Animal Physiology
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Lecture - 17
Excitation Contraction Coupling with Nervous System

Welcome back to the 2nd lecture of the 4th week. So, in the last lecture when we concluded, I told you that muscle fibres based on their myosin subtypes could be classified into fast twitch and slow twitch fibres. Today there are three aspects what we are going to deal with. First of all, we will talk about the force curves which are generated in the slow twitch and the first stitch fibres point one. Second, rather in the beginning we will talk, give the technical definition what we meant by twitch which we have done partly, but I have not introduced the terminology twitch and the next, we will talk about the force velocity characteristics of the muscle and isometric contraction within the muscle.

So, to start with twitch, what really is the definition of twitch? Twitch is essentially a contraction of the muscle which can physically see, which happens with a small delay and that delay is because of a electrical impulse. So, if you remember in the last class we talked in depth about it.

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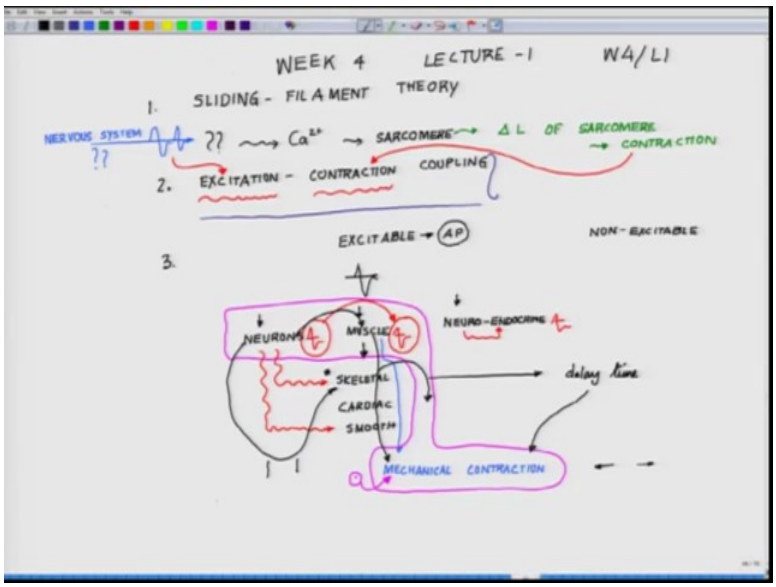

So, there is a neuron which is sending a signal to the muscle, right and then, the muscle does and mechanical action or mechanical contraction. Now, there is a time which the neuron takes to send the signal to the muscle. So, that time followed by a muscles own electrical activity, add up to that delay time and this delay time followed by a mechanical motion.

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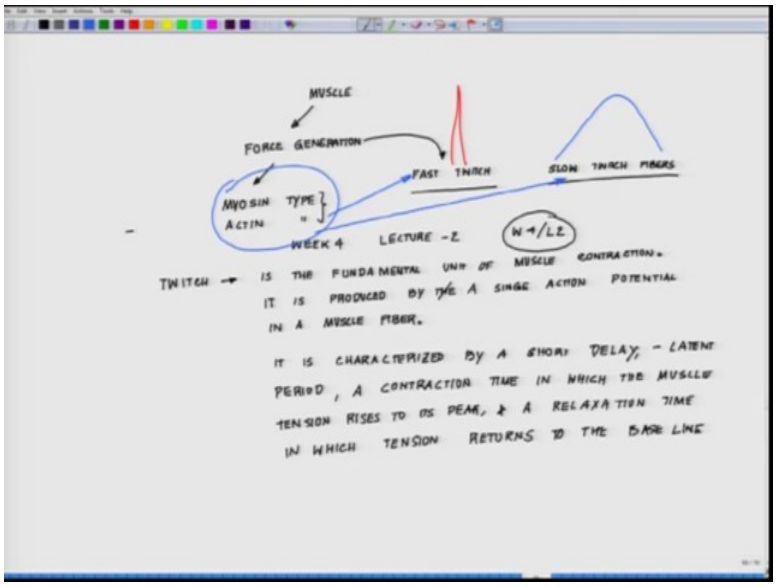

So, technically if I go by the definition of a twitch, so the definition of the twitch is a fundamental unit of muscle contraction. So, let me put it this is our lecture 2, week 4. So, W4 slash L2 that is we are resuming what the definition of twitch is. So, twitch is the fundamental unit of muscle contraction. That is the first thing you need to remember. It is the contraction that is produced by a single action potential. It is produced by the; or by a, you can put it by a single action potential in a muscle fibre. It is characterized by a short delay called a latent period, a contraction time in which the muscle tension rises to its peak and a relaxation time during which tension returns to the baseline. Now, does that reminds you something returns to the baseline?

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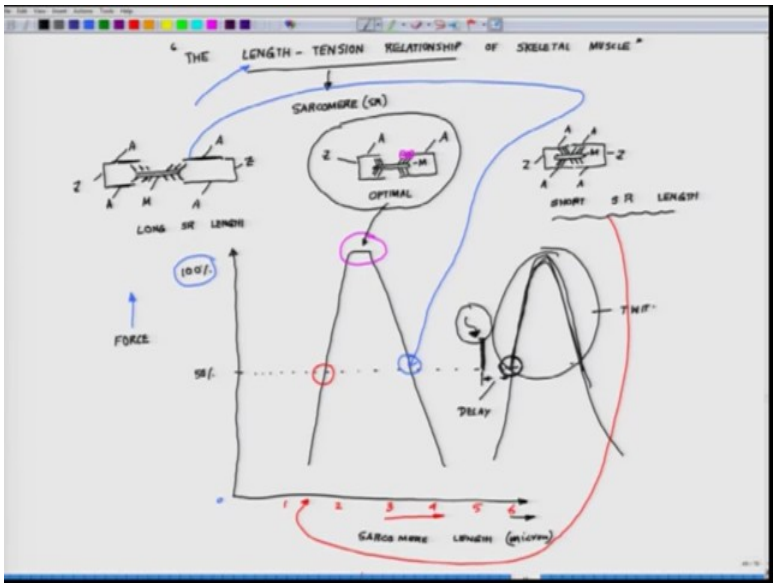

Does it remind you something like this raises up. So, this process what is happening out here like this is where say for example, the neuronal signal coming like this. This is that neuronal signal followed by this action. So, this whole process, there is a delay between the neuronal signals. This is that delay. This arrow is that first signal which you are not seeing and this is what is the twitch. Now, once you have defined twitch, now we can define; what is a fast twitch and what is a slow twitch fibre, fast twitch and slow twitch.

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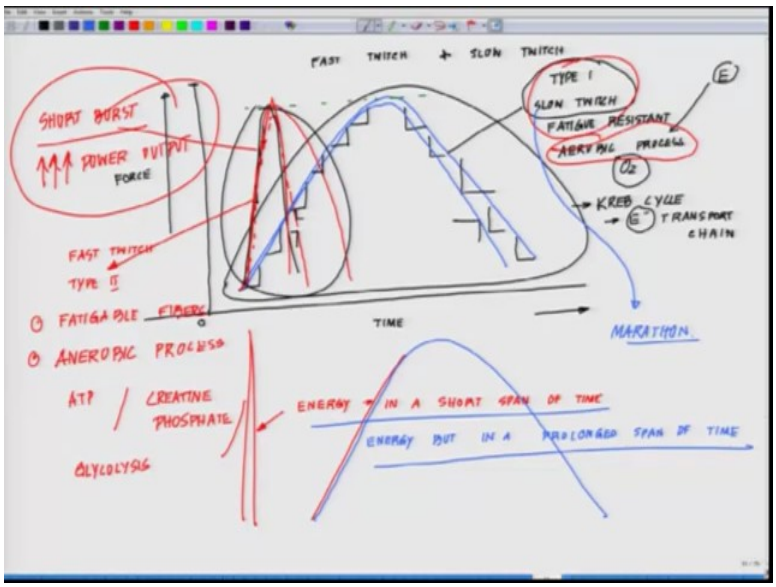

So, as the name indicates, the force generation pattern will be different in the fast twitch and slow twitch. So, your Y axis is again telling you the force and your X axis is telling you the time it is moving like this. So, here you have the origin and here, you have the increasing forces. Now, when it is a fast twitch fibre, I am putting rate for the fast twitch fibre. So, the curve is like this or the curve could be even much more sharper could be like this, where as in the case of slow twitch while we using the blue colour, the curve will be like this. So, what is the highlighting feature? If you look at it, the generating the same amount of force almost I can even put it like this, but mathematically if you look at it, this is going up and going down.

So, if you measure the slope out here say for example, I requested you to measure the slope and if you measure the slope, then you will see the difference. What is the difference which is happening whichever way you measure it because this one is falling like this say for example, you go up and fall down like this which is leading to the twitching action that is the red whereas out here, it is going a long distance. It is going up and falling down, but it is all doing. So, look at the rise whereas, look at the rise, so you can calculate the rise by calculating the slope of this curve. So, if you calculate the slope of this curve, you will realise what I am trying to tell you. So, it is rising slowly; it is falling back slowly.

So, it means it has ample of time whereas, this is like this just like if you have heard about super capacitors where there is a burst like this, whereas out here there is no burst. It is kind of slowly going up and slowly going down, but that simple thing tells us something way more than you can think of. This is just a graph. This is mathematics you measure something and you plot it, but there is a intricate biochemistry involved in it in order to generate something like this, boom like this you need a huge amount of energy in a short span of time. This is the problem. Energy is not a problem in a short span of time, where as if I look at this graph which is in a, sorry which is like this, you will need the same energy, but in a prolonged span of time what is the significance of these two? These 2 lines are very important to realise. So, what kind of biochemistry do they follow?

So, now I will enumerate some of the points which will help you to realise how an observation helps you to develop the physiological and biochemical mechanism by virtue of with these 2 different muscle type works and further, it brings you to certain evolutionary perspective to this. So, first thing what you have to realise for a fast twitch and a slow twitch fibres, you have different kind of myosin heavy chains. Step one if you remember I told you they could be classified based on the myosin subtype. So, it means the fast will have a different configuration as compared to the slow because in the fast, you are having this is Y axis is showing the force, where as in the slow you have something like this.

Next point to ponder upon is now coming let me put it together in terms of, there are 2 distinct muscle fibres, the speed of contraction and their metabolic characteristics. So, they are also called Type 1 fibres which are slow twitch. So, this also called slow twitch and these are fatigue resistant. They do not get fatigued easy because they doing it slowly. They are not really rushing and derive most of their energy from aerobic processes. All their energy derivation is taking place from aerobic process e stands for energy. That means, in the presence of oxygen, they are slowly doing it. Aerobic processes of what is the major one which is essentially your Kreb cycle, if you pick up Kreb cycle followed by the oxygen electron transport chain electron.

E stands for electron transport chain. So, C from physiology we are correlating

everything to biochemistry and these are called Type 1 fibre which are the slow twitch fibre. Contrary to it if you look at these once, these are called Type 2 fibres which are fast twitch Type 2 fibres. These fibres when you look at them, they are basically fatigable fibre and derive most of their energy unlike aerobic processes out here. These derives by anaerobic processes because they need huge amount of energy. Most of their energy comes from anaerobic processes including energy stored in the ATP bonds and creatine phosphate as well as pathways of glycolysis.

So, these are adapted for short burst and very high power output, whereas on the contrary to it, these ones the slow twitch type, these are the ones which are very prominent in marathon runners who are running slowly because they have to cover some 45 miles of stretch, where as compared to a person who is running 100 metre dash. You really have to be very fast. I mean your start should be fast. So, theoretically speaking if you look at the muscle type of some of the famous marathon runners in the history, Wiki Law from Ethiopia or if you look at Carl Lewis 100 metre dash, so you will see they should have a different adaptability in terms of their fast twitch and slow twitch muscles. Those who are long distance runners, they will have a higher percentage of well developed slow twitch muscle which adapt themselves over period of time and it has been proven.

Now, there is huge amount of adaptation which happens in the muscle subtype over years together of practice. So, you can develop such muscles subtypes if you are practising from the very childhood and especially, if you look one thing very carefully, most of these marathon runners are from African continent especially from Ethiopia, Nigeria, all these places. So, one of the reason is specially in Ethiopia, it is a very toryne is like this and it is not that these are not the kind of places where we stay and you know everything is available so easily. These are places where you really have to you know walk down or run through you know get your stuff starting from your very basic amenities. So, from the very childhood, people are used to you know moving to this torynes. So, if you get used to in moving those torynes, your slow twitch muscles develop very differently as compared both your slow twitch as well as fast twitch to develop very differently as compared to a person who is living in a plain or somewhere in our country, where you have lot of plain. You live in the plains. It develops differently.

By the same token if you are living in the mountains, where you are climbing up and down every day, you are trekking, again your muscle development will be different. So, your adaptability will be different and that adaptability is a function of how much your muscle has the potential to undergo anaerobic methods to derive energy or aerobic ways of deriving energy. If your muscle have more power of deriving energy by anaerobic process, then your muscle is in a position to generate extreme amount of power in a very short span of time, where as if your muscles are adapted for an aerobic condition where there is lot of oxygen, then your slow twitch are more well developed. Keep that in mind. So, depending on the environment where you are developed or you are developing or you are growing, you are of course the kind of physical activity or endurance you are undergoing, your muscle subtypes varies. Keep that very strictly in mind.

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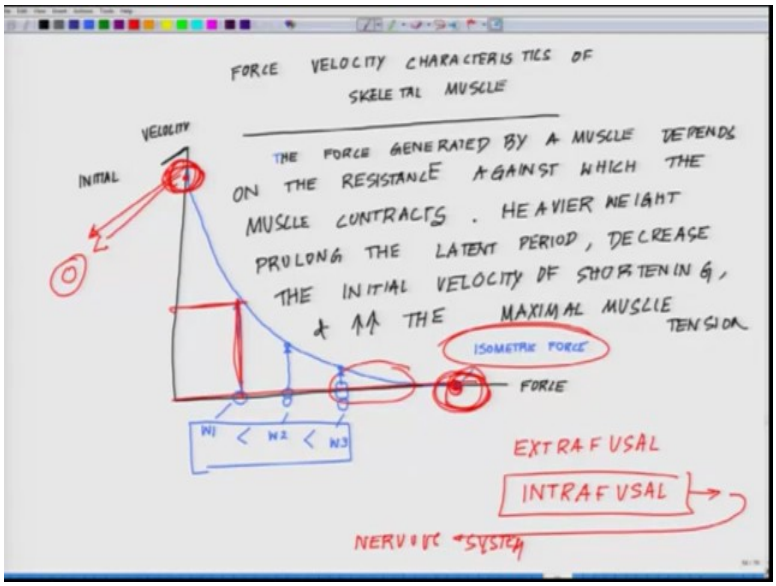

So, from here I will just put another graph which will give you the force velocity characteristics of skeletal muscle. If you look at the force velocity characteristics which is essentially the force generated by a muscle on the resistance against which muscle contracts, so if you look at that, this is how the force velocity characteristics of the muscle will be where you are plotting the force on the X axis and you are plotting the velocity on the Y axis, where this is your initial velocity. So, the plot will be something like this and out here if you put it at different points, I am putting, so this is you have. So,

W1, this is W2, these are the weights you are putting. You are increasing the amount of weight.

So, this is increasing. This leads to something like and this is where we call it the isometric force. So, what is your isometric force? Now, let us put it together. Once you have put the drawing, so once again the force generated by a muscle and again mind it, this is all function of that subtype of myosin which is present. They are generated by a muscle depends on the resistance against which the muscle contracts, fine. Now, the heavier weight prolongs the latent period. Now, you are talked about the latent period. Earlier prolonged, the latent period decreases the initial velocity of shortening and increase the maximum muscle tension.

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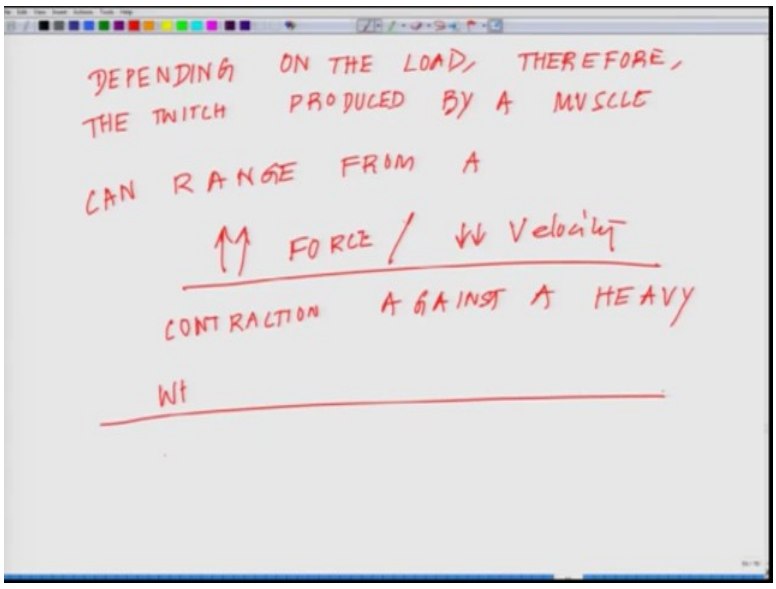

As you can see here, look at this part of the graph, maximum muscle tension depending on the load. Therefore, the twitch produced by a muscle can range from a high force.

Low velocity as you could see high force and a velocity contraction against a heavy weight. Two, if you just see the reverse side to a situation where you have and if I pick up this situation to a low force, the force is low, there is a high velocity, though there is a higher velocity against the lightweight. So, the force generated in a muscle by a maximal

when it contract contrast or contract against the force generated by muscle is maximal. When it contract against a load that is too heavy for it to lift and that is what we meant by isometric force. Isometric contraction and the velocity of shortening is maximal when it contract against no load. There is no load, 0 load. This is 0, this is the maximal velocity, this is the least velocity, where you have the maximum amount of force and this is what is meant by the force velocity characteristics of the skeletal muscle. So, if you look here, you have hardly any force. You have the maximal velocity, you have the maximum force, you have the least amount of velocity.

So, remember this is the basic situation. So, say for example, if you are trying to, so you do this experiment. If you are trying to pick up something very heavy, really heavier, there will not be any velocity. It will stretch beyond anything the muscle will stretch beyond anything and there you won't find any velocity and that contraction process as compared to something which is very lightweight or almost no weight. So, that brings us to a point where we can say that we now have some fair idea about the different sub-types of muscles and the muscle biology.

Now, from here what I will do, I will first of all request you people to make a mind map of this different myosin. We in our next class which will be the 3rd class, we will talk about 2 different aspect of muscle; one called extra fussell muscle and the other one will be talking about intrafusal muscle, and we will proceed further with the intrafusal after talking about extrafusal and there we will enter into the nervous system. You will realise why I pick up this intrafusal topic because that is something which will be our gateway to cross that thin line of muscle system or muscular system and a nervous system.

So, once again kind of you know re hash the point that try to develop a mind map of all. These things do not try to remember. You just have to create a mind map of how these different forces has generated, what is sliding filament theory and as we will proceed to excitation contraction coupling apparatus, try to develop a very clear mind map and that will be very helpful for you people instead of you know just remembering the facts because it is not about facts, it is about some basic logics which are happening. Of course, some of the biochemistry behind it we may not be knowing, but the logics are logics and has slowly the whole field of physiology is moving towards more molecular

physiology. We are more and more understanding the relevance of the biochemical phenomena which are leading to the fast twitch, slow twitch and the adaptability, adaptation the genetic evolution which is taking place. So, try to develop, take a sheet of paper always whenever I give a lecture, try to develop a mind map what is possible because I am just giving you very core facts, so that you do not have to really go back to the text book or anywhere. You can develop your basic fundamentals based on it.

Thank you.