and ground reaction force. But nowadays, we have sophisticated starting blocks, and when it comes to sprinting performance, starting blocks play a vital role in the initial 10 to 15 meters because they help athletes achieve a better start and push.

As Newton's third law states, for every action, there is an equal and opposite reaction. These starting blocks help athletes push. Quickly and with more power. So, this is what we are going to see here.

We are in the Center of Excellence in Biomechanics and High-Performance Center for Sports, Tamil Nadu Physical Education and Sports University. We have Poovarasan. So, he is a second-year B.Sc. in Sports Biomechanics and Kinesiology student. Actually, he is a professional 400-meter sprinter.

And what you see here is - an **instrumented starting block**. The instrumented starting block is nothing but a starting block inbuilt with four sensors. These four sensors help us identify the amount of force, peak force, average force, foot contact time, power, and impulse. All these metrics can be assessed from the starting block. Apart from this, we do have the force plate in the place where the athlete keeps their hand. So, it will help us identify the kinetic parameters like peak force, impulse, and power from the hands. And I would just like to explain to you about the **Ki-sprints**.

So, we have an athletic track, it is a **PU polyethylene** athletic track. And this is mimicking the real-time environment where international athletes perform. First, let us see the parts of this ki-sprint. The ki-sprint is nothing but a part of this block. It is a **piezoelectric sensor-instrumented starting block**. And this starting block has two blocks.

Here you can find out the one block for the right foot and one block for the left foot. And in between, there is one spine. And if you see here, we can move this block to different angles. And the angle is from 40 degrees to a maximum of 70 degrees.

The athlete can sufficiently adjust it according to his comfort. He can keep the angulation of the block, and also the front block can be kept between 40 degrees to 70 degrees, somewhere where the athlete feels comfortable. The second one is the distancing of the starting move.

Type of block Start:

We are going to see first the types of start. In sprint, we have three types of start: one is bunched start, another is medium start, and the third is elongated start. So, the **bunched start, medium start,** and **elongated start** can be categorized based on the block-to-block spacing. For example, normally athletes will keep about 30 centimeters from one block to the other block distance.

Here we have a front block, and the rear block. The distance between the front block and rear block is one foot, which is almost 30 centimeters. So, when you keep approximately 30 centimeters, it is called a bunch start. When it comes to one and a half feet, almost 45 centimeters, it is a medium start, and when the athlete keeps two feet, which is 60 centimeters, it is an elongated start. The type of start, which Poovarasan is going to perform, is the bunch start. He is very comfortable with the bunch start.

[Now we are going to see how he is fixing the block spacing and how he adjusts the angulation].

When it comes to the bunch start for Poovarasan, first, he has to fix the distance of the front block. So, the front block is 2 feet from the starting line. From the starting line, you can see it is 2 feet. The front block is adjusted exactly, and we have already fixed the block. The rear block is 3 feet, meaning from the starting line, you can see him keeping it 3 feet from the starting line.

The block-to-block spacing is only one foot, I would say. Now the block is comfortably fixed, and he has to fix the angle. What is your preferred angle for the front block? What is your preferred angle? - This can be set by positioning the athlete on the block, then we can adjust.

[Now Poovarasan is going to sit on the block, and we will be adjusting according to his convenience. So, now we have set the front block to 50 degrees].

We set the angle of the front block to 50 degrees, which he did not find comfortable, and now we have set it to 45 degrees. So, the angle of the front block is set at 45 degrees for Poovarasan.

What about the rear block? Are you comfortable with the rear block, or should I increase it? So, he says that he is comfortable with the rear block at 40 degrees. Now, we have set the starting block, the block angle, and the block distance.

This is how we fix the angulation and distance of the block. Now, it comes to relax. We are going to see what the components involved in this starting block are. So, the first one is a spine, and two blocks are there. So, these are all sensor-fixed blocks, and these sensors are connected with wires, and both the blocks' wires are connected to a DAC, which is called a data acquisition system. So, data is transmitted to this DAC, and from here, you can see two cables coming to this DAC, another two, which we have here, is a laser component. This laser will track the athlete up to 30 meters and will tell us what their acceleration is. Also, we have one more video camera, which is sagittally fixed, which is not shown in this video, but it is just opposite to me. It is kept sagittally to the athlete's movement plane.

Now, the camera, the video camera, which is kept perpendicular to the plane of motion, and the laser and two blocks, all are connected to the DAC. And from the DAC, you can find one cable moving to the system. So, the data is transmitted to the system via a USB cable. So, all the hardware and software.

The system hardware has exclusive software. This is how we are going to fix it. And now we are going to see how Poovarasan is going to perform the crouch start. Particularly, he is going to perform a bunch start. So, we have set up this starting block and fixed it according to the convenience of Poovarasan.

One more component we have is a force plate. So, in front of the starting block, it will measure the hand force. Apart from this, we have subsequent force plates which are kept here underneath the ground. You can see the force plates which are fixed underneath. All these force plates are three-dimensional, having piezoelectric sensors. Now, the athlete will have a comfortable runway, on par with the international competitive track environment, and he will not feel any difference, so as to have absolute and real-time values when we

measure the crouch start technique. When we have this system, the personnel must be well-trained. We have an operator. This is none other than our faculty member, Mr. Tamil Selvan, and he is going to operate the whole system. Now, we are going to place Poovarasan on the starting block.

When does it become a false start?

In athletics, people often refer to a false start. A false start is when the athlete starts before the gun is fired or before the gun sound, I would say. For example, it is considered a false start when the reaction time is less than 100 milliseconds. That is also a false start. A human cannot have less than a 100-millisecond reaction time. So, we will see what the reaction time is. Reaction time is the time interval between the gun firing and the first reaction that the athlete makes. So, the reaction time is always between 130 milliseconds to 160 or 170 milliseconds for all elite-level athletes. And whatever reaction time they have, it should be consistent enough.

For example, if it is between 130 milliseconds to 150 milliseconds, yes, the athlete can have a better advantage. Apart from the reaction time, we will also have the block release time, and this system will help you determine the reaction time and the block time. These are the time parameters.

Then, the velocity parameters, how fast the athlete releases from the block. So, that is the block release time. That is also measured in milliseconds.

When it comes to time parameters, the next comes the strength parameters. What is the amount of strength he applies to the front block and the rear block?

So, when we have the strength and time parameters, we can determine the power parameters. So, what is the amount of power he applies to the front block and the rear block? And when we have time, strength, and power, the fourth component is impulse. So, how long is the foot in contact with the ground?

Force multiplied by time, which is measured in Newton-seconds. So, the impulse in the front foot and the rear foot. And when it comes to all these four primary parameters—that is, time parameters, strength parameters, power parameters, velocity parameters, and impulse parameters. So, here you can also identify these parameters with respect to your hand. [So, now we can ask—I think Poovarasan is ready, right?]

So, he adjusts his body, prepares his position, and sets himself in the starting block. Now, the operator is ready and will mimic the competitive situation—you mark 'set,' then the gun is fired. So, I just stand here without blocking the camera.

[Yes. The athlete is ready. So, now the operator will operate].

The athlete had a brilliant start, a beautiful start. And now, all the data is recorded in the software. From the hardware, the signals, all the information is passed down to the system, and we have all the templates, as I already said: all the time parameters, velocity parameters, strength parameters, power parameters, and impulse parameters with respect

to starting. And also, we have the connectivity on the, I mean, the hand force. A separate force plate is fixed, and subsequent force plates were fixed when the athlete was sprinting.

So, those force plates will help us identify the contact time, flight time, and the peak force in three dimensions. So, all these force plates are three-dimensional force plates, and those force plates will give us three-dimensional data. And what is the peak force—I mean, peak vertical force, peak medial-lateral force, and peak anterior-posterior force—and how long the athlete is in contact with the ground and how long the athlete is airborne, the flight time. So, all these parameters can be measured.

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