Exercise & Sports Biomechanics
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Lecture 46
Introduction to force plate

[Hello everyone! Welcome back to the course].

Today, we are going to learn about force and the tools to measure force in sports and exercise movements. Though you may have studied force in previous lessons.

What is force?

We always define force as either a push or a pull. Force acts in two directions: either pushing or pulling. Not only horizontally, but if it acts vertically, pushing force is **compressive force**, and pulling force is **tensile force**. In sports, sometimes force acts exactly as a pull or push, and sometimes it is a combination of different forces, such as pull, push, compression, and tensile. So, it acts in combination.

What is the unit of force?

The unit of force is the Newton. How can we express a Newton? One Newton is equal to the amount of force required to accelerate a 1 kg mass at 1 meter per second squared. This is how one Newton is defined.

[And next comes]

Measurement of force:

When we measure force, we either say in Newton or times the body weight. We will see in the right picture, so you can see different forces acting on the hammer thrower. So, ground reaction force and his body weight is acting as another force, which is, and the friction force is another force. So, different forces will be acting on a human body during the exercise and sports movements. [And here you can see the tool to measure the force].

What is the tool to measure the force?

Force plate: What is a force plate?

First, we will see a force plate. The force plate is a tool to measure the force. Though there are so many instruments to measure the force, force plate is considered as the one of the finest valid instruments to measure the force.

You can find out the force plate, which is given in this picture. Yes, these force plates are the one which instrument which measures the contact force and the reaction force along with the time parameters. Any force plate will have a load cell and the load cell will measure the force as well as the time, and rest of the parameters are derivatives.

Which are the areas where we use force plates?

We use them for gait analysis, walking, running, sprinting, and jumping, and even throwing, because wherever the foot is in contact with the ground, we use force plates to measure. At the same time, in boxing, when boxers punch on the force plate, the force is measured.

[Next comes the normal jumping movement and weightlifting movements].

So, we use the force plate to measure whether the weight is equally distributed or not. Then the functional assessments, like drop jump, countermovement jump, and dip jump. So, these are all the different ways the body moves. These are all the functional movements where force plates are used to measure different key performance indicators, which we will see later.

I**nstrumented starting block:**

An instrumented starting block is used for measuring the block phase and key performance indicators when the athlete starts sprint events.

What is the importance of force plates in sports and exercise?

Rehabilitation:

Force plates are used in the field of rehabilitation to bring the athlete back to normalcy. We need to assess the movement, the asymmetries, and identify the weaknesses of the athlete. Then we give the remedial measures. And performance optimization. We can even get the values of elite sportspersons and, with the benchmark values, assess the budding intermediate or elite athletes. We can measure their performance and also compare.

Data-driven training:

To get some insight into where they are and to provide data-driven training. So, what is data-driven training? For example, when a long jumper goes for takeoff, how long their foot is in contact with the ground and what is the amount of force acting on their legs during the takeoff? So, with regard to vertical force, that is ground reaction force. So, this will be big data or important data, vital data for the strength and conditioning population to design and develop the training program for the jumpers.

Not only for the jumpers, but for all sports persons. So, whether it is hockey, football, volleyball, or basketball, whichever the game may be, So, depending upon the different movement patterns, they get better insight to design and develop any performance improvement program.

Injury prevention:

The force plates are used to prevent injury because we will come to know about the landing pattern of the athlete. For example, So, we will be using the force plate to measure the different reaction forces, that is, three-dimensional reaction forces in the XYZ direction.

Integration of force plate with motion capture system:

We already studied 3D MoCap, that is, the three-dimensional motion capture system. The 3D MoCap helps us to identify the object's position with respect to three dimensions, that is, in the X, Y, Z directions. So, in a simple way, if I want to convey it, that is anterior-posterior, medial-lateral, and transitional, that is, the transverse plane. In these three planes, how a body moves, what distance it moves, and what speed it moves.

So, that is what we used the motion capture system for. In the same analogy, we do have three-dimensional force plates. The three-dimensional force plates are useful in assessing and measuring the three-dimensional force. That is, the force plates always measure the force vectors.

The ground reaction force is referred to as the Z force. The angular posterior force is measured along the Y-axis, and the medial-lateral force is measured along the X-axis, which we will see in detail in later chapters. Furthermore, for injury prevention, we perform whole-body biomechanical analysis using the force plate. So, these are all the important fields of application, and we assess athletes using the force plates.

Components of force plate:

If I use a force plate, what components are required? So, the first one is—yes, you can see it in this picture. So, number one, we need the force plates—that is the hardware. And the second one is, we need the cables. [So, the cables are not shown here], but in the instrumented starting block, you can find out the cables. The cables are connected with the force plate and the one end. The other end of the cables are connected with the DAQ. DAQ is nothing but it is an instrument which receives the signal from the force plate and it transmits the force signals to the computer and the software.

So, the number one denotes the force plate, the number two with regard to ki-sprint, the instrumented starting block is concerned. We have laser as well as the video camera which will see the movement of the athlete when he is performing any activity on the force plate. So, totally there are four components

1. Force plate
2. Video camera
3. DAQ (data acquisition system)
4. System software.

And further to this, the cable. The cable is the one which, transfers the data from the force plate to the system. And so you can see the cable. So, the cable is one end of the cable connected with the small component.

DAQ:

You can see there are two components. So, the small component is connected to the force plate, and the large component is connected to the DAQ. And this is the DAQ you can find.

So, each DAQ—I mean, the DAQ has around 64 channels. So, the 64-channel DAQ is used where we can connect almost 8 force plates to one DAQ.

The moment the data is transferred, you can find the specific software, which will give us the data about the ground reaction force, moment, center of pressure, impulse, and all the forces in three dimensions. So, what we have seen are analog force plates. So, each force plate has to be connected to the DAQ. So, at the bottom, with the red line on the right side, you can see the DAQ box. There, and here in the digital force plates, that is going to come manually from the Kistler, so you can connect 'n' number of force plates with one single cable. At the same time, there is no need for a DAQ. Obviously, the cables—a single cable—it is a daisy-chain link, and it can be connected to the system.

We can connect 16-plus force plates in one stitch, and we can synchronize them. At the same time, we can fix these force plates at more than 100 meters. Then, the cabling is very minimal. So, this is the advantage of digital force plates. So, in the future—maybe after this course— So, in India or in the Western world, you might come to know about digital force plates.

How a force plate works and how the force plates records the data?

The force plates are having an important component called the sensors. The sensors are otherwise called as load cell. So, the load cell are fixed in the force plate and the load cells reads the force and transmits the force via cable and the cable further takes the data to the DAQ and then from the DAQ, the data is transmitted to the software. The software gives us all the values in numbers as well as in the graphical form.

Load cells in force:

So, the load cells, we have two types of load cells in force plate predominantly used in the industry. One is **strain gauge**; another one is **piezoelectric load cells**. So, we will see what are the advantages and different features we have in the load cells. So, each type of load cells will have a different feature.

Type of load cells and their features:

[First, we will see the strain gauge load cells].

Strain gauge:

The strain gauge load cells are used in different force plates and it measures the electrical resistance due to the deformation of spring element. So, the spring element deformed. So, the moment the spring element is deformed, there are some electrical resistances being measured. So, based on this metric, we measure the force. And further, so you can see here how the spring element functions.

When there is a pressure or when the force right, which creates the deformation on the load cell. So, obviously, the resistance of the electrical changes is measured at the same time the force is recorded. So, you can see as we discussed the compressive force and tensile

force. So, compressive force when forces are acting towards each other and the tensile forces are when it acts opposite to each other.

[And next comes]

Piezoelectric load cells:

The piezoelectric load cells it measures the electrical charge. When the piezoelectric crystals are encountered with certain pressure or force, so it creates some electrical charge. So, these electrical charges are recorded and then the force is estimated. And here you can see how strain gauge load cells are functioning. At the same time, how the piezoelectric cells are functioning.

It is given in the graphical component, we can see how the load cells are fixed in the force plate. So, before that, we can see that what is the comparison between strain gauge load cell and piezoelectric load cell. First one is the piezoelectric load cells. The piezoelectric load cells are very sensitive and it can record high frequency data, and whereas the strain gauge load cells are used for some static function.

Functions of piezoelectric load cells:

And first, we will discuss about what are the advantage or features of piezoelectric sensors. So, the piezoelectric sensors can record any high natural frequency. So, in sports, most of the time, we go for high natural, I mean, frequency movements. Say, for an example, landing in a basketball jump, and when volleyball player undergoes the takeoff and landing. So, obviously, these types of movements are high frequency and these high frequency movements can be recorded by a force plate which has piezoelectric load cells.

And, second one is all the dynamic movements can be captured as it is recording the high natural frequency movements obviously is the dynamic movements are captured through the piezoelectric load cells, that is the ideal force plate to measure any dynamic movement and so any dynamic movement will happen only for a less amount of time. Say for an example, when a sprinter is running, we will be having lesser amount of, say for an example, it is 80 to 150 milliseconds. The foot contact time of the sprinters. But when we have this force plate, hardly it is on about 3 to 5 seconds, maximum 10 seconds. So, the high dynamic movements will be over within 5 to 10 seconds and but when these force plates are functioning beyond certain time, say for example more than 10 seconds or 20 seconds, so when is it is recording the data, so there is a possibility for drift. Drift is nothing but the additional force because the

The piezoelectric sensors are very sensitive. The piezoelectric sensors are very sensitive. That is why we use them for dynamic movements, but they can be on for 5 to 10 seconds, not more than that. But What about strain gauge force sensors?

Functions of strain gauge:

The strain gauge force sensors have a lower natural frequency. So, these force sensors are used to measure movements that are lower in frequency. And so, they are not suitable for fast events. They are suitable for slow events.

They are good force plates for events like archery and shooting, where the shooters and archers stand on the force plate for quite a long duration, say for example 20 seconds or 30 seconds, from the initiation of the movement to the completion of the movement. So, these force plates are very comfortable and valid for using and recording the data for low-frequency movements like shooting and archery. But whereas in maximally the sports movements are very dynamic in nature and have a high frequency.

Piezoelectric sensors are ideal for fast-paced movements. As compared to piezoelectric sensors, strain gauge sensors have less possibility of minimal drift. So, this is the advantage of both strain gauge force plates and piezoelectric force plates. You can decide based on which application you go for, and then you can decide the force plates.

Obviously, yes, piezoelectric sensors can also be used for low-frequency movements, but they are not as comfortable as strain gauges. But strain gauges can also be used for high-frequency movements, though they are not as robust as piezoelectric sensors. So, here you can see the components, the elements of a force plate. So, you can find three load cells which will measure three-dimensional forces like x, y, z—vertical force, medial-lateral force, and anteroposterior force. So, the load cells are fixed at the four corners of the force plate.

So, you can find the three-crystal, differently colored load cells that are placed in each corner of the force plate. So, these will receive and transmit the signal through the cables.

[And next come]

Types of force plates:

1. **Uniaxial force plates**

Uniaxial means the force plates will give you only one-dimensional data. That means only the vertical force, z-force. So, the other forces cannot be measured. So, these force plates are predominantly available in the form of portable force plates and dual Uniaxial force plates means we use counter movement jump and drop jump, squat jump. So, these are all different movements we use both the feet on the force plate and perform the activity. So, to isolate the force, how much amount of force in each leg is applied. So, we can identify those forces by having two force plates. So, that is dual uniaxial force plates. It is I mean used for counter movement jumps, squat jump and all strength and conditioning functional movements.

2. **Tri-axial force plate:**

It is a three-dimensional force plate. In other words, it is called as tri-axial force plate. Tri-axial force plate is the one which we have already I have told you about X, Y, Z. Yes, Z force is the vertical force and X force is the medial lateral force and Y force is the anteroposterior force. What is a force plate and what are the components of a force plate and what are the different load cells and what are the advantages of strain gauge and piezoelectric sensors and what are different axial, it is dimensional force plates, one dimensional and three dimensional.

[next we move on to **different force vectors**].

Though I have already told you about XYZ, so again I can come out with a practical picture. So, when the subject is walking, you can find the force vector which is shown here in the green color and the direction of locomotion. So, towards the direction of locomotion, we have all the positive force.

Whenever there are three-dimensional forces, we can have six components. That is X plus and X minus, Y plus, Y minus and Z plus, Z minus. But we take the positive force because it helps us to propel forward. We discussed about ground reaction force in human movement. So, here we can see the pictorial representation of the force plate.

It is a strain gauge force plate for your easy understanding we have given here and there is a ground and on the ground the strain gauge force plate is fixed. On the top of the force plate, the subject candidate walks. The moment he applies the force downward, yes it is a contact force which is received by the top plate and transmitted to the load cell. The load cell receives the force and the moment there is a deformation and again the Newton's third law occurs. For each and every action, there is equal and opposite reaction. So, for the contact force, the ground reaction force is the one which is being measured.

What is the importance of ground reaction force?

The ground reaction force helps us to find out the amount of load borne by each segment of the joint. So, it is transmitted to the ankle, knee and the hip. So, how this ground reaction force can be dissipated or minimized using different technique, landing technique or using different footwear.

[Next, we are going to see the]

Force plate dimensions:

We have discussed about different key factors of the force plates and what are the dimensions the force plates come with and do we use the same dimension of force plates for all applications or should we go for different dimensions is the class we are going to see further in detail. So, here you can find out the force plates with different dimensions. So, we have different dimensions of force plate given here.

Two force plates are there, so first one is length that is given in millimeters, 600 mm. So, second force plate comes with 298.5 mm. Then comes the width of the force plate. So, the width of the force plate is 500 mm, for the first one and the second one also has the 500 mm width and then height. So, the height of the force plate is like it is 50 mm for each force plate. So, these are the force plates used for portable purpose and small movements. Then the measurement range, when it comes to a force plate the measurement range also taken into consideration. So, we will see uh about the force plate dimensions in details, so far we have discussed about uh what is force plate and what are the different types of load cells and what are the features of each load cell and how to select force plate for each dynamic as well as low dynamic static movements in sports and exercise.

[Now we are going to see about force plate dimensions].

Force plates come with different dimensions. One is like the first one what we see here is the **portable force plates**. So, the force plates dimensions are mentioned with respect to length, width and height. So, here you can see two types of portable force plates which comes with 600 millimeters and 298 millimeters in length.

Another one is **width**. So, in width, we have 500 on each force plate and next comes the height. The height of the force plate is 50 mm. So, then next comes the measurement range. So, the measurement range is like since it is a three-dimensional force plate, we have x, y and z. So, the measurement range is measured in kilo newtons and as far as fx and fy that is a medial lateral force and anteroposterior force we have minus 2.5 kilo newton to plus 2.5 kilo newton in this force plates and always the z force will be higher than the fx and fy that is x and y so why because always the vertical force is higher than the rest of the two forces. So, if you see here, they have Z, that is vertical force range, measurement ranges up to Z from 0 to 5 kilo Newton. So, what the maximum range of measurement that can happen on a force plate? Roughly, if we say 5 kilo Newton, so it is 5000 Newton. So, up to 500 kg measurement can happen with respect to vertical force.

Another one is the frequency. So, frequency is nothing but how fast the load cells can record the data. So, it is, which is measured in hertz. Yes, the frequency of XY force is somewhere 400 hertz for the first force plate and for the second force plate, it is 900 hertz. And when it comes to Z force, it is 200 and 300.

And, the weight of the force plate is also taken into consideration. So, the first force plate is 8.6 kg, and the second one is 5.5 kg. So, other than these force plates, we do have different force plates with different dimensions used for various sports applications. Yes. So, we have—this is a permanently mounted force plate on the mounting frame. So, this is used in laboratories where it can be fixed permanently, and this is used for different sports applications. For example, the first one has a length of 900 mm, a width of 600 mm, and a height of 100 mm, and the second one is 1200 mm in length, 600 mm in width, and 100 mm in height, and the third one is 900 by 900, which is square in shape. When it comes to the measurement range, you can see that it is greater compared to the portable force plates. Here, fx and fy range from minus 10 kilonewtons to plus 10 kilonewtons. And the other force plates range from minus 5 to plus 5.

So, we can choose different dimensions, different measurement ranges, and the frequency as well. There are frequencies that can be set in the software. So, we can either increase or decrease the frequency. And the weight of the force plate is around 25 kg, 28 kg, and 30 kg, respectively, as shown in the picture here.

The use of force plates:

For example, if we are using these force plates for sprint mechanics, yes, normally sprinters will have a stride length of more than 1.5 to 1.6 meters. So, if you take the elite international sprinters' stride length—I mean step length, step length. In other words, we call it stride length in sprinting. So, the distance from one foot strike to the other foot strike. So, obviously, for Usain Bolt, it is almost 2.4 to 2.5 meters on average.

On average, the step length or stride length is 2.4 to 2.5 meters. So, these types of force plates, right, will not help those athletes. That is why we go for longer force plates. But when it comes to walking gait, the average step length is 60 to 80 centimeters. And these types of force plates, which were previously mentioned, are portable.

So, if anyone has 60 to 70 centimeters, obviously they have to go for the second force plate. But this small force plate, cannot be useful for measuring walking gait. So, it can only be used for static movements.

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