Mechanics of Human Movement

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Lecture – 06
Mechanics and Modeling of Muscles

So, last class we looked at the muscle structure and then the length tension relationship for the muscle at the sarcomere level, the sarcomere is the individual unit that is responsible for the contraction in the muscle.

So, the muscle of course, is not just these sarcomere is the contractile component, but there are other you know there is connective tissue surrounding the muscle, there is also the tendon which actually transmits the force generated by the muscle to the bone and so, those also influence the relationship of the force transmission and so, today in this class we will look at some of those factors.

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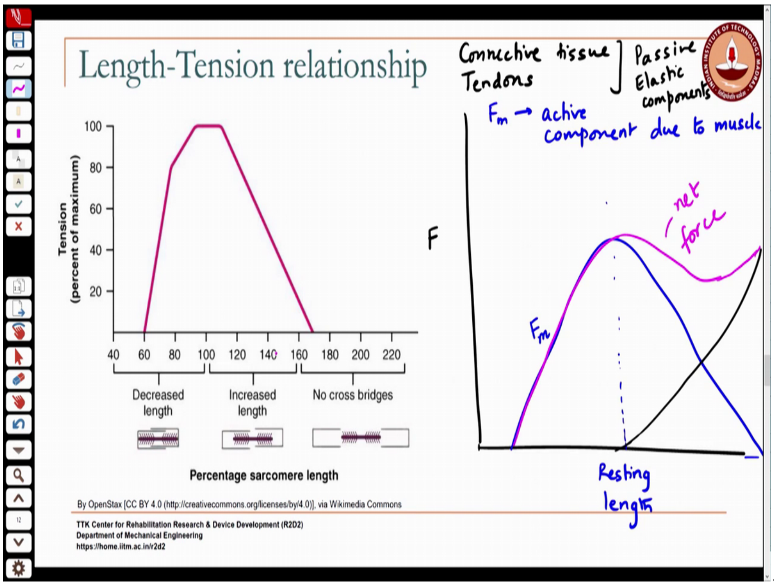

So, the whole muscle behavior will also be influenced by those relationships.

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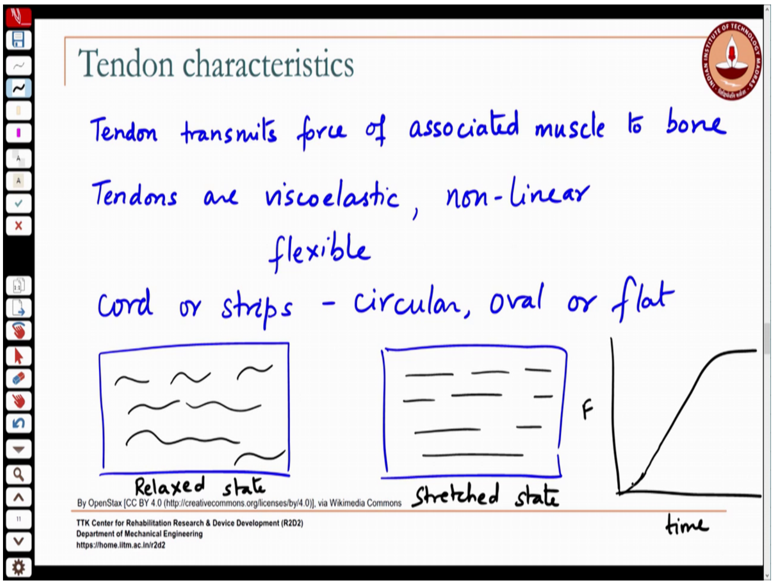

So, if you look at tendon characteristics, essentially the tendon serves to transmit the force of the associated muscle to the bone, they are pretty powerful tendons are they carry large loads.

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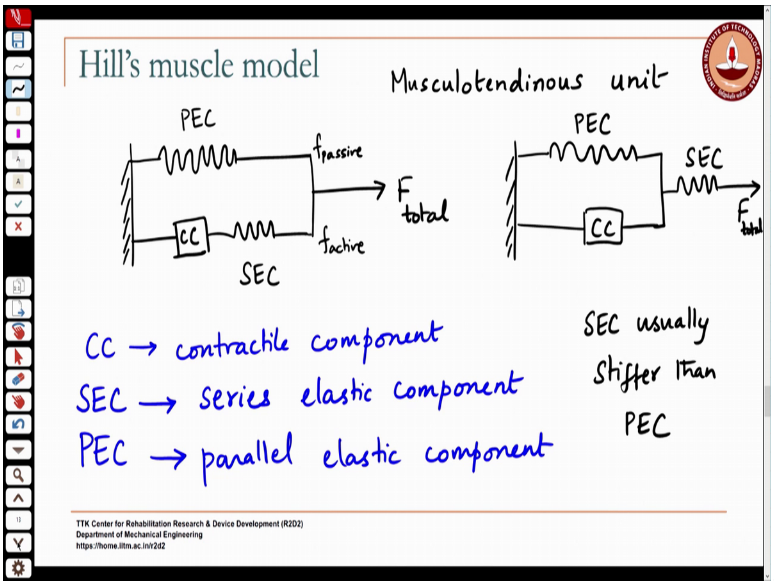

They have sorry about that and their characteristics so, they tend to be viscoelastic.

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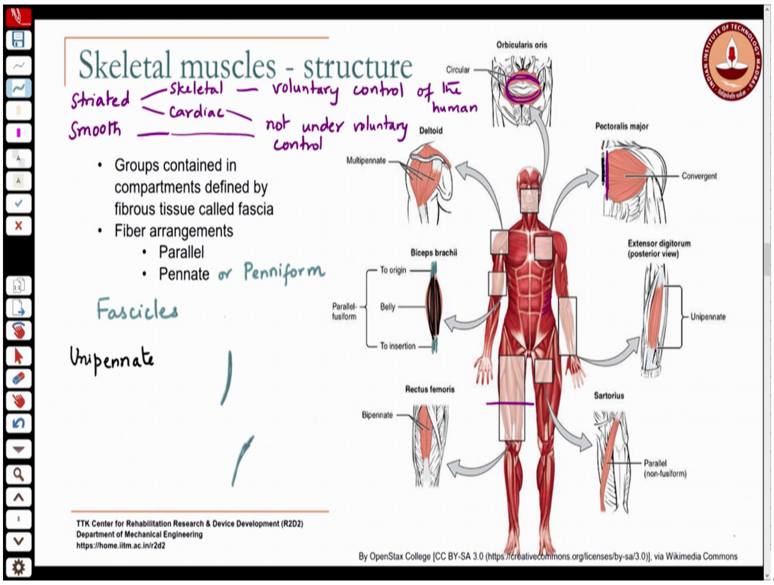

So, tendons are viscoelastic structures which means; they exhibit both viscous and elastic behavior so, but it is and they linear in their stress strain relationship. So, tendons can store energy they are elastic, but they also exhibit hysteresis generally tend to resist stress stretch and are quite flexible. Because in the body they have to move you know like more strips and they could be you know different cross sections, you could have circular, oval, or flat shapes for the tendons and tendons are basically a bunch of in elastic fibers, but the fibers in the relaxed state are kind of wavy, they are slack and wavy.

So, if you have this and you have the fibers with this is a if you look at the fibers in the tendons they tend to be like that they tend to be wavy. ok. So, when force is applied initially they tend to stretch. So, this also influences so, when there is when a tendon is stretched these fibers straighten out right relaxed state and this is the stretched state and because they are viscoelastic their behavior is time dependent. So, you load it very quickly exhibit greater resistance. So, that those are some of the characteristics of the tendon that will also influence the overall muscle behavior.

So, if you look at force versus time force that is transmitted versus the time, you will see that initially because of the slack in the tendon the force transmission is low to the bone and then the force increases linearly and then levels up. So, when you look at the muscle force overtime initially because of the non-linear nature of the tendon you have, it takes time to develop force and then once it is stretched out. Now it is trying to stretch it even further and that has to do with the properties of the tissue and not so, much this structural aspect of the waviness of the fibers. So, now you are starting to pull on the straight fibers and that part of the force transmission is tends to be linear with time and then it sort of levels of after point.

Student: We are applying force that the tendons. So, tendon (Refer Time: 06:19).

Contractile the muscle is what is generating the force.

Student: (Refer Time: 06:25).

The muscle generates the force the tendon first you know like a spring it kind of straightens out and then it is able to transmit the force to the bone that to which it is attached so, there are this model. So, if you look at the whole muscle force versus the lengthening. So, this is for the individual sarcomere right, if you look at the whole muscle you will see that somewhere close to thee again the resting length let us call this the resting length is where you will see the maximum force developed in the muscle.

So, this is the force generated by the muscle. ok. So, this is the contractile component of the force that is generated and similar to in the sarcomere case you will see that, if it is shorter than the resting length then it tends to part in between where close to the resting length where you see the maximum force production in the actuator the muscle the contractile component.

Now, if you look at the elastic tissues the connective tissue you have tissue surrounding the muscle you have the tendon. So, these are called the passive components passive elastic components. So, the connective tissue around the muscle epimysium and you know all those tissue surrounding the muscle and then the tendons because they cannot generate force. ok. So, they are called the passive elastic components and the muscle is your active component. So, this blue is your active component muscles active component, component due to the muscle muscles contactability. ok.

Now, if you look at the passive elastic components what happens is they start as the muscle is past it is resting length they start acting because now you are stretching these tissues. ok. So, the there they start developing force because of the stretch, when the muscle is below it is resting length you do not really have much of an effect of the passive components, but with because once what you see is how much whatever force is generated by the muscle is transmitted to the bone. ok. So, the net if you look at the net force then initially it is just it follows the contractile component and then because it is basically the sum of these 2, this is the net force, that is transmitted to the bone.

So, the passive elastic components start contributing more once the muscle is past it is resting length that I am sorry that becomes

Student: What it (Refer Time: 11:25).

Passive it is only because of the stretch you do not call a spring an actuator it is whereas, the muscle is producing the force, the it is a resistive force it is a response because of stretching it is generated yes.

Student: Generated with stretching this part of the muscle force rate so, why are we adding the 2.

No so, when I talk about the blue one I am talking about only the contract contractile force that is generated by the muscle, by the muscles active component that is why I am adding. So, you have tension generated by the muscle now, you are also stretching some additional tissues that are attached to that muscle that additional force is because of these passive elastic components.

Student: (Refer Time: 12:27) into the (Refer Time: 12:29).

Because it is the response to an applied stretch

Student: This is mounted at one end and the other end is the connected to the actuator.

Yes.

Student: We are pulling that actuator. So, in a sense we are just transmitting the (Refer Time: 12:42) from the actuator to the wall where is spring is.

True, but beyond a point when you stretch this beyond that. ok. So, initially that is why in the when the muscle is just in the contracted state on the left side of this graph you see lack you do not have a contribution to the tension from the passive components, it is only when they are stretched that they start.

Student: Muscle.

It is transferring to the bones of the body, the additional force is the resistance of this. So, you have let us see this is like a flexible, but rather in extensible cable right that tendon is like that, you are pulling on it with a force that is the muscle the muscle is generating a force which is pulling on this.

Now, when this starts black lines so, if you are at the you saw with the sarcomere that when it is past the resting length the force drops off right. So, after a point you cannot even apply the contractor force, but you still have resistance, that resistance is only due to the passive elastic component. So, you see here after it drops off to meet the net force is only due to the.

Student: In the case of contract the without generating any tensioned the tendons how is it transmitting.

It is transmitting so, it is contribution is minimal at that point it is contributing see if it is not stretched beyond. So, I straightens out and transmits the force do that now you start stretching it even further, then it starts resisting that stretch. ok.

Because that is at the molecular level now you are the material is reacting to the force that is applied to it. So, we can model this muscle and the tendon and the connective tissue so, one of the objectives of you know any time as engineers we try to approximate something with the model so, approximate behavior with a model. So, we can create so, hill came up with this model for a muscle and that has and it is known as hills muscle model.

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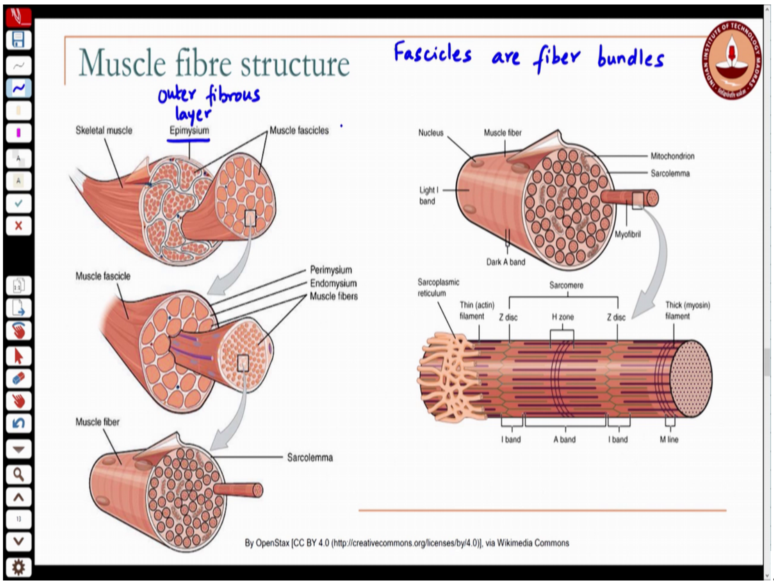

The muscle the whole muscle so, this is for the musculotendinous unit, it is for the entire muscle plus tendon. So, the muscle tendon unit can be modeled using these elements, where this CC component the contractile component and it represents the muscle the actuator which is generating the force. Then you have the contractile component is in series with the tendon you can think of it in terms of SEC series with. So, it is called the series elastic component, wait a minute yeah and in the is the parallel elastic component.

So, these are the tissues so, you have whatever force generated by the muscle and then that is the same force experienced by the and the tendon and the muscle experience the same forces because they are in series and then you have the parallel elastic it is in parallel to the system of the muscle and the tendon and that is your connective tissue are. So, that is your parallel elastic component so, when you model and you want to represent muscles, this is one of the most common models used to represent the muscle and it is called the hills muscle model. In some places you will also see a slightly different form of this where you have PEC and then you have the SEC.

So, this represents the structure more closely you have the contractile component you have the passive and then you have the SEC, but typically the contribution of the PEC is lower so, both types of models are used for modeling the muscle behavior.

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Now, we look at so, before we do that, let us look at this when do we experience this passive and active tension and when does it make a difference when do we operate in most normal activities we will be operating in the central zone.

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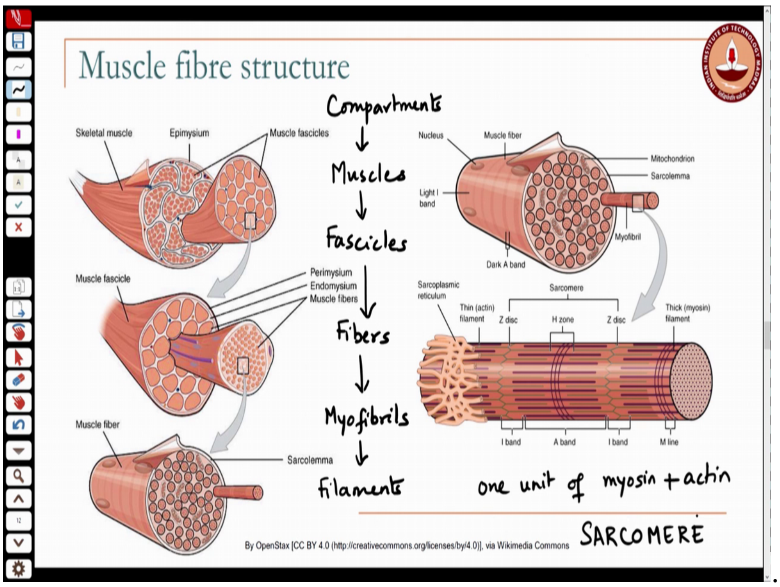

But there are times where you will in some muscles you will find that we operate at the extremes. ok. So, biarticular muscles where the passive tension starts to make a difference. ok.

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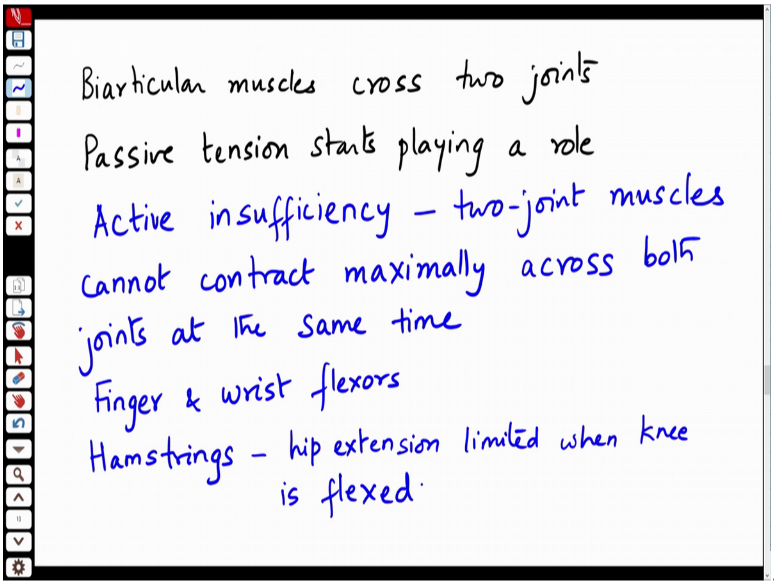

So, the biarticular muscles cross 2 joints, the most muscle joint so, the influence delay in these cases the passive tension that we saw starts playing a role this passive tension starts playing a role and I will explain it with an example and also you start operating at the 2 extremes of this curve. ok.

So, let us see so, if the muscle so, biarticular muscle crosses 2 joints your finger flexors they flex both your wrists so, they cross them here.

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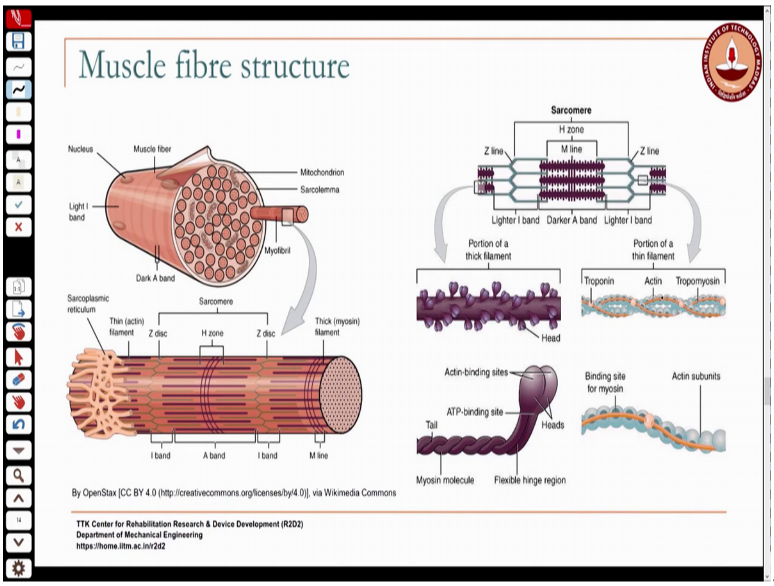

And sort of fans out the tendons fan out to the fingers. So, when my wrist is in the neutral position. ok. So, they are crossing both I can get a pretty good grip I can contract my muscles and grip something pretty hard. ok. Now, suppose I also flex my wrist flex your wrist. So, grip something then flex your wrist, as you increase your flexion what happens you start losing your grip because now the muscle has shortened beyond it is resting length.

So, it is ability to generate force has now gone down, because you know when the when you are flexing it this muscle is contracting. So, it is so, I am not able to generate maximum flexion in both the joints by. So, this case is called active insufficiency sorry about that so, what it means is 2 joint muscles or biarticular muscles, muscles that cross 2 joints cannot across, if you are lying face down whenever same thing happens another set of muscles. So, this is the at the finger and wrist flexors right this is an example, example of active insufficiency another example are your hamstrings.

If you are lying face down hamstrings flex the knee hamstrings are the muscles at the back of your leg when they contract your knee flexes. So, if my knee is flexed the hamstrings also cross the hip, then I cannot extend my knee fully sorry I cannot extend my hip fully because the hamstrings also extend the hip move the hip back move the thigh back ok. So, again that is an example of active insufficiency because the hamstrings are already in a shortened position.

So, if your knee is flexed. So, I can do this when my knee is extended I can extend my hip further ok, but if my knee is flexed then you will feel the tightness you would not be able to extend it further. ok. So, the hamstrings with knee flexion so, hip extension is limited when knee is flexed I cannot. So, actively I cannot extend my hip when my knee is flexed, the other situation that is where the passive tension starts playing a role is called passive insufficiency.

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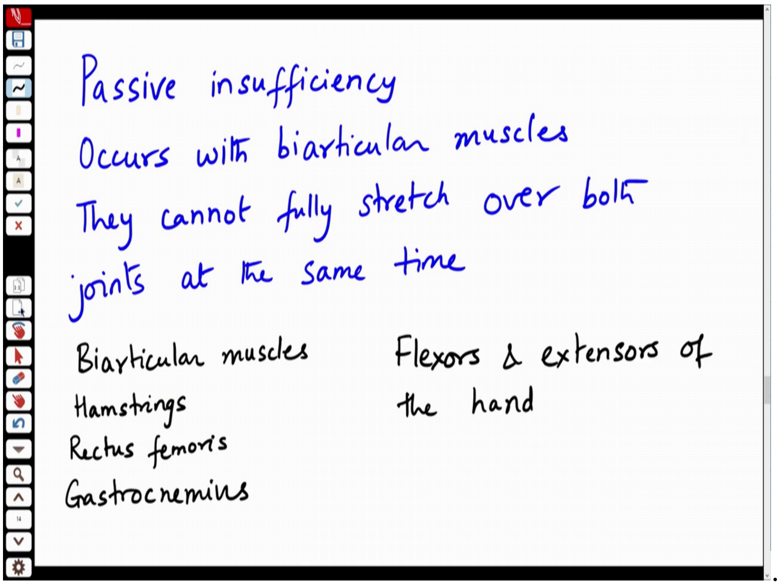

Again you see this with muscles that cross the 2 joints because that is when you can get them to operate at the more extreme positions. So, if you look at passive insufficiency darrens at the same, time again duck muscles.

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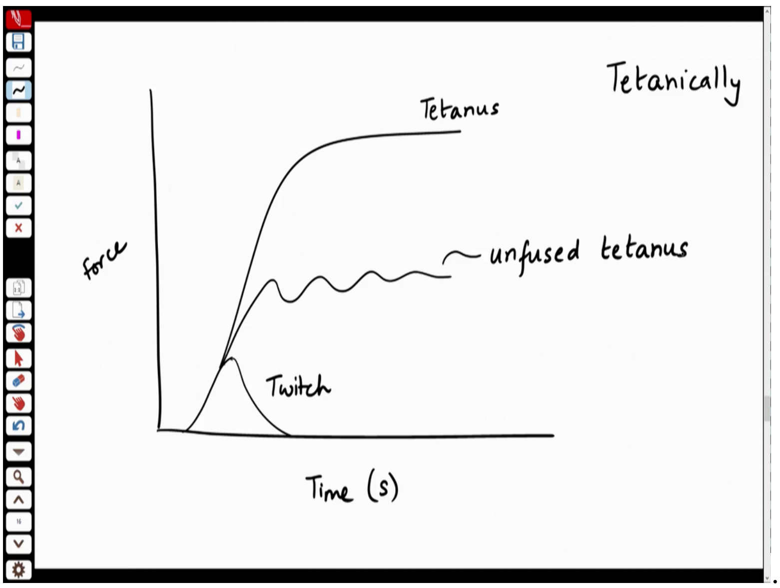

Again you can use the hamstrings as an example so, now, you are stretching the hamstrings. ok. So, you lie down in the supine position on your back you lie down on your back and the start lifting your leg you are flexing your hip try not to bend your knee you are lifting you are keeping your legs straight and you are lifting your leg at the hip now what are you doing you are stretching the hamstrings as and. So, the hamstring is lengthened and you are lifting your leg what happens, unless you have very hamstrings right because it is the tissue now that is providing the tension providing the resistance the passive tension is coming into play. It does not matter how much you try to cut you know it is not your the contractile component that is playing a part as much as it is the passive tension. So, this is called passive insufficiency because it is because it is a playing a room passive component of the muscle that is playing a role so, these happen with the biarticular joints.

So, other biarticular muscles are. So, some examples of biarticular muscles and you can try some of these try experiencing the passive and the active insufficiency. So, you have the hamstrings, you have the rectus femoris which belongs to the quadriceps, you have the gastrocnemius muscle which is your calf muscle that crosses the ankle and the knee these 2 cross the hip and the knee the hamstrings and the rectus femoris, the gastrocnemius crosses the knee and the ankle and the flexors and extensors of the hand which cross the rest and several fingers. So, these are muscles over which you can experience the extremes of the length tension relationship of the muscle and surrounding tissue, some more terminology with respect to muscles.

We talked about the ORIGIN.

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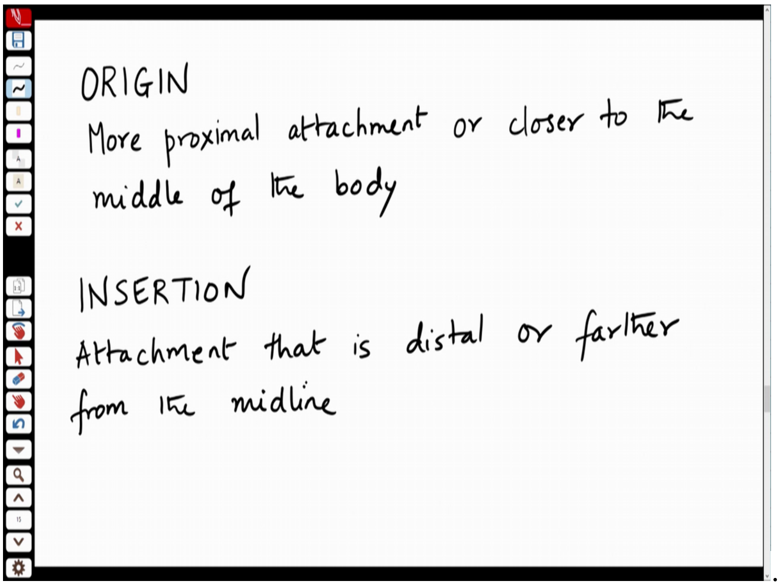

So, a muscle is typically attached to 2 bones, we talked about the origin. So, you the muscle is attached to a bone at both ends so, the more proximal attachment or the attachment closer to the midline of the body. So, the proximal distal remember we talked about it in terms of the appendicular skeleton right or closer to the middle of the body you call it the origin that is called the origin of the muscle.

The other end is called the insertion so, the attachment that is distal or farther from the midline is called the insertion and usually this is where it converges to attention to attendant and inserts because trying to make. So, the insertion usually converges you know the muscle converges to a tendon and then you have your point of insertion in the both. So, more than one attachment site is always possible at both ends and the muscle can move over it can move either both in most cases.

Student: that inside this muscle to tendon or tendon to bone.

Tendon to bone yeah that end where it attaches the distal place where it attaches the muscle in only in a few cases it attaches directly to the board usually it is through a tendon. So, it is the location we are talking about here. So, wherever the more proximal or closer to the midline that is your origin it is called the muscle origin, it is understood that it is the typical it is the tendon that is inserting into the bone ok.

So, we talked about, but we say because it is the muscle action we talk about it as the muscles insertion muscles origin muscles insertion. ok. So, if you look at for instance so, the muscle can move either of the bones you have 2 bones connected by a joint, the muscle can move either bone there is nothing that says that only one bone is more by what happens usually is that other muscles or other things come into play at one end to kind of stabilize that bone and so, you have movement of the other bone.