

Exercise & Sports Biomechanics
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Week 12
Lecture 57
Practical Application of EMG in Sports

[We are going to discuss **wireless EMG** in dynamic sports activities in detail].

The **wireless EMG** surface EMG sensors are used by placing the sensors on the skin, making them more portable and easier to assess the athlete seamlessly compared to wired sensors. The wireless surface EMG is used for more dynamic and high-impact sports and exercise activities. At the same time, if you want to discuss examples of high-dynamic activities like sprinting and jumping, functional movements, and even sports-specific movements such as basketball jump shots or cricket bowling.

These are all different sports and functional activities, such as half squats or bench presses. Beyond these movements, the surface EMG is also used for diagnostic purposes during clinical tests. Furthermore, it provides real-time notifications on how to improve patient safety. Additionally, we will discuss needle EMG, which is used for intramuscular applications. This is to help students understand how surface EMG is used in different applications.

How needle EMG is used for specific applications?

Needle EMG or intramuscular EMG is based on an invasive method, which may cause discomfort to the subject. It requires a specialized medical professional to perform the assessment and interpret the data. It is used in clinical settings for diagnostic purposes related to neuromuscular disorders. When it comes to needle EMG, it provides detailed information about muscle fibers and their response to nerve signals.

The examples are amyotrophic lateral sclerosis. In short, we call it as ALS and then myopathy, and radiculopathy and carpal tunnel syndrome that is CTS. And the types of needles which are used in needle EMG is like monopolar and concentric and single fiber. These are the different needles they use for needle EMG and the trained medical professional use the methodology of this practice.

What is the difference between the needle EMG and surface EMG with respect to its application and practice?

The needle EMG can access the deep muscles and it is invasive but more precise and it is always a gold standard for diagnosing neuromuscular conditions and it requires a trained medical professional to conduct this experiment. When it comes to surface EMG, it is limited to surface muscles that is superficial muscles.

The deep muscles cannot be, I mean, assessed using surface EMG. And it is non-invasive, purely non-invasive and more comfortable for the athletes as well as the assessors. And it

is also a golden standard for monitoring the muscle activation in research, particularly in sports and rehabilitation and movement sciences. And with respect to surface EMG, anybody, any movement science professional can conduct this experiment.

It is, it can be by an exercise, I mean sports and exercise scientist, exercise physiologist, biomechanist, health and conditioning professional approach. Anybody, a teacher, a professor who teaches about the muscle function and EMG. Anybody can use surface EMG because it is non-invasive.

[We are going to discuss about the familiar EMG systems which are available in the industry].

First comes **DELSYS**. DELSYS always stands for the first EMG I mean sensors from Carlos De Luca who is the founder of DELSYS, and further **NORAXON** and **Cometa**, then **motion lab systems**, and then **biometrics**. **These are all the predominant EMG sensor products available in the industry for research and assessment domain.**

[And here we are going to discuss about the hardware component which is used for EMG assessment].

We are going to discuss in **detail about DELSYS**, because in our lab, we do have only the DELSYS EMG sensor that is surface EMG sensor. In Centre of Excellence in Biomechanics, High Performance Centre for Sports, Tamil Nadu Physical Education Sports University, we have DELSYS system, which is 32 channel EMG, along with the Trigno-Avanti sensors, we do have Galileo sensors which are used to identify the nerve conduction velocity.

First we will discuss about the **Trigno-Avanti sensors**. The name of the sensor is Trigno-Avanti. They have, the DELSYS product comes with different sensors. One of the products which are used, which is used to identify the muscle activation pattern is Trigno-Avanti.

And, we have **32 channel EMG** and this is a base station. Base station is used for charging the sensors as well as the base station is the one which receives the signal from the surface EMG which is attached on the muscles of the subject. The power adapter always charges the base station, and the base station is charged and the sensors also charged in the base station and so here you see an EMG sensor that is wireless surface EMG sensors. This is how a Trigno Avanti sensor will look like and we have a trigger module.

When we use different hardwares along with EMG when we use different hardwares, so we use trigger module to synchronize the timing sequence at the same time these hardwares like sensors are fixed on the muscles. And what are the signal muscle signal that is transmitted to the base station from the base station we connect with the system computer. The computer is having a unique software, so each and every hardware company comes with their own software. When it comes to DELSYS, so it comes with EMG works and EMG analysis. These are the two softwares used to acquire the signal of the data as well as to further process the data, process the raw data I would say,

So for further analysis. And now the DELSYS is working on to come with the ready-made template where the real-time data can be captured, so that is in process. All the software

companies or all the hardware companies are producing, designing their own software. To give the real-time data because the post-processing takes much amount of time where the athlete and coaches or any movement professional expects the instant data which is in real-time.

Now all the hardware companies are working on I mean softwares which can give them the ready made instant real time data. Further, we will discuss about the workflow of the data from the EMG and how the data is visualized from the EMG assessment. Here we have the surface EMG sensor which are fixed on the targeted muscle. And the moment it is, the sensors are fixed, yes, we can perform the movement. The moment the muscles are contracting, the signals are captured by the surface EMG and further the electrodes.

Electrodes transmit the data to the base station and from the base station, the further data is transmitted to the software which is already installed in the computer. The software captures the data and from the software we can go for acquisition of data as well as visualization of data. But one fine component I would like to discuss here is that the DELSYS EMG sensors are made up of silver chloride. The silver chloride component captures the data. Muscle electrical signals are captured by this silver chloride components which is very valid, robust without any loss of signals.

That is the advantage of silver chloride-coated electrodes, and further, how the real-time view of EMG is done and how it is analyzed. real-time EMG can be done—see here—for any movement, whether it is a half squat, bench press, walking, jumping, throwing, or any form of movement. Here in this picture, you can see an athlete or a person running on a treadmill, and the EMG sensors are fixed on different muscles. The EMG sensors capture the signals and the muscle's electrical activity and transmit them to the base station.

From the base station, it is transmitted again to the system, and we can easily visualize the real-time muscle activation pattern in the software. And what information can we gather? Yes, the muscle activation pattern, the muscle fatigue, and the time of activation. That is the important component we can measure from the EMG.

The guidelines for the placement of the EMG sensor:

When it comes to surface EMG, we always follow a protocol based on SENIAM. SENIAM is nothing but a short form of surface electromyography, for non-invasive muscle assessment. As a first step, we need to prepare the skin.

Whenever the athlete is going to be assessed, right, with respect to EMG, we have to identify the target muscles to be assessed. The target muscle zone has to be cleaned and shaved because the hair on the skin may interfere with the placement of the surface EMG. We have to remove the hair. After removing the hair, we have to apply alcohol wipes, to clean the surface area where the surface electrodes can be fixed perfectly.

We also need to identify the location of the muscles. How can an electrode be fixed on a muscle? Sometimes, the impact of sweat can also affect the activity of the muscle. So, ensure that sweat is wiped off frequently during the movement. Because of sweat, there may be a baseline drift.

The signal may appear in a different form. At the same time, electrode adhesion issues may occur; the electrode sometimes may not stay fixed properly on the muscle, and it may detach. There may also be cross-talk and signal distortion. Adjacent muscle or skin cross-talk may occur, leading to signal distortion, and increased skin conductivity is a result of sweat.

And electrical impedance between the electrode and the skin. These are all the limitations when we have sweat. Whenever we do the assessment and please ensure that so you wipe out the sweat from the athlete during the complete process of the movement. And marking the location.

due to time constraints, it will take more amount of time to explain all locations of the muscles, but one general information we would like to convey is that, yes, you can follow the SENIAM protocol. The SENIAM protocol is the one which will clearly tell you how to fix the surface electrodes. But whereas, we give you the general guidelines how to fix the electrodes. First, we need to mark the muscle origin and insertion and mark the exact sensor placement point.

That means the belly of the muscle. The sensor has to be placed exactly on the belly of the muscle. The moment we come to know about the origin and insertion, so it is easy for us to fix the belly. For easy understanding, I would like to tell you about the biceps. Everybody knows about biceps.

In the previous slide itself, I told you, I have shown and explained to you about a single sensor movement. The belly of the biceps can be easily identified. And next comes the moment you identify the belly of the muscle. Next is the orientation of the fibers. Some of the fibers will be, I mean, parallel to each other.

Some of the fibers may be oblique in nature. In this case, the EMG sensor has to be fixed parallel to the orientation of the fibers. It is the responsibility of the assessor or biomechanist to identify the muscle location, origin and insertion, the belly of the muscle, and the orientation of the fibers. These are the two important pieces of information the biomechanist should acquire and equip themselves with.

And here is a picture shown here. You can easily identify the anatomical landmarks. At the same time, the origin and insertion of the muscle, where you can identify the belly of the muscle and the orientation of the fibers. And the sensor location is shown here. When you fix the sensor in different locations of the muscle, how the EMG signals will be recorded is the point of discussion we are going to see here.

And so as I already told you EMG that is muscle electrical signals will always be conveyed with respect to amplitude, the intensity of the firing of the muscle. And here the first the bigger arrow mark comes with the belly of the muscle where the EMG sensor is fixed. And you can find the clear signals which is captured when the muscle is under contraction. And when you place the muscle, I mean the electrodes, just below the belly of the muscle you can see the different pattern of or reduced pattern of contraction of the muscle. And when it is fixed on the insertion point or maybe towards the tendon, right, so this EMG signal is totally different.

And even if it is in the origin and the EMG signal orientation is different. It is essential and vital that the sensor placement, the belly of the muscle and along with the orientation of the muscle fiber is the most important information the biomechanist should keep into consideration. And frequency spectrum. The moment amplitude and frequency is the point of discussion.

The frequency also is different when the sensors are fixed in different location of the muscle. What are the points to be avoided? You should avoid on the innervation zones and origin or insertion location should be avoided and edge of the belly of the muscle also, because the belly, the center of the belly of the muscle has to be considered.

And the aim, what is the aim of this sensor perfect location? That is the sensor has to be fixed middle of the muscle belly along with the position in orientation with the fiber. What is the result when we perfectly fix the sensors exactly at the center of belly of the muscle and in line with the orientation of muscle fiber parallel to the orientation of muscle fiber, the result is that you will have a better signal to noise ratio

That is valid signal you will have. And there will be reduction in muscle crosstalk. Obviously we will get the quality data, here we are going to see what crosstalk in electromyography is. The crosstalk in electromyography is nothing but when we fix the electrodes on the surface of the muscles, and when it records the electrical activity of the muscles, so adjacent muscles and adjacent segments may produce some noises or signals along with the targeted muscle signals, so this is called cross-talk. The cross-talk has to be eliminated. We do have the technology particularly in DELSYS surface EMG. The cross-talks are clearly eliminated through a filtering system.

And if you could see the crosstalk based on this image. There is bone crosstalk, and actually, the muscle being targeted is the tibialis anterior. But whereas in the adjacent segments, the bones and the peroneus longus muscles are producing the crosstalk. These crosstalks can be easily eliminated based on filtering methods.

How can we integrate with other hardware? Particularly, the EMG integration with other sensors or hardware. Here we have shown a video.

We have three different hardware devices which can be integrated with EMG.

One is a MOXY. The MOXY is a sensor which is placed on the muscle to read or measure muscle oxygenation. How does the muscle utilize oxygen? At the same time, what is the hemoglobin content? These are the two main pieces of information which can be identified using MOXY.

The MOXY, the SMO2—that is, muscle oxygenation—is measured in terms of percentage, which you can find here in the first SMO2 value. At the same time, the hemoglobin value is given in grams per deciliter. The MOXY predominantly measures, along with the EMG signals—that is, EMG electrical activity, muscle electrical activity—we can identify the SMO2, which is muscle oxygenation percentage, along with the hemoglobin content. And second comes the VO2 master. The portable VO2 master can be integrated, and we can identify the respiratory rate, tidal volume, and VO2 max, which is measured in milliliters per minute. Apart from this, the heart rate variation can also be

measured, which is represented in beats per minute. The DELSYS EMG has been specifically integrated with the MOXY, VO2 master, as well as a heart rate monitor. These three values can be visually seen in real time.

This will give us a clear picture of the muscle activity, along with the MOXY—that is, muscle oxygenation percentage—along with the hemoglobin unit, and the VO2 master provides the respiratory rate, tidal volume, along with VO2 max and heart rate.

Apart from this, we can integrate EMG with a motion capture system, a force plate, as well as an isokinetic dynamometer. When it comes to DELSYS EMG, I would like to give a clear picture of DELSYS's contribution with respect to electromyography in human and exercise science, human movement and exercise science, particularly in biomechanics. DELSYS has a separate funding scheme called the De Luca Foundation.

Through De Luca Foundation, a lot of award research fellowships and award schemes are available exclusively for Indians and also some of the schemes were open for the budding researchers. So anybody researcher can write a proposal and win an award and where the De Luca Foundation gives the free sensors along with the monetary benefits. And there are certain exclusive fellowships available for Indians and all the candidates can refer the De Luca Foundation website. Apart from this, to promote science, to promote research in movement exercise science, De Luca Foundation comes with some subsidized sensor disbursement.

For example, 60 to 70 percentage of the product cost will be borne by the De Luca Foundation, and any researcher or any educational institution or any faculty member can apply for the grant and they will get two sensor and one workstation along with the software at subsidized cost. Maybe within a lakh, one lakh amount so they can get it. This is what the, I mean, schemes available in De Luca Foundation, particularly from DELSYS Foundation.

Further, how signal processing flow can happen in EMG analysis. The moment we fix the sensors on the belly of the muscle, so the electrodes capture the signal emanated from the muscle. And then, the first one is the raw signal. The raw signal is filtered. The filtration is happening through, by filtering out the noise, the crosstalks. Then comes the rectification. All the muscle signals are rectified and smoothed.

It is visualized through the RSM method, that is, root-squared method or root mean square method. Here you can see both the amplitude and time parameters. Then here I would like to convey some practical examples how the electromyography is being used. First we go with the squat. So here the candidate is performing squat and there are two sensors placed on the right and left that is quadriceps muscle.

There are four muscles in the quadriceps but only one muscle is targeted on each side that is vastus lateralis. When any person is performing squat the targeted muscles or involved muscles are vastus medialis, vastus lateralis, rectus femoris, and semitendinosus and biceps femoris and here we have targeted only the right vastus lateralis and left vastus lateralis that is how the two sensors are placed on the subject. And here we can see how the real time data is being streamed.

The athlete is performing the squat and you can see for each and every repetition. You can find the firing rate of the squat. The firing rate of the squat can be visually seen in real time. The amplitude of the muscle is seen in millivolts and the time parameter is given at the bottom in the x-axis. And the real time information comes with how much percentage of activation of the muscle in each movement is seen here.

Next, we can see the squat results. With respect to the **activation of peak EMG root mean square** and mean EMG root mean square. This is all the information from this EMG during the squat movement. Then, here we have another example: the repeated calf raise. During the repeated calf raise, you can see the subject performs the calf raise or is going for plantar flexion, where the gastrocnemius is being used. The gastrocnemius muscle has two heads: one is medial and the other is lateral. In this movement, we have targeted only the lateral head of the gastrocnemius, both on the right and left. This analysis helps us determine how each site is recruited and whether there is any asymmetry with regard to amplitude. Here you can see the real-time data.

When the athlete performs, you can see for each raise the amplitude is measured in millivolts with respect to time, and the percentage of recruitment is also seen here. With respect to root mean square. And this is the result of the repeated calf raise. It is given in graphical representation. The bar graph shows the peak EMG RMS.

As well as mean EMG RMS. And the pie chart also gives the recruitment pattern of each muscle. And next comes the grip strength. So the grip strength is measured by keeping the elbow flexed at 90 degree and the type of contraction is isometric in nature.

These are all the involved muscles that is brachioradialis, brachialis, biceps brachii and flexor digitorum profundus. Digitorum superficialis and flexor pollicis longus and flexor carpi ulnaris. And there are different muscles being involved, but here we go for only a few muscles which are focused or out of interest for us. The target muscle is the left brachioradialis and biceps on the left side. And here you can see the placement of the sensors on the subject, both on the left biceps and left brachioradialis muscles.

And here is the jammer held by the subject is performing the isometric grip contraction. And here you can see the real time value. When the arm is flexed at 90 degree, you can find the contraction of each muscle that is left biceps as well as brachioradialis. And the muscles recruitment so obviously the biceps is the one which is maximally contracted compared to the brachioradialis.

And at the same time, you can find the results from this graph when three repetitions are given. For isometric contraction, the subject was asked to perform three maximal contractions. And you can find the recruitment pattern of both the biceps brachii and brachioradialis. The biceps brachii contributed 64% of the total force generation. And next, when it comes to five repetitions.

When the subject performs 5 repetitions, you can observe the graph. The graph itself shows how the force generation varies. And the mean peak grip is 48 kg. And the biceps brachii recruitment is 70%. And the brachioradialis is 30%.

Out of five repetitions when the subject performs the movement. Here we have discussed the fundamentals of electromyography, different types of electromyography, the basic types of muscle contraction, and how muscle physiology and contraction occur along with the motor unit. We also covered the EMG workflow, how EMG can be used in different applications of movement science, and how the results and interpretations are done.

[Thank you so much. See you in the next video].