Exercise & Sports Biomechanics
Dr. Rahul Tiwari
High performance Analyst – Biomechanics, SAI
Netaji Subhas National Institute of Sports, Patiala (PB)
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Lecture 51
Introduction to force transducers and Isokinetic

[Hello, friends! In this section, we are going to discuss **Force Transducers**].

Force Transducers:

In sports biomechanics, a force transducer, also known as a force sensor or load cell, is a device that measures force, converting it into electrical signals for analysis. Force transducers and pressure sensors are essential tools in sports biomechanics, widely used to measure forces and pressure acting on the human body during movements. They provide objective data that helps in analyzing sports performance, improving techniques, understanding load distribution, and preventing injuries.

Human movement involves the application of forces that generate motion. Measuring these forces helps in understanding how the body produces and controls movement. Accurate force and pressure data help in identifying movement inefficiencies, designing rehabilitation programs, and optimizing athletic performance. Examples of biomechanical forces in sports include ground reaction forces during running or jumping, impact force during tackling in rugby or football, and pressure distribution in footwear to optimize running gait, and there are various examples that we will discuss in the upcoming slides. So, the question comes:

What is a force transducer?

A force transducer is a device that measures the magnitude and direction of mechanical force and converts it into an electrical signal. This allows us to analyze the data and derive meaningful information from that particular force. It can be used in clinical settings, sports settings, or for rehabilitation purposes. Force is measured in newtons, as we all know.

Principle on which the force transducer works on, actually it is based on the concept of mechanical deformation. Like when a force is applied, the material inside the transducer deforms that causing changes in the electrical properties like the resistance, charge, capacitance, etc. So this change is converted into an electrical signal proportional to the applied force. The application of the force transducer in sports, it may involve like the ground reaction forces during walking, running and jumping. The joint loading during dynamic movement.

The muscle strength testing using isokinetic machine. We are going to discuss this in detail as well in coming up slides. The digital resistance in sprint like the resistance and assistance both we can do now. What about the pressure sensors? The pressure sensors measures the distribution of force over a specific area and provide information on how pressure is

applied to the body or equipment. Like the force sensors, they measure the force that the body has applied.

On the other hand, the pressure sensors, they measure the pressure the particular body part is exerting or facing like, so it basically gives you the heat map of the pressure at the sole of the foot for example. So, we all know that pressure is defined as the force per unit area and the unit of pressure like it is measured in pascal. It can be applied in sports like the foot pressure distribution in the gait analysis, it can be applied like for the pressure mapping in shoes, and equipment design, and assessing load distribution in rehabilitation exercises. So, the application of the pressure sensors in sports like we can use it for the foot pressure distribution in gait cycles,

We can use that for pressure mapping in shoes and equipment design. It can be used to assess load distribution in rehabilitation exercises. There are various types of force transducers and pressure sensors available. Let us look at them. Both force transducers and pressure sensors come in different types.

Each is suited for specific applications based on sensitivity, accuracy, and response time. The first type I am discussing here is the strain gauge sensor. It basically works on the principle of measuring changes in electrical resistance when a material deforms under load. It consists of a thin wire or foil attached to a substrate. When a force is applied, the material stretches or compresses, changing the electrical resistance.

The change in resistance is converted into a signal that reflects the force applied. It has several advantages, such as high sensitivity, durability, reliability, and suitability for static and dynamic loading.

On the other hand, it has several limitations, such as being affected by temperature variation and requiring careful calibration. It has been applied in various forms in sports. Like it is used in the force plates to measure the ground reaction forces and it is also being used in the isokinetic devices to measure the muscle strength. The another type of force transducer which I am discussing here is called piezoelectric transducers and this generates an electrical charge when subjected to mechanical stress. It is based on the piezoelectric effect. So, it basically works like this piezoelectric crystals. For example, the quartz. It generates a charge when compressed. And this charge is proportional to the applied force. And this high frequency response allow capturing the fast movement. So, this is considered to be the more advanced transducer compared to the frame gauge sensors. It is having several advantages like it is the high frequency response is ideal for the fast movement analysis and it is high sensitive which is very compact and easy to integrate into equipments.

On the other hand it has a limitation like again it is affected by the environmental factors like humidity and it require a very careful handling as well as it is very fragile in nature. The piezoelectric sensors is applied in sports in the form of like it is used in force plates for vertical jump analysis and in addition it is also used in the impact analysis during the ball strike as well.

Another type of transducer which I am discussing here is called **capacitive transducer** and it measures the changes in capacitance due to deformation. It works in a way that a capacitor consists of two conductive plates separated by a dielectric material. And when a force is applied, the separation between the plates changes, altering the capacitance.

The changes is converted into electrical signal. So it has several advantages like the high accuracy for small forces. It has a fast response time and it is suitable for dynamic applications. It has the limitations like it has a lower durability and complex signal processing. It is used in the sports at the various capacity like it is used in the gloves, the pressure sensitive gloves.

It is used in the biomechanical research for small load movements. Type of transducer which I am discussing here is called magnetostrictive transducers and it measures the changes in magnetic properties under the load. So it works like a magnetic material changes its magnetic properties under the mechanical stress and the changes is detected and converted into the electrical signal that has been converted into the analog signal and being displayed. So it has several advantages like high accuracy, suitable for static and dynamic loads and the limitations like it is costly and it is very sensitive to electromagnetic interference so that there may be the noise in the data which we are collecting. It is being applied in the sports like it is used in the high precision sports equipment testing and it is used in specialized biomechanical researches.

Now, moving towards the pressure sensors. So the first sensors which we are discussing here is called piezoresistive sensors and it basically measures the changes in the magnetic property under the load. So it works like there is a thin film or the wire that changes the resistance when deformed and this changes in the resistance is proportional to the pressure applied. And this pressure is then being converted into the analog signals and then displays in the display unit. This kind of sensor has been applied in the various settings like in the foot pressure mapping in the gait analysis.

They are being used for the pressure distribution in the footwear designs. The another type which we are discussing here is called capacitive sensors. This measures the changes in capacitance due to pressure. They works like like you know the pressure changes the distance between the two conductive plates and these changes alter the capacitance which reflect the applied pressure. They are being used at various capacity like they are used in the wearable in sole center gloves as well as they are used for the real time pressure monitoring in the sports performances.

Another type of sensors which we are discussing here is called the optical sensors and this basically measures the changes in light transmission or reflection under the pressure. It works in a way that a flexible optical fiber changes light transmission under the pressure and the changes is converted into an electrical signal here. It has been applied like in the high-end sports research laboratories and as well as it is used for a high precise pressure mapping. The biomechanical considerations for this sensors and the transducers are like, you know, it is considered for the accuracy and the precision. A proper sensor calibration ensure the consistent and accurate data.

The environmental factors like temperature and the humidity can alter the sensor response. Talking about the sensitivity and the frequency, so the response sensor should match the expected range of force and the pressure. The high frequency response is critical for dynamic movement. Otherwise, there will be a difference in the data which we are getting. The load application and distribution like the uneven load distribution can cause false reading.

And Ensure even placement of sensor and the proper alignment with the body mechanics for the accurate data. And last, the data interpretations like the breakdown force into components like the vertical and the horizontal and the shear forces or the pressure and analyze the pressure distribution relative to the anatomical landmarks.

These are the **challenges and the limitations** which we can face, like the challenges like the calibration drift. So it changes in the sensitivity over time. But the solution for this is the frequent calibration. We need to calibrate the system very frequently just to check whether there is a drift or not. Another challenge would be the signal noise. It is like the external interference.

They are affecting the data. And for that, the solution is simple. It is it should have a shield and the filter so that we can avoid the noise. And the last challenge is which I am discussing here is environmental sensitivity, like the temperature and the humidity changes. They affect the data which we are getting.

And the solution is we should use temperature-stable material, and we can control the humidity in a controlled environment and all. So, the force transducers and pressure sensors are vital in sports biomechanics for assessing performance, improving techniques, and reducing injury risk. Understanding the working principle, biomechanical considerations, and proper application ensures accurate and meaningful data collection.

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