

Exercise & Sports Biomechanics
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Lecture 56
Introduction to EMG

[Hello, everybody! Welcome back to the course. Today we are going to see about electromyography]

What is electromyography?

Electromyography means is the study of muscle electrical activity during the sports and exercise movement.

The electromyography we use sensors or electrodes which are placed on the belly of the muscles, and the sensors will record the electrical activity of the muscles to identify the activation pattern of any muscle.

[And further discuss in detail about what is electromyography].

Here, electro means electric, myo means muscle, graphy means graph. It is the study of electrical activity of the muscle during exercise and sports movements, and to read and record the electrical activity of the muscle, we use electrodes which are placed on the muscle's belly. **Carlos de Luca** is the first person to come out with the finding through his research paper that skeletal muscles can produce electrical signals during the contraction. [To see how a muscle is functioning, here we have the elbow flexion].

Once a single electrode is placed on the belly of biceps muscle. Now you can see the biceps muscles flexion. When it is flexed, we can see on the right side the graph, the amplitude or the amplitude in other words we call it as the intensity of muscle contraction or the magnitude of the electrical contraction of the muscle or electrical activity of the muscle. Here we have the amplitude which is in millivolts or microvolts and the time data. The muscle electrical activity is measured in microvolts or millivolts against the time.

During muscle flexion, you can find the graph with certain amplitude which shows that the muscle is activated. We can filter the signal and we can get the clear signal against the time. When it comes to continuous contraction, so along the time we can find the amplitude of the electrical activity of the muscle during the movement.

How difficult is it to measure EMG?

Those were the days when they started assessing the electrical activity of the muscle, there are lot of difficulties in filtering the data because there will be noise because of the adjacent muscles and cross torque. And that is how Carlos de Luca when he publishes paper he came with the statement, so the EMG has to be used with perfect methodology and vivid methodology and it is easy to use and abuse. Nowadays, we have got an advanced

technology where we can filter the data, reduce the crosstalk and get the fine and valid data which is produced from the muscle's electrical activity.

We will discuss the scope of EMG in sports and exercise biomechanics:

First, it is used in biomechanical analysis and injury prevention. In biomechanical analysis and injury prevention, we have muscle activation patterns. The EMG electrodes can be fixed on different muscles, and when an activity is performed—for example, when a person is walking—we analyze the gait.

When analyzing the gait, during heel strike, we identify the muscles activated at the ankle, knee, and hip joints in the lower limb. We can identify the activation patterns of different muscles in a particular movement. This is the advantage of surface EMG during any movement. Second, we can identify muscle imbalances.

For example, when moving any limb, contralateral—that is, right and left limb muscle imbalances can be identified. At the same time, adjacent muscles or agonist-antagonist firing rates can also be identified during any movement. Further, it helps optimize technique. Optimizing technique means not all individuals will have the same movement pattern because of the anthropometry, the learning method. Each and every person will have different movement pattern and this surface EMG will help us to identify and optimize the technique in any movement.

Next comes rehabilitation and recovery domain.

How this EMG is used in rehabilitation and recovery?

Rehabilitation means bringing back the athlete to normalcy or any person to normal functioning after an injury is occurred. In this we can monitor the muscle reactivation because due to injury the muscle is completely may be partially activated or completely dysfunctional, during this after the recovery or rehabilitation. Again we can during the injury we can identify how the muscle is activated and post recovery how the muscle is improved based on the electrical activity of the muscle.

Further we can also detect the muscle fatigue. So after the rehabilitation and recovery so the muscle may not come back to normalcy immediately. How long the muscle can function without fatigue and when at what point of time the muscle can attain the fatigue. These are all the facts we can identify through the EMG analysis.

We can also assess the effectiveness of rehabilitation. How quickly an athlete can be rehabilitated, how quickly the muscles return to normalcy? These can be identified.

[The next is Performance enhancement].

In **performance enhancement**, we can optimize the training, based on the muscle activation pattern. And we can optimize the training for the athletes. And we can also perform muscle fatigue analysis during different sets of activity, prolonged sets of activity, different intensities of activity, and the point of fatigue attainment by the muscle can be

assessed. And further, we can improve the movement efficiency of the muscles. Then Research and development.

Electromyography is used in research and development to create new technologies. EMG alone will not give us all the information, whereas it can be integrated with other technologies or other hardware. And to further understand muscle function, we go for applications in various fields. The first one is medical application. In medical applications, neurological and muscular disorder diagnoses can be done. Nerve conduction velocity studies can be conducted through EMG, and further pain management and fatigue assessment can also be performed.

Further, in ergonomics and occupational health: posture correction, workplace ergonomics, and injury prevention. In ergonomics and occupational health, I would like to just elaborate on how EMG can be used. EMG is used to identify fatigue levels or muscle activation patterns in seat-bound professionals, such as bank employees, IT professionals, or people working in front of a desk—desk-bound workers.

How the muscles are continuously activated, when they get tired, and what is the activation pattern of the muscle during any movement. These are all the factors we can identify to optimize ergonomic factors, key performance indicators in the design and development of any furniture. to optimize and improve the work environment.

[Next comes posture analysis and correction].

Posture analysis and Correction:

Any movement whether sitting, standing, or even exercising, the squat movement is important. Here you can see the asymmetric squat and natural squat in the picture. We can identify which is natural and which is asymmetric based on EMG studies. Then comes robotics and prosthetics. In robotics and prosthetics, we use human-robot interaction and also employ assistive technology.

This is one of the most fascinating fields where we can explore bionics or any artificial limb improvisation. These are the gifts of EMG applications, which are helpful to the human community. Furthermore, EMG is used in biomedical engineering and research in wearable and smart technology.

Here we will see in detail how EMG analysis is done.

First, the physiological effect. In the physiological effect, we examine how EMG signal characteristics are represented and how the computation is done. First we will discuss muscle effort, that is, force. During an activity, muscles produce electrical signals. The amplitude of these electrical signals, in other words, is called force, and here the electrical signals of the activity of the muscle or the intensity of the electrical signals is termed as amplitude. The amplitude can be calculated through either RMS or MVC. RMS is root mean square. Root means square is a representation of the square root of the average of the squared values over a specific period of time where the muscle is producing the electrical activity. And this is measured in either millivolts or microwolts.

The other method of computation is that it is **maximal voluntary contraction**, which tells about the strength of the amplitude of the muscle. And it is measured in percentage of maximal voluntary contraction. Here apart from the muscle effort, next comes the muscle activation timing. Whenever the electrical activity is produced, it always comes with certain point of time, how long a muscle is in contraction or how long the muscle produces the electrical activity in a sequence manner.

And in this, the threshold amplitude is measured. Threshold amplitude is nothing but, so how long the amplitude is or the electrical activity is in present. And so here we go for the RMS and their threshold. So RMS as I already told you, it is root mean square which is direct method of measurement of the amplitude of the electrical signal of the muscle. And third one is muscle fatigue.

How can muscle fatigue be identified?

When there is an increase in amplitude that is a signal of the electrical activity of the muscle and a decrease in frequency. This is the identification or indication of muscle fatigue. The median frequency is another method of calculating or computing muscle fatigue. Here, we can see the graphical representation of how muscle fatigue is identified through the graph. The progressive increase in EMG amplitude and decrease in frequency are always indicators of muscle fatigue.

How does the muscle act after exercise? How does it change after intervention? These are all the questions that can be addressed through EMG studies. And here, you can see the muscle amplitude in the first picture. The top picture shows the muscle amplitude keeps on increasing. And when there is an increase in the muscle amplitude and a reduction in frequency, you can see the bottom, which is given in hertz. The hertz is an indication of the frequency of muscle activation. And you can see a slope line coming down, showing the decrease in the frequency of muscle activation and an increase in the threshold. These two indicators are the patterns which show that the muscle is fatigued. And then, EMG can be applied in clinical neurophysiology.

You can see the biomarkers of neuromuscular skeletal function. The methods—different methods used—are clinical tests, functional tests, and strength tests, isometric and dynamic movements. And the target applications are neuromuscular disease progression and pain rehabilitation outcomes. Obviously, these methods are used either for the elderly population, pathological conditions, or injured athletes. And you can see here the healthy surface EMG signal—how it is—and myopathy surface EMG.

Myopathy means the muscles which are injured or dysfunctional. At the same time, we come out with a healthy MUAP range. MUAP means motor unit action potential, because the electrical signals are produced from the motor units. And if you can, you can see the difference between healthy MUAP and myopathy motor unit action potential range. By seeing the difference, you can identify the difference.

[Here we are going to discuss in detail the **physiology behind muscle contraction**].

[Let us discuss what muscle contraction is].

Muscle contraction is nothing but the muscle fibers generating tension. Either by shortening the fibers, lengthening the fibers, or keeping the fiber length the same while still developing tension. That is how we study the types of muscle contraction, maybe in the previous sessions, our co-authors or co-lecturers would have told you. But however, I would like to again just refresh the types of muscle contraction.

One is isotonic contraction, where it is dynamic in movement, we go for concentric and eccentric movements. Whenever we do—for example, I would like to give an example—biceps curl. During the biceps curl, when you lift the weight, the biceps muscles undergo concentric contraction, which is shortening the length of the muscle fibers, and tension is produced. And it is the muscles producing tension against gravity.

At the same time, its paired muscle, the triceps, is undergoing eccentric contraction. And this combination—concentric and eccentric contractions—serves as part of isotonic contraction. Doing half squats, push-ups, walking, jumping—these are all isotonic movements. But when it comes to isometric contraction, remaining in a half-squat position for a prolonged period is an example of isometric contraction, where tension in the muscle is produced.

But the length of the muscle remains the same. This is the other type of contraction. And the third contraction is isokinetic movement. Where the speed of the movement remains the same, and the resistance alters.

This type of movements can be performed only in isokinetic dynamometer. In all these movements, we can identify the muscle activation pattern by integrating the EMG with the equipment. And you can see here how the muscle contracts and comes to normal length. When it contracts or when it shortens, it is concentric contraction. By shortening, it produces tension.

And when it comes to normalcy or lengthens from its normal length, so that is isometric contraction. These are the two surfaces of isotonic contraction. And whenever we study about the musculoskeletal system, so it is always the muscular system, skeletal system along with the nervous system. It is neuromuscular junction, we say. Before that the nerves are the one which creates or sends the message to the muscle to contract.

And let us discuss about the nervous system in brief. So nervous system comes with PNS that is peripheral nervous system. In peripheral nervous system we have somatic nervous system. And what is the function of somatic nervous system? It controls all voluntary actions.

Whatever we do, we go for walking, jumping, throwing, biceps curl, whatever the voluntary movements we do, and it is under the control of somatic nervous system. In somatic nervous system, voluntary actions, we use the skeletal muscles. Whatever the voluntary movement we perform, so that is based on the somatic nervous system's function. Next, comes autonomic nervous system, it is not in our control.

Your heart function is based on the autonomic nervous system. It is involuntary action. All our internal organs are functioning based on involuntary movements function. So

breathing, digestion, pumping of the heart, all the examples for involuntary actions which is coming under autonomic nervous system. Then comes the central nervous system.

The central nervous system is based on the functions of brain and spinal cord. It is responsible for higher level functions like, thinking, memory, emotions and taking decisions. As far as the movement is concerned, the somatic nervous system takes the predominance and because of its voluntary actions where the muscles are, particularly the skeletal muscles are in action. Then, when the signal is processed or the trigger is processed from the nervous system,

To the muscle. How the muscle responds. And the muscles are made up of muscle fibers. The smallest structure is muscle fibers, followed by the myofibril.

We have the actin and myosin filaments. In this moment, the trigger the action potential or the nerves sense a signal, the nerves sense the chemical messenger, which is acetylcholine, and the chemical messenger reaches the neuromuscular junction, then the muscle fibers contract.

We will discuss more about the muscle, how the muscle contracts. Because muscle fibers are combining together to make a muscle. And there are hundreds of muscle fibers in a muscle. And when it comes to muscle fiber, we always come with motor unit. Motor unit is nothing but a single nerve and how it innervates the number of muscle fibers.

One single motor unit is referred as how one single motor nerve is connected with a number of muscle fibers. And further we discuss about how the muscle contraction happens through the action potential, that is chemical messenger, the moment it reaches the neuromuscular junction, how the muscle reacts. There is a term we always call it as **depolarization and repolarization**.

The muscle in the neuromuscular junction, the moment the action potential reaches the neuromuscular junction, in the muscle, the sodium ions are positively charged and they just get into the muscle fiber, whereas the potassium ions are expelled out during the **depolarization status**, more sodium ions are inside the cell and less potassium ions are inside the cell. The moment it is depolarized, the muscle fiber tends to contract.

And after the depolarization, the next process is **repolarization**. During the repolarization, the sodium ions come out of the cell, whereas the potassium ions get into the cell during the repolarization state, more number of potassium ions will be in the muscle. When it comes to the threshold, so the muscles will be the skeletal muscles will be under minus 55 millivolts threshold during the rest. When this threshold is broken the skeletal muscle is somewhere between minus 70 and minus 55 millivolts during rest. And the moment muscle is contracted, so after the contraction, this is how the motor units are functioning based on depolarization and repolarization which is a cyclic activity as long as the muscle is in contraction.

[And here is the picture which shows how the muscle contracts and relaxes through different chemical phases of reaction, as we discussed about the depolarization and repolarization status]

Further, the calcium which is present in this sarcoplasmic reticulum so enters into the troponin and tropomyosin and makes the muscle the actin and myosin to slide over where the muscle contracts. And this picture clearly tells us how the calcium binds with troponin and tropomyosin to create a muscle contraction. And here you can see how the motor units are recruited to make the muscle fibers to contract. There are different motor units present in a single muscle. And in the muscle there are number of fibers which are connected with one single neuron that is called as motor unit.

During a particular muscle contraction there are different motor units being activated to produce the signal. And so motor unit firings are happening and you can see the different motor units in fire. The cumulative signal is elicited as a force output. You can see the force switches from different motor units. The accumulated motor units force switches is the outcome of muscle amplitude or firing rate.

The number 4 tells you about the final output of the muscle electrical signal and muscle force output, which is shown as a graph in the EMG signal. The EMG signal comes with the muscle amplitude. That is shown here in the graph. And further we will discuss about the types of electromyography.

We do have two types of EMG. One is SEMG in short, otherwise called as surface EMG. Surface EMG electrodes are a non-invasive method of EMG, assessing the muscle's electric activity.

[And next comes the needle EMG].

The **needle EMG** is in an invasive technique where we are not going to discuss about the needle EMG because it is completely medical oriented. And here whatever we have discussed so far and whatever we are going to discuss hereafter is only based on surface EMG which is a non-invasive technique and this surface EMG can be used only on the superficial muscles. The surface EMG cannot detect the signals on the deeper muscles, only on the superficial muscles the surface EMG can be used to detect the muscle activation. And so in the surface EMG we have wide surface EMG, and because of the advancement of technology, we do have the wireless EMG.

What is the wired EMG's advantage?

It has lower latency, which means the signals can be easily, quickly transmitted without any delay and better signal quality. And whereas, the wired EMG will have the complexity for both the subject that means athlete as well as the assessor. Because so the athlete may find it difficult to move with the wires different wires when it comes to three or four muscles being targeted once in single assessment. And it is cost effective, so less cost comparing to the wireless EMG and when it comes to mobility, so we do have different wires hanging here and there, obviously, it is difficult for the subject to move freely.

Whereas, the wireless surface EMG, very easy to use. You can fix it over the surface of the skin and on the belly of the muscle by using some adhesive tapes. And you will freely move because it is less in weight and greater in mobility and it will not affect any movement because it is not having wires, it is wireless and then it is easy to set up. At the moment, we identify the muscle architecture.

On the belly of the muscle, the orientation of the fibers is known. Obviously, we can mark the place of the sensors, then we fix them. And when it comes to cost, yes, surface EMGs are expensive. Surface EMGs are expensive compared to wire surface EMGs. And signal interference will be there in surface EMGs because of the adjacent muscles.

Now, the new technology helps us filter and eliminate unnecessary noises to get a clear signal from the muscles.

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