

Exercise & Sports Biomechanics
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Week 11
Lecture 54
Pressure Plate System

[Hello, friends! So, in this section, we are going to discuss the plantar pressure system].

Plantar pressure:

A plantar pressure system measures and analyzes the pressure distribution on the sole of the foot, providing insights into foot function, gait, and potential health issues. This system is used in various fields like sports medicine, physical therapy, and footwear design.

Particularly, a foot pressure plate. A **foot pressure plate** is a sophisticated biomechanical tool used to measure and analyze the distribution of pressure and the forces exerted by the foot during static and dynamic activities. Static like standing activities and dynamic like walking, running, and jumping activities. It provides detailed real-time data about the interaction between the foot and the ground which is critical for understanding gait mechanics, foot alignment, and postural control.

Talking about the **purpose of foot pressure plates in biomechanics:**

It is required to analyze foot strike patterns in athletes. It is required to assess foot alignment issues, like overpronation, high arches, or any other problems. To monitor postural stability and balance and to design customized orthotics and footwear. The analysis of foot pressure basically identifies injury risks and improves rehabilitation strategies. This kind of analysis enhances sports performance through gait and foot strike optimization.

The significance of this kind of analysis, like the athlete's foot mechanism, directly affects the performance and the injury risk. Running and jumping efficiency depend on how the foot interacts with the ground. A faulty foot mechanism can lead to overuse injuries and reduce efficiency. The foot pressure plate offers objective data to modify training strategies and enhance biomechanics.

Considering a plantar pressure system or the foot pressure system, there are **various components of that plate:**

One of the component is called a **sensor array**. There are a number of sensors which are basically attached in a particular area, like in this particular kind of pressure plate. You can see this white rectangle, so there are the sensors which are spread over this particular area, and this is called the sensor array. So, a foot pressure plate system includes this kind of system, and it is made up of thousands of pressure-sensitive elements, like piezoelectric, capacitive, and resistive, which we have already discussed in the previous section. And they are embedded across the surface of the plate. The sensors are embedded.

The high-resolution sensors capture even subtle variations in pressure. So, that is why the higher the number of sensors available, the more accurate—or, you know, the more data we get. The frequency of data collection will be higher. The sensors are arranged to cover different regions of the foot.

They can provide you the data for the heel, midfoot, forefoot, toes, everywhere. The data acquisition system is another component of the foot pressure plate. And it converts the analog signal from sensor into the digital signals. And high speed data transmission ensure the accurate capture of dynamic movement. It is capable of having the sampling rate of around 1000 Hz, or I can say the 1000 measurements per second the plate is capable of. It ensures the low latency for the real time feedback, and it depends on the number of sensors. So, higher the number of sensors, there will be low latency.

The software interface is another component of the foot pressure plate:

It processes the raw data to generate pressure maps, force time course, and the center of pressure trajectories. It provides real-time visualization, and data storage. It allows data export for further statistical analysis.

The calibration system is another component:

It ensures the accurate pressure measurement by compensating for environmental factors, like temperature and humidity. The calibration ensures consistency between trials and between different pressure plates.

How does it work?

The subject needs to stand, walk, or run over the plate. The sensors, which are spread over the sensor array, detect variations in pressure and force exerted by different foot regions. The data acquisition system records the pressure and force signals in real time, converts them into digital signals, and the software processes the data. You will get the report straight away. So, the software processes the data to create, you know, the pressure maps. It shows the pressure intensity, which is usually color-coded. The darker the color, the more pressure there usually is.

This is roughly how the **pressure map system** works. We can get the force-time curve. So, to show how force changes over time, we can get the center of pressure, which is the COP trajectory. To show the shifting point of pressure during the gait, and obviously, the data is analyzed to identify biomechanical parameter abnormalities and performance inefficiencies.

The **biomechanical parameters which can be measured using the pressure plate are**, first, the **peak pressure**. So, it measures the maximum pressure applied on a specific foot region, like the heel, mid-foot, and the forefoot. A high peak pressure may indicate abnormal foot mechanics or overloading. For example, a high heel strike pressure may increase the risk of Achilles tendinopathy. So, this kind of risk factor we can identify using parameters like peak pressure, we can get the forces, force distribution. So, it measures the total force exerted on the plate during movement. It provides insights into the ground reaction force and how these forces are absorbed by the body.

The high impact force may suggest poor shock absorption, leading to continuous injury. We can track the center of pressure here. So, it measures the shifting point of pressure during the different gait phases like; what is the center of pressure during the heel strike during the mid-stance, during the loading phase, during the heel off, during the toe off, and how is the line of progression of walking? How is the center of pressure moving in that direction? What is the sway distance the center is basically having? What is the sway velocity? Everything we will be getting into this parameter. So, the COP trajectory reflects the posture control in the balance.

For example, a lateral shift in COP may indicate supination or ankle instability. Another parameter which we are discussing here is the contact area. So, it measures the total area of the foot in contact with the plate. Or roughly, we can get the area of the foot with this. So, that is again an estimation of the parameters that we can get.

A large contact area indicates flat feet or excessive pronation. And a small contact area indicates a high arch or reduced foot mobility. There are different ways of interpreting the values and all, which we will discuss in detail during the demonstration of the equipment. It measures the percentage of time spent in different phases of the gait, like during the heel strike phase, during the mid stance phase, or the toe off phase. The asymmetry in this phase distribution indicates gait abnormalities. So, this kind of thing we can identify with this kind of parameters.

We can get the pressure time integral with the help of the software interface in the plate. So, it measures the cumulative pressure applied over time. The high values indicate the excessive loading and increased risk of stress fracture. Like for example a marathon runner will with high pressure time indicate that often suffer from stress fracture.

We can get the asymmetry index with the equipment, so it measures the difference between the loading pattern in the left and the right foot. So, that we can identify the symmetry and the asymmetry among the right and left side. High asymmetry may suggest the leg length discrepancy or the muscle imbalance or the postural control issue. So again, there are various ways to interpret the things.

There are different type of pressure plates which are available in the market:

One of them is called **static pressure plate**. It measures the foot pressure while standing only and it used for evaluating the postural stability and the foot alignment. It is common in the clinical settings for assessing foot deformities like the flat foot or the high arch foot kind of thing.

Another type is called **dynamic pressure plates**. It measures the pressure during walking, running, and jumping. On the other hand, it can also measure the pressure during static positions. So, this is always better than the static one then. And it is useful for analyzing gait mechanics and sports performance, and it detects abnormalities like heel strike and forefoot loading.

Portable pressure mats are another type of pressure plate available in the market. They are very lightweight and flexible, and they are used in field settings and outdoor

environments. They are less accurate than fixed pressure plates but convenient for quick assessments.

So, this is the biomechanical consideration in sports and clinical practice, like considering the foot structure and alignment. If we are testing a particular person or athlete on the pressure plate for different foot types, what could be the pressure pattern that we can observe, and what could be the biomechanical impact of that? This is something you can see in this particular slide. For example, if a person has flat feet. Clinically it is called pes planus. So, the pressure pattern will be more on the medial side. We can observe increased medial pressure in the output, and it indicates poor shock absorption and overpronation.

On the other hand, if we talk about another foot type like the high arch, clinically called pes cavus. So, the pressure pattern will show increased heel and forefoot pressure in the pressure mapping. And it means there is a reduced contact area and poor balance that we can observe in the particular athlete or subject.

If the foot is neutral, like it is having an optimum amount of arch, so we can see the balance pressure distribution into the pressure mapping and it is optimal performance we can get and it is good for the injury prevention as well.

Talking about the biomechanical considerations in sports and the clinical practice, so we can utilize this kind of setting into the gait cycle analysis. So, the foot pressure plate measures the key phases of the gait, like it can measure the heel strike. The pressure mapping during the heel strike like the high pressure on the heel. The mid stance, so during that we can identify the center of pressure shift from heel to mid foot, and during the toe off like the high pressure on the forefoot. So, you can see in this particular image also you can see how the pressure is being changed from the heel strike to the toe off kind of thing.

So, this kind of analysis we can define the practice we can use using the planter pressure plate. We can utilize the equipment during the sports performance optimizations like in running, jumping and the cutting and pivoting, the agility movements. Like in running, the foot strike pattern affect the impact forces and the performance,

We can identify that with the portable devices. In the jumping, the optimal takeoff mechanism reduce the injuries. So, we can again place the pressure plate at the side from where the athlete is taking a take off so we can identify the pattern that side as well and as well as during the agility movement or the cutting and the pivoting movement we can check the balance loading that may enhance the stability of an athlete. So again, it is you know there are different ways of using the equipment, and there are different ways of interpreting the values. So it is as per your own usage and the requirement.

We can utilize the device in case of injury risk and the rehabilitation. So, we can identify the various conditions of the foot, like the plantar fasciitis, metatarsalgia, stress fracture, ankle instability very easily, and we can definitely work for the injury prevention as well as the rehab, we can monitor the rehab during that time. So, like in the plantar fasciitis we can see the high heel pressure, so we can indicate we can interpret the data from there if there is an increase forefoot pressure this probably may indicate towards the metatarsalgia. Like high localized pressure may indicate a stress structure and the lateral center of pressure

deviation. So, that basically indicate lateral or medial whatever it may basically indicate the anchor instability.

Again a different way of interpreting and using the data. So, this table basically indicates the data interpretation and the application. So, there are several observations which have been indicated here. And the biomechanical implications and the correction strategies are shown here. Like for example, if a person is having a high medial pressure, it indicates that it is an overpronation and the correction strategies are the orthotics or the arch support. Although this is not a fixed one, this is just an indication one. So, if the person will be having an increased lateral pressure, so that indicates supination and there are various correction strategies for that as well. If we can observe asymmetry in the left and the right foot loading, so this may indicate the leg length discrepancy. And if the person is having a high forefoot pressure, so in this case we can, you know, say that or consider that the person will be having a poor toe of mechanism. And we have several correction strategies for that as well.

[Lastly, if I am talking about biomechanical considerations in sports and clinical practice only].

What are the advantages and what are the limitations?

The advantages of the device are that it is non-invasive and provides real-time data. The feedback is highly sensitive, and the person can easily correlate it with the symptoms they are having or the pattern they are following.

We can obtain objective and reproducible data very easily, and it is portable and very easy to use. I am personally using it. Talking about the limitations, again, the surface contact variability is there because it is made up of different surfaces and materials. The soft tissue interface is there, and interference is definitely present. It requires expertise for interpretation, and the high-resolution plates are costly. So, the ones with more sensors are obviously more costly, and those are the ones that provide more accurate data.

Conclusion, in this section we discussed how foot pressure plates provide detailed insight into foot mechanics, gait patterns, and posture control. They are critical for improving sports performance, preventing injuries, and guiding rehabilitation. Understanding and interpreting pressure plate data enables targeted interventions to enhance biomechanical efficiency and athletic performance.

Let us have a demonstration of the pressure sensor plate.

This is also called the plantar pressure plate. And this is made of OHM, and the model is OHM 6,000. So the 6,000 indicates that it has a 6,000-sensor under this white rectangle that you can see on the plate itself. And you can see it is written as OHM 6,000, and it has an interface, something like this. So we need to log in here.

And once we log in, we have an interface, something like this. So, let us register here for a new patient. We need to fill up the demographic data here. Once we have the profile created, you can see the name has appeared in the first place. So after clicking that, we can proceed with the step test or advanced test.

So, let us start with the step test first. Here also, we need to first go for the assessment because we need to fill in more information here.

And here the past history is listed. We can input the past history as well, including any medication if the person is undergoing treatment for diabetes, hypertension, and so on.

But we need to go over the personal history here. And we need to put in the weight and height here. It is needed in order to get the right pressure mapping done. And if you want, you can fill in the required data as well, but that is not mandatory. So, just go for the save. And we are all ready.

So, for that, first we need to do a mat setup. The mat setup involves the mat needing to be first connected to the electrical supply via this adapter, and this USB cable needs to be connected to the laptop. So, this setup needs to be there, but before doing any test, the mat itself or the software itself checks whether the connection is made or not. So, we need to go for the mat setup first. Yeah, so it asks us whether the mat is placed. Yes, we need to check it and connect the USB cable, and we're done. So, the software is doing a connection calibration part. So, it is already connected. We are done.

Now we are ready to do the test. So, you can see that there are a number of tests that can be done. One is called the **bipedal stance test**, one is called the **foot posture test**.

We are not having currently the foot posture, but the foot posture comes with the camera setup that connected with the mat and we can do the foot analysis. Then a stabilometry test can be done. Dynamic test can be done. In the last row, it is like the capture evaluation and the report generation. But the major test we can do here is the bipedal stance, stabilometry and the dynamic test.

Let us start with the **bipedal stance test**:

It gives you the instruction like for the bipedal. So how the patient need to be stand here. So, let us have the athlete here. So, let us ask the athlete to stand on the mat first. So, athlete will stand as per the instruction which is provided there on the screen. Ask the athlete to look forward and start the test. So it record the pressure sensors or the pressure of the foot for around 20 seconds. And it is done, it will process for some time. And you can see the pressure mapping is already here.

And the device basically gives you the pressure map or pressure mapping for both the fields. And you can see the color code somewhere here. So the darker the color, or it goes towards the pink side, the more pressure the particular part is basically having. You can see that this particular part. This part of the foot, they are the one which is basically having more pressure. And the blue one and the white one. So you can see the blue one, the outer edge is a blue one which is basically having a very least pressure.

On the other hand, some toes are basically not coming here. Means they are in the white color. So means there is not at all pressure on that particular thing. And we can accept it or we can retry it. So we are accepting this first, and end test. We can see that report in the report generation. So, we can go to the report generation.

The report is being generated. So, this is the report that we are getting for the bipedal stance test. You can see that. We are getting the pressure mapping on the left side, and here you can see that the pressure distribution is on the left—it is 51.76%, and on the right, it is coming around 48.24%. For the forefoot, it is coming around 29.8%, and on the right side forefoot, it is coming around 18.46%. Similarly, if you go down.

If you go down, yeah, you can see the hindfoot for the left side—it is coming around 70% and 81%, respectively. And on the right-hand side, you can see the values are coming like the maximum pressure that is coming in kilopascals. So, for both left and right, it is coming. The average pressure in kilopascals is coming. The total weight distribution is supposed to be 50-50.

In this case, it is coming around 51.76 and 48.24 for left and right, respectively. The foot area—so the foot area is basically the pressure sensors which are in contact with the foot—which are coming as the foot area here. The foot length and the foot width are also somewhat the same. We are basically getting some preset remarks by the software, like in this case, it is coming as 'increased weight bearing on the bilateral hindfoot.' And we can put our own remarks here as well.

Yeah, these are the place where we can put our own remark here.

Next test, we are going here is the **stabilometry test**:

Let us have a look at that. So, stabilometry, we can basically go for both eyes open and eyes closed. First, let us go with the eyes open. So, again here, the software or the interface will give you an instruction how to stand. So, that is why it is always recommended to have a bigger screen in front of the plate. So, that the athlete or the patient or the subject can get the clear feedback out of it. Okay, get on the plate please. It is coming on the plate like this, and we will start it. Keep both the feet together. We will start it and it will run for around 20 seconds again. It is done the process and it will again give you a pressure mapping. And you can see here also I can see some of the more pressure area on the left side compared to the right side.

Right side is freer than the left side here. We are accepting this as well. And now let us go for the close eyes. So let the person stand on the plate itself. And in the same position, we just ask the person to close the eyes for 20 seconds, just start it, again for 20 seconds.

The patient or the athlete need to be stand with the close eyes with the position which is being demonstrated into the interface. So as the 20 second finish it take a moment to process the things and you can see the again the pressure mapping is coming. So, here also if you see. It is coming more like the same with what it came for the eyes open. He has a more pressure on the left side compared to the right side. We are accepting this as well. Yeah, and the end test. Again, we can go for the report generation.

We have a detailed report here. Again, you can see the distribution of the left and right here. We can get the distribution of the forefoot and the hindfoot on the back. On the right side, we can get the same report, like the maximum pressure, the average pressure, weight distribution—the same kind of thing we got in the bipedal test. So, we can compare.

This is a good comparison report between eyes open and eyes closed. This particular part on the left side is basically for eyes open, and this is for eyes closed. You can look at this particular big black dot. This black dot is nothing but the center of pressure. You can see this dot is not an ideal one, but it is basically a rough dot. It shows that the center of pressure moves somewhat in the case of eyes open.

But in the case of eyes closed, you can see it covers a larger area. It covers more area. So this is the difference that appears. And you can see some differences in the pressure distribution as well. The pressure mapping also appears in the case of eyes open and eyes closed.

When we go down, we can see the detailed report here like what the sway distance is. The **sway distance** means the sway of the center of pressure. So in case of the eyes open, we are getting the sway distance as well as the sway velocity. That is the second one 17.43 and in eyes closed also we are getting the same thing.

We can see here that the sway distance and the velocity both are more in case of the eyes closed. And apart from that, we are getting the bilateral weight distribution. We are getting the anterior weight distribution, posterior weight distribution, maximum medial lateral deviation, anterior, maximum anterior deviation and the posterior deviation. All the values we are getting here for the left and right. You can have a look at complete thing here.

So here we can compare the things or we can correlate the things with the symptoms and we can go for the intervention based on our own understanding. And then again, we can give our own comments and all in the reporting format.

Next test, we are discussing here is called the **dynamic test**:

Dynamic test is nothing but a walking test. So in the walking test, it is basically asked the subject to walk from the plate. It is advised to get both the foot on the plate or it is not necessary also.

If we can get one foot at a time also, the system can take that and it can basically make up a walkway. We will start the thing. So before starting the things. We will ask the subject to first have their markings for the walking, so that we can have a foot placement on the mat itself. So this way you can see, the foot are coming. We have already placed some markers here. And from this side also, if you can walk, the foods are coming, right?

So he has a good marking for that thing. Once we start the test and we will ask the subject to walk. So, we can add this walkway here on the screen. We can add this on the screen again. So, we already have three walkway when we finish the test it takes certain time to get prepare the walkway. It is done already, if you open the dynamic test here and see

that these are the walkways which are coming when you go down, yeah we can see all the three walkways are here. So, if you select the w one and then if you play, so you can see the walkways are coming like this the pressure nothing sense this is walkway number two which is coming up and this is walkway number three.

And if you go to next, from here you can see the graph is coming so this graph is basically the pressure versus time curve. You can see it is somewhat, you know the graph looks like the force time curve as well, and you can see we have selected three walkway walkway number one, two, and three, and all the three colors are coming up coming up here. So, again if we move a cursor on the graph somewhere here and there. So, you see, we can see the particular value of that, the amount of pressure the particular part of the cycle is having.

We can bifurcate this graph into the different phases and we can identify which part of the phase will be exerting how much pressure and all. If you go down, see, we can find out the detailed thing like for the left side, they detected one this thing the foot strike, and on the right they detected two. So, the total number of foot detected were three, and the ambulation time was coming here, the cadence velocity, the walking speed, everything will be coming up. And when we go down we are having some more temporal parameters. So, more detailed analysis, like we are getting the strike time, step time, stance time, stance, swing time, in the second swing percentage, the single support, double support, the heel contact time, and the mid stance. Like all the possible parameters which can be available are basically coming up here.

There are some special temporal parameters as well. As you can see, the step length coming, step velocity, step width, stride length, stride velocity, walking support. So, what I always suggest that we can have a baseline value for all the athletes and all the patients if we are having. And then we can, after the intervention and all, we can compare it with all the previous testing and all. When we go again up and next.

Again, we are getting the previous one, which was the overall analysis. Now, we are getting the specific foot strike that has come here. And in the heat map, if you can see, there is a black line which is going. This black line is nothing but the direction of movement or the line of progression. The line of progression of the center of pressure. How it moves. So this is for the walkway, one for the left and the right. And although the whole foot did not come here, this is something we can change on both sides. Like from this particular arrow, we can shift it to walk number 2 or walk number 3. Whichever is the best possible, which has the best pressure mapping, we can use that for our analysis.

When we go down, okay, then we—sorry—we go to the next. So this is the pressure transfer tracker, and you can see all the parameters here, which will be the pressure transfer for the heel, for the full foot, for the forefoot, the average values—everything will come up here. And if we move on the graph, we can get the value at that particular distance as well. And when we go down from here, you can see some interesting parameters coming up here. One is called the arch index. So with the arch index, we can definitely find out the level of foot pronation and more. Then we are measuring the stance time, the contact area, the peak pressure, average pressure, and maximum pressure. So, there are various parameters—an N number of them—that are coming up, and we can use them for clinical settings and rehabilitation as well. So, as we go down, you can see there are various parameters appearing. So, I believe this could be very useful for clinicians and biomechanists.

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