Biomechanics
Prof. Varadhan SKM
Department of Applied Mechanics
Indian Institute of Technology, Madras

Lecture - 17
More on Pennation Angle

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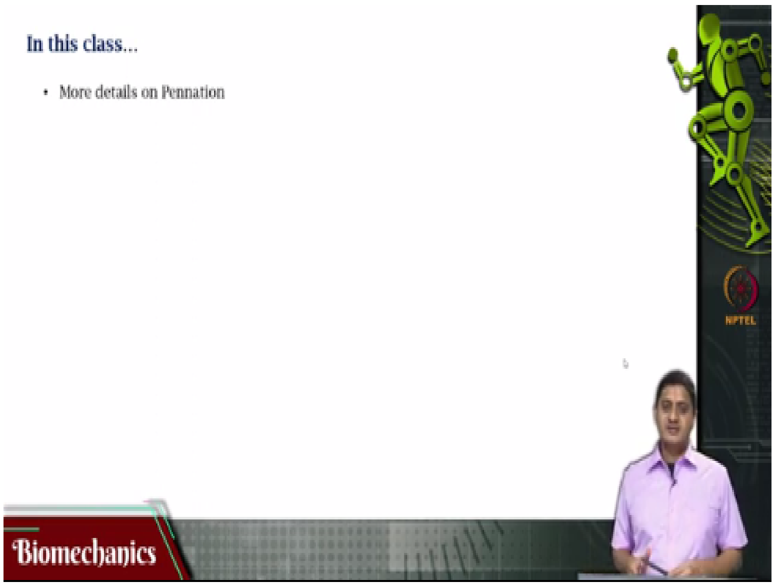

Welcome to this video on biomechanics. We have been looking at the skeletal muscles. Specifically in this class I wanted to discuss and provide some more details on pennation. We introduce this notion of pennation in one of the previous videos. I thought it makes sense to go a little deeper and discuss what pennation means for us? What is its practical consequence? Some it us with some examples.

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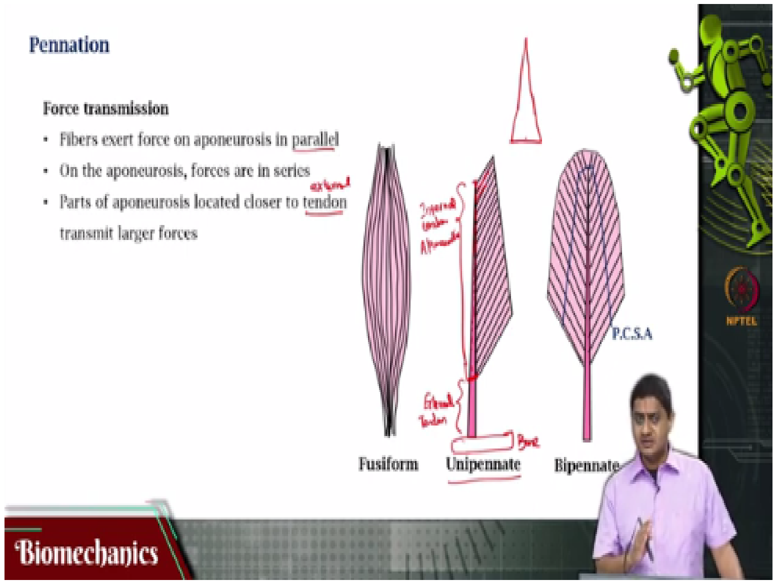

Remember something to note is that, when we say muscle force. What do we mean by that? Is it the sum of all the muscle fibre forces or is it the force that is felt at the bone. What exactly is meant when you say muscle force. The answer is in general when someone says muscle force. That is the force that is exerted by the tendon on the bone. This is what it means for a bio mechanist.

So, we are looking at the force exerted by the tendon on the muscle, not how the tendon itself is getting the force. That is not what is called as muscle force. Muscle force means force experienced by the bone; force exerted by the tendon on the bone this is muscle force. If the muscle fibres are all parallel to the tendon, then the sum of all the muscle fibre force will be the muscle force but this is not a given, this is not a must.

So, muscle fibres may or may not be parallel to the tender. There are many cases in which the muscle fibres are not parallel to the tendon. That is the case that we discussed. Here is a case in which the fibres are parallel to each other but not to the tendon they are inclined at an angle to the tender is it not, the case of the unipennate muscle. Note how this internal tendon what do we mean by this? Internal tendon is that part of the tendon where it is attaching to the muscle fibres.

The external tendon is the one that is attaching to the bone. Now also note importantly how the number of fibres that attach to the internal tendon grows the width of the internal tendon increases. Because it must be able to support that much force more force so as it as that is a need to support more force. The strength of the internal tendon itself keeps increasing. Of course, your question would be why not keep a very broad tendon from the beginning?

Because it is inefficient, see that is where the biological system is so efficient. It starts with a narrow tendon in the beginning because that much is sufficient to support the force of one fibre. And then as it goes down there is this width so that is the arrangement. When so mean this is what I am going to say. At the end of the internal tunnel this part of the tendon that is attaching to the bone is called as the external tendon.

This part that is attaching to the muscle fibres is called as internal tendon or in a previous class I mentioned this as upon neurosis. On the aponeurosis forces are in series. So, forces get added here in series. Each fibre is producing force in parallel, so the fibre force and aponeurosis is parallel. But the force on the aponeurosis keeps on getting added in series. Of course, the parts of the aponeurosis located close to the tendon what tendon?

We are referring to when we simply say tendon, we are referring to the external tendon. When we refer to the aponeurosis, we must specialize that we must specifically say that that is the internal tendon. If I do not say the internal tendon if I simply say tendon that means it is the external tendon. Parts of the aponeurosis that are located closer to the external tendon they transmit and they can overcome withstand and transmit a large amount of force.

When compared with those parts that are far away there because of this efficient arrangement. Now let us zoom in a little bit and take only one fibre. Let us assume for the sake of discussion that the fibres are parallel to each other and the pennation angle which is the angle at which the fibre is attaching to the internal tendon is the same for all fibres. This is an assumption. This is not always true? But it is true in many cases.

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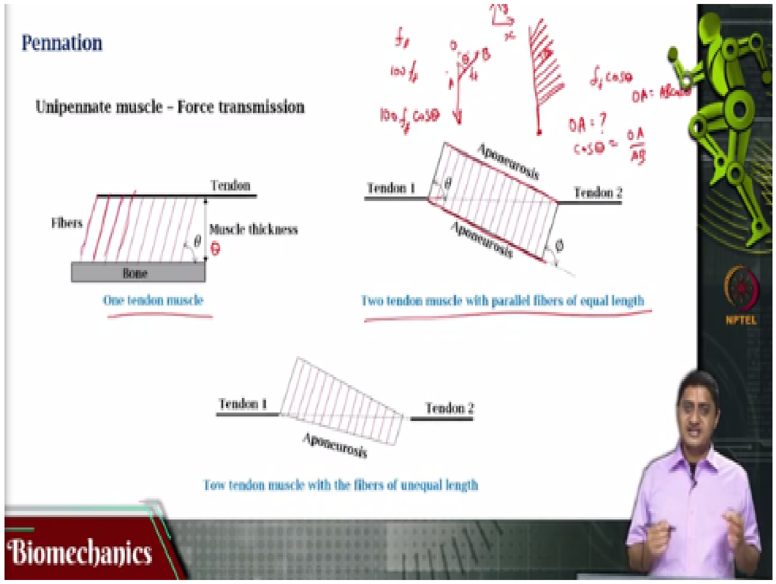

So, let us look at this with the bit more detail. The fibres are attaching like this, in the case of the unipennate case. The fibres are all parallel to each other and they are attaching like this the angle of attachment is sum theta, is the angle at which the fibres are attaching. There are many cases many possibilities in which this can happen. One is there is only a single tendon muscle, the fibres are all attaching to the bone directly like this.

This is a one tendon muscle. Then you have a two-tendon muscle with parallel fibres of equal length like this with some theta to the tendon. Whereas you see that there are two aponeuroses that is one aponeurosis here and there is one aponeurosis here. So, the angle that you are having there will be two of this right there will be one theta here and there will be another angle that need not be theta that can be something other than theta in this case marked as phi.

Of course, I have assumed that the fibre lengths to be equal but this need not be the case. More special cases when the fibres length also keep changing as we proceed from one side of the muscle to the other side and as we proceed from the origin to the insertion, you are going to have a convergent type of feature, that is the other possibility. Let us take the simple case where there is where I have an internal tendon and there are these parallel fibres attaching at some angle theta.

Let us say that each and let us say that I have 100 such fibres. Remember a muscle can have thousands of fibres. Let us say that I am having hundred such fibres and I am going to call the force produced but by each fibre as some small f f. And let us assume that they all produce an equal amount of force also an assumption. Because they all may or may not belong to the same motor unit. Maybe they will belong to the same model but that is not a necessary condition.

Let us assume that they all produce an equal amount of force f f. I will assume there are hundred such fibres. So, the total force that is produced by all these fibres put together is 100 f f. The question is what will be the force that will be felt here at the external tendon bone Junction? That is the question, well that is obviously a function of theta. Let us assume that all of them are making same theta. So, let us take one fibre and this is the fibre.

I am interested in this component. Let us analyse this using our principle of statics. I am interested in the y component of this f f what would that be that would be you know that distance. So, if I know f so this is f f I am interested in this distance, this component this is what I am interested in. What would that be? That would be f f cos theta. Let not or in this right triangle l am going to call this as O and I am going to call this point as A and I am going to call this point as B.

I am interested in finding OA this is what I am interested. In this AB is the hypotenuse. So, cos theta is OA by AB it is not, so OA would then be AB cos theta it is an example. Now if I were to align AB such that it is along way or theta is very close to 0 that is the parallel fibre muscle for me. So, that means it is useful to have minimal pennation angle so that maximal force transmission happens.

That is a desirable quality but that is not always the case because I am interested in packing many fibres in a small volume there is a third dimension that we have not discussed right here I am doing simply a planar analysis I am interested in packing a large number of fibres in a relatively small volume. So, I am inclining this you know these fibres. So, only a component of the muscle fibre force f f will be felt at the external tendon level.

So, each fibre will contribute you know f f cos theta in this case I am calling this as f f AB another f f cos theta. So, if I have 100 such fibres, I will have 100 f f cos theta is what will be felt at the tendon this is the muscle force when I say muscle force, I am talking about the force that is felt at the tendon. So, I will only have a component it is indeed desirable to have this data to be smaller from the viewpoint of having maximum force transmission efficiency.

If I was producing this much force might as well transmit all of them. But that is not the only factor under consideration, there are many other factors under consideration force transmission efficiency is one of them, of course we would like to have first transmission efficiency but we are also interested in packing more fibres a trade-off will have to be made somewhere. So, this is the situation only a component of the fibre force gets transmitted to the external tendon and felt at the bone something to keep in mind.

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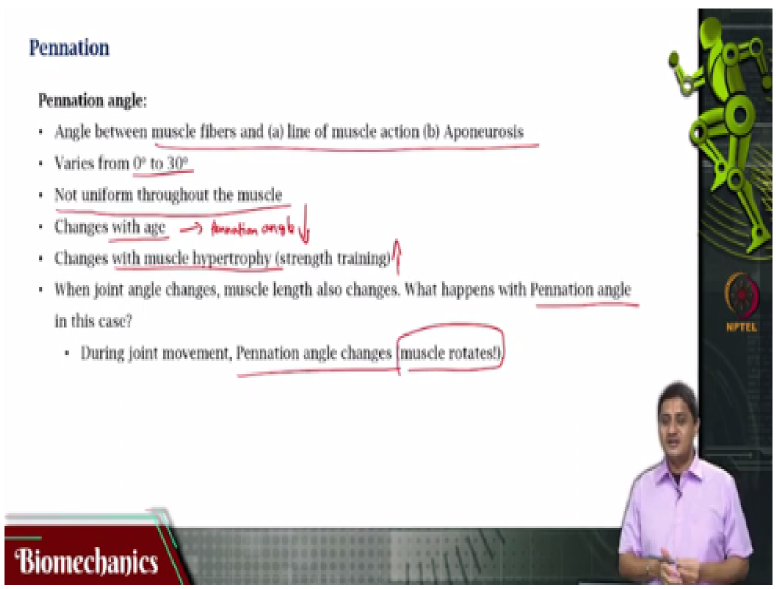

So, what is this pennation angle? We already mentioned this, this is the angle between the muscle fibre and the line of muscle action or the aponeurosis. It says line of muscle action or aponeurosis because sometimes there might be no alignment between the line of muscle action and aponeurosis. Sometimes the external tendon and the internal tendon may not be aligned, so that is the other possibility.

Fortunately, it does not go very high because cos 0 is 1 cos 90 is zero, it goes only between 0 and 30. Which itself is relatively large range. Something to keep in mind in the previous slide, I mentioned that all the fibres are having the same pennetion angle this is not true. This is not uniform throughout the muscle. It changes with age and it changes with weight training strength training and people build muscles it changes.

Now let us look at these two things take a few seconds and take a look at these two things when you say it changes with age. What do you mean? does it increase or does it decrease. Because a decrease in the angle in the pennation angle is the desirable quality is a desirable thing. And an increase is undesirable and because we know that aging generally brings in a lot of undesirable things one might think one might be tempted to think that pennation angle actually increases with the agent.

But that is not what happens, so it defies intuition you think that an undesirable thing one of the many undesirable things that happen with the old age might be that the pennation angle will increase with the edge this is not what happens. Pennation angle actually reduces with age because there is death of muscle fibres and the need to pack there is general muscle atrophy. So, the need to pack more number of fibres in a small volume reduces because of this need more and more fibres start aligning along with the aponeurosis.

Thus, reducing the pennation angle this itself is not a good thing. Because I mean this alone taken alone might be a good thing but the reason why it happens is not necessarily a good thing. So, although the force transmission efficiency increases the force itself reduces because of the depth of muscle fibres something to keep in mind. So, now the other question is what happens with muscle hypertrophy when someone is doing strength training and building muscle?

Now you would think that the desirable thing is to have you know alignment. So, exercise brings in alignment or reduces. So, you would expect that exercise brings in more alignment or reduce pennation angle. Know actually what happens is muscle hypertrophy will have a need to pack in more and more fibres in a small volume? Thus, gradually increasing the pennation angle and reducing the force transmission efficiency.

The transmission efficiency of force will reduce but the force produced will increase. how is this possible? Because more and more fibres are getting added as people do strength training more and more fibres will get added and the transmission efficiency will reduce because you will have to pack that in a given volume. So, muscle hypertrophy due to strengthened weight training actually leads to an increase in pennation angle.

So, let me write out for clarification pennation angle reduces with age pennation angle increases with strength training something to keep in mind. Also, something to keep in mind is that the joint angle changes muscle link changes. In that case what happens with pennation angle? It turns out that pennation angle is not a constant, pennation angle is defined for a configuration. So, in many cases as the configuration changes the pennation angle itself changes or in other words the muscle rotates. So, it not only you know changes the angle it also.

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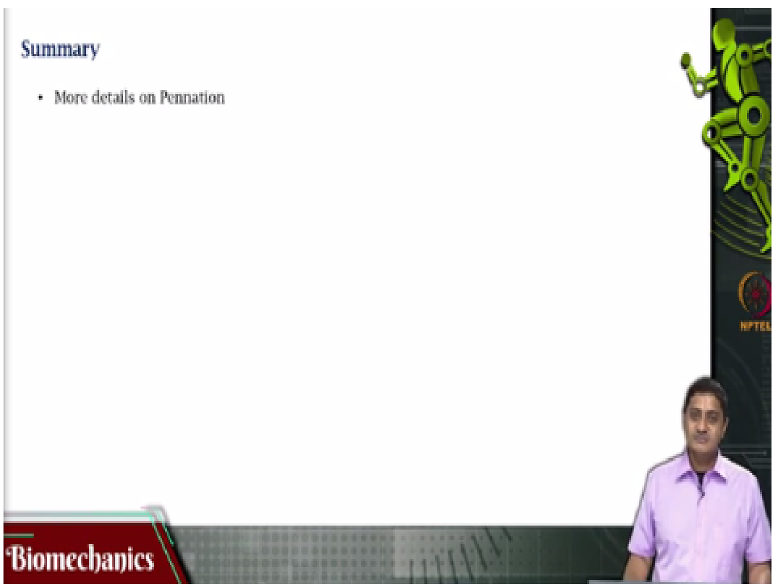

So, in this video we saw some more details on pennation angle and how pennation angle changes as a function of age and as a function of strength training and exercise. Thank you very much for your attention.