Animal Physiology
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Lecture - 16
Length Tension Relationship of Skeletal Muscles

Welcome back to the lecture series in Animal Physiology. So, we have finished 3 weeks. Now we are into the fourth week. So, in the third week we started talking about the muscle. And we ended up at the sliding filament theory. So, this week we will resume our journey into the muscle, and slowly we will merge on to the nervous system. Because they are very interlink and it is very difficult to you know separate out where I should draw the borderline, because anatomically they may look different structure, you know there is muscle there are neurons, but there are lot of functional interactions which takes place and which kind of blurt the line what you draw between these 2 systems. So, one such line blurring of the line takes place last week when we talked about the sliding filament theory just have a recap so, that I can exactly point out where the blurring starts.

So, we talked about the action myosin arrangement, the self assembling of actin myosin, forming the smallest functional unit which is termed as the sarcomere. Such millions and zillions of sarcomeres eventually generates the force right. So, I told you in a normal resting condition the myosin heads. So, if you remember the myosin are formed of 2 heavy chains and 4 light chains and it form the head like this, and on top of that you have the axin actin right. So, in a normal condition, the myosin heads are not in physical interaction or chemical interaction with the actin. There may be close by like this, but there is no interaction as per say, but the reason the since we are recapping the reason is myosin has a binding site this myosin head which is there has a binding site on actin filament right. Actin filament is made up of tropomyosin, a long chain and a actin filament and the binding site for the myosin is covered by the tropomyosin right. And there is the another protein there which is called troponin which has 3 attachment sites it has an attachment for actin. It has an attachment site for tropomyosin and it has a calcium binding site.

Apart from it there is a fourth feature in the actin filament, where we have the myosin

head. So, let us recap what all 4 things actin has actin is made up of actin filament tropomyosin, filament and troponin and it has 2 more feature it is a calcium binding site and it has a active site. So, the calcium binding site is present on the troponin. Whereas, myosin head binding site which is also termed as active site is at a separate location. Now under normal condition this myosin head binding site on this actin tropomyosin filament generally, it is called actin filament is not seen. So, myosin head cannot see that particular binding site right,but then when in that matrix of sarcomere, the calcium arise calcium binds to troponin step one. As soon as calcium binds to troponin, it removes the binding site for the myosin head to the actin.

So, now, the myosin head binds to the actin like this, and as soon as the myosin head binds to the active site of the actin filament, there is a motion like this, which is called the power stroke which happens and that brings a contraction in the muscle right. This is what we talked about and these are some Nano newton forces which are generated at an individual actin myosin head site, some frame to Nano newton individual molecule and that is what I told you as the natures motors or molecular motors of nature where there is a stroke like this. So, imagine this is such a big thing imagine it is in an nanoscopic things how this will look like. So, if such stroke is taking place with millions and millions of it that that will sum up to a huge amount of force and that is what you use.

Now, where is that blurry line first question from where this calcium came, what is the genesis of this calcium because what we see in muscle is at this point what we learnt about muscle is a physical contraction. It is a mechanical activity which took place in muscle, but before this mechanical activity something else happens. Muscle initiates this activity either spontaneously all by itself. And such thing happens in the case of cardiac muscle we will come later into that, but in the case of a skeletal muscle, unless otherwise it is auto twitching here I mean is the contraction there is a prerequisite of getting a neuronal signal and that neuronal signal leads to the first wave of signalling which leads to the contraction. So, there is a very thin blurring line there we will come back to this later and which will take us. So, we have talked about the sliding filament theory briefly last week today I will put 2 terms.

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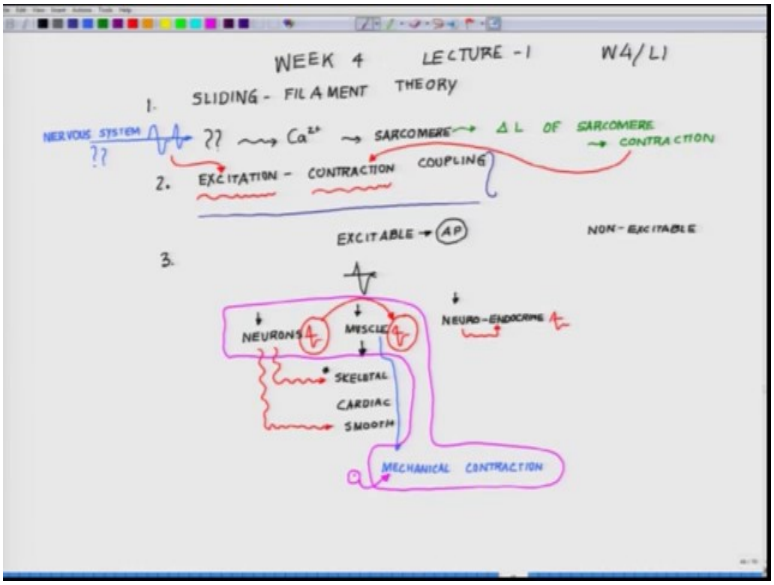

So, we are into week 4 lecture 1. So, W 4 L 1 right. So, the first thing what you have learnt in the muscle in terms of it is physiology is the sliding filament theory. Now in the sliding filament theory, I ask this question calcium what is the signal which leads to the generation of calcium in the sarcomere. Now this is where I said there is a connection here with the nervous system. Now second part into the into this puzzle is there is a theory which will not cover today, but just kind of give you a flayer is called excitation, contraction, coupling theory. What does that mean now I told you that there is an electrical signal here coming for the nervous system some electrical impulse which actually leads to I have not described it, but I told you there is an electrical impulse. This electrical impulse is actually the excitation, that is this world, but then there is something happening here, change shown by delta change in length shown by capital L of sarcomere. Or in other word this is what we call as contraction. So, now, add up the point to it is this contraction which is coming here.

There is a way to couple these 2 together which is happening here. So, that is why it is called excitation contraction coupling. I will come later into this because this is one small piece which needs to be discussed in detail because this excitation contraction coupling has some other ramification in terms of how in the 3 dimensional geometry of muscle, where you have lot of these fibres which forms a 3 dimensional geometry, how the signal

really travels all across it. So, that is why at this point unless I start with the nervous system this excitation contraction coupling is not a easy it stuff to deal with so, but keep it in mind we will come back to this, from where this calcium came what is the genesis of the calcium.

And here I will again bring your attention back to the fact that those 3 excitable tissues in our body, I told you can classify the system into excitable and non excitable. So, among your excitable tissues which are generating action potential. So, here we mean those which generates AP or action potentials or the electrical impulses you can call it falls are neurons or nervous systems falls or muscle and some of the neuro endocrine cells, and among these muscles we have all the 3 muscles skeletal which what we are currently dealing with cardiac and smooth and our link what I highlighted is out here, or even as a matter of fact here right. And of course, here is a already link out here like this.

So; that means, if these are excitable cells. So, in these also generate their own action potentials along with the neurones. So, how then action potential of neuron interacts or cross talk with an action potential electrical activity of the muscle because mind it muscle has another additional task all these muscles have another additional task that is mechanical motion or mechanical contraction.

So, one has to draw a symmetry or some form of a sequence where you can connect 2 3 distinct stuff which includes a signal from the neuron a signal to the muscle and the muscle contraction. So, you realizing it is a very complex process, what we are dealing with at this point we have only dealt with this part of the story how the mechanical contraction is taking place, but we have an talked about how this is linked to the electrical activity of the muscle as well as before that the electric electrical activity of the neurons, why is it important first practically think of it your muscle. Suppose here they are not twitching your or my muscles they are not twitching we are very fortunate they are not twitching all by themselves they will only twitch, if there is electrical or some signal x y z signal coming then only they will twitch. So, keep that in mind.

So, the reason to put it like this is. So, that you put your rational question at every point from where this is coming then only this whole thing will make sense.

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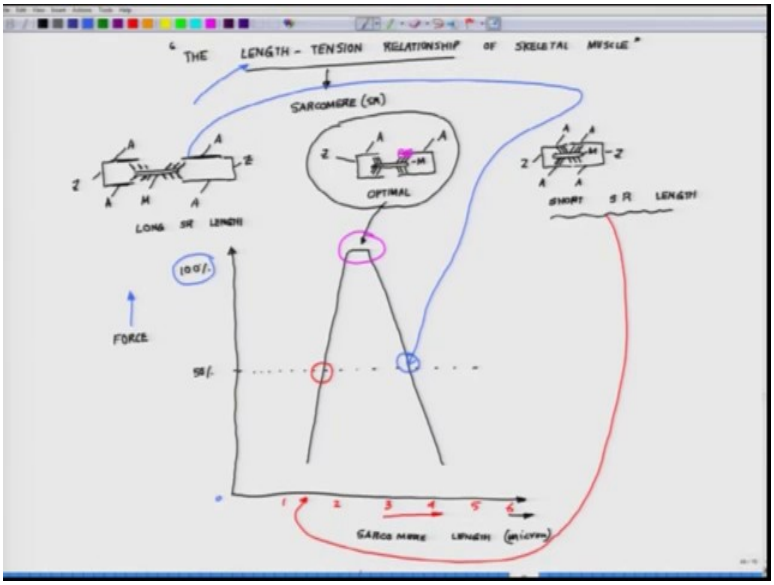

Now, what we will do next is, I will move on to the next slide where we will first before I touch upon this we will talk about the length, tension here, tension I meant by not your physical tension mental tension is basically the force generated by the muscle length's tension relationship of skeletal muscle. So, in terms of the length tension relationship, we will be dealing at the level of the sarcomer because this is the smallest unit. So, we will deal with the sarcomere and you can extrapolate it at the level of muscle. So, in the sarcomere if you remember it there are 3 possible situation.

So, one is a situation where say for example, if this is the sarcomere, where the line which I have drawn are the actin thing, and this is the z line, this is the z line imagine and this is your a stands for actin and in between you have the myosin filament. And here you are forming the cross bridges like this. Fine this is one possible configuration the other configuration could be when it shortens say, for example, it shortens out. So, this is if I call this as position say optimal position where you have this situation. So, it become shortened out when it shortens out. So, what will happen these 2 filament actin filaments, this is the a and this is your myosin and this is the myosin head what you see let me just put it in pink. So, this is where the myosin heads are interacting with the actin filament.

Now, when it shortens it becomes something like this, almost the actins come. So, close

from all sides, a stands for actin this is the z line this is the z line, and here you are having the myosin present there. So, this is a short shortness of the sarcomere length has become shortened fine, short I am just putting sarcomere as S R short S R length and the second state could be when this is a stretched even further. So, something like this where or something like this where the number of interaction has kind of you know reduced down. So, here you have the As, As actins, actins, actins, here you have the z line, z line and here you are having the myosin right. Myosin. So, this is when long sarcomere length. Now it has been observed in these 3 situation, if you draw a graph like this, where y axis represents the force percentage we can or unit force generated, if I keep it as maximum force say hundred percent. So, you will see the depending on the sarcomere length the if I put it like this. So, and this y axis is going for sarcomere length in microns sarcomere length and micrometre, what will you observe is something like this.

Graph comes like this. So, you will observe at 50 percent. So, this is when the optimal thing the maximum force or 100 percent force you achieve when the length is optimal and when the length shortens. So, if I talk about the shortened length I am talking about this part because length is increasingly like this if 1 unit, 2 unit likewise if I put it 1 2 3 4 5 6 likewise, I am this is just imaginary unit I am putting. So, sarcomere length is at 50 percent when it shortens out. Similarly, when sarcomere length is very relaxed, it lies here and for maximum this lies here. So, what do you observe here is, sarcomere length is a function of the percentage force generation. When the sarcomere length is at optimal distance then you generate maximum force. Or if the sarcomere length is relaxed or kind of you know comes very close that time what do you observe is the force almost becomes half or reduces. So, this optimal length of sarcomere and the force generation brings us to the concept of in brief the concept of length tension relationship of the muscle. And it is extremely important that you understand this particular part that this sarcomere length is a function of the force how it works.

Now, I will bring you back to one fundamental concept, where I started I told you that the amount of force which is generated say for example, if you look at here the percentage force I have given. So, the amount of force which is generated. So, this is in percentage right. So, but theoretically speaking they should be some unit in newton or something some physical unit has to be there. Now we have talked about in the very

early if you remember we have talked about how we started this topic I told you that if you look at your heart the cardiac muscle they are doing like this right. You can feel there your heart is beating second example I give you are eating the food and it is passing through your elementary canal, but you really do not feel the force getting generated there right. Yet at the third example I told you about this skeletal muscle, where you literally can see the twitching happening and I told you that all these muscles are or could be classified based on.

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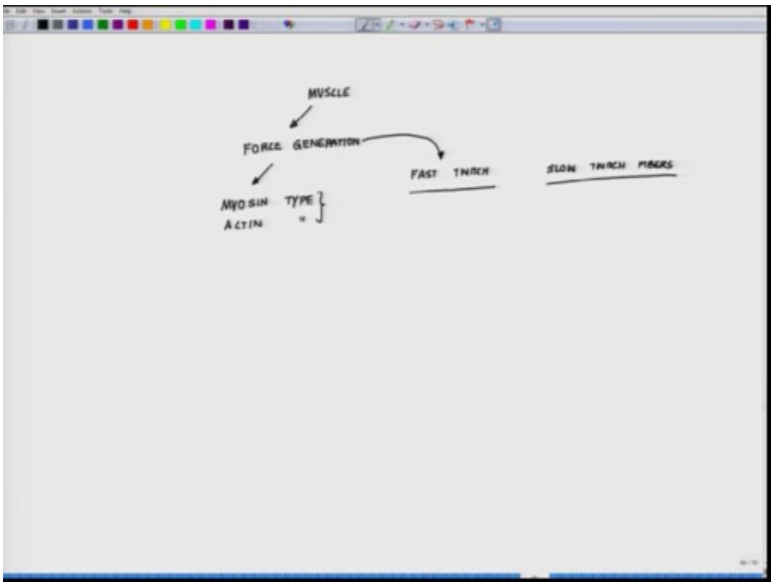

Now, here is that point what I am trying to highlight muscle, could be classified based on force generation. And this force generation is a function of myosin type.

We will you agree with me now, because you have seen the muscles are generating this force like this. So, that force generation is a function of what is the kilo Dalton or what is the molecular weight of that particular myosin fibre in that particular myosin type. So, it is based on the myosin subtype. So, that is why if you remember I told you.

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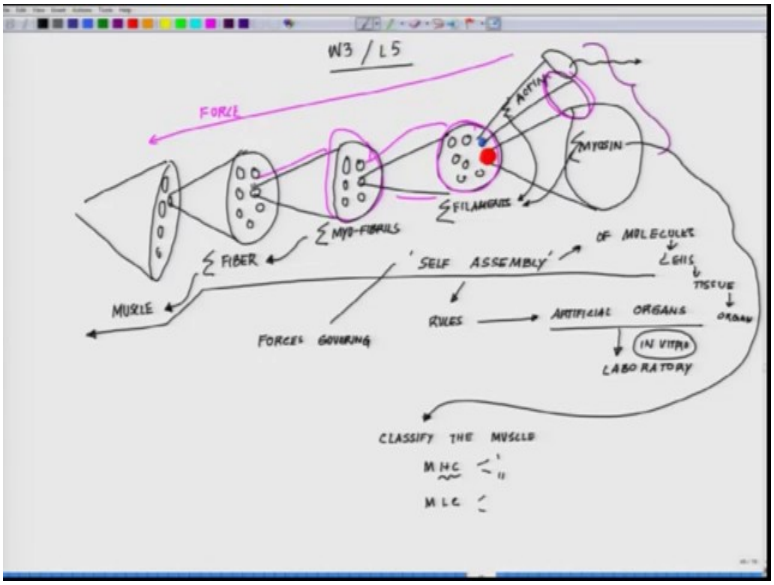

Now, if I go back 2 previous weeks lecture, when I show you the hierarchy like here based on the myosin subtype that is the lecture last lecture of third week, you can classify the muscle, classify the muscle based on myosin subtype. So, you have different. So, the way they call it is that myosin heavy chain H C stand for myosin heavy chain and then they have types type one type 2 likewise, you know similarity myosin light chain apart from it you have classification of actin which actin or we dealing with and it is the permutation and combination there are several subtypes, I am just giving a couple of examples here that determines what will be the force which will be generated by the muscle, and at different part of our body there at different kind of muscle subtype. So, one such example is of different myosin types force generation myosin and of course, you can add the actin type, but mostly it is based on myosin types based on the force generation these are classified into fast twitch and slow twitch fibres. Now what are these fast twitch and what are these slow twitch fibres.

We will talk in the next class about what is the fast twitch and what is slow twitch, and little bit more about the myosin subtypes. And how that brings us to another form of muscle within the skeletal system what I just very briefly mentioned you remember the interfacial fibre and that is exactly where we will slowly move on to the nervous system, and I will tell you the reason in the next class.

Thank you.