Mechanics of Human Movement

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Lecture - 25
Static Analysis of the Knee and Ankle

So, we have been looking at the mechanics of loading the knee joint. So, we looked at, how to do a static analysis for a loading case.

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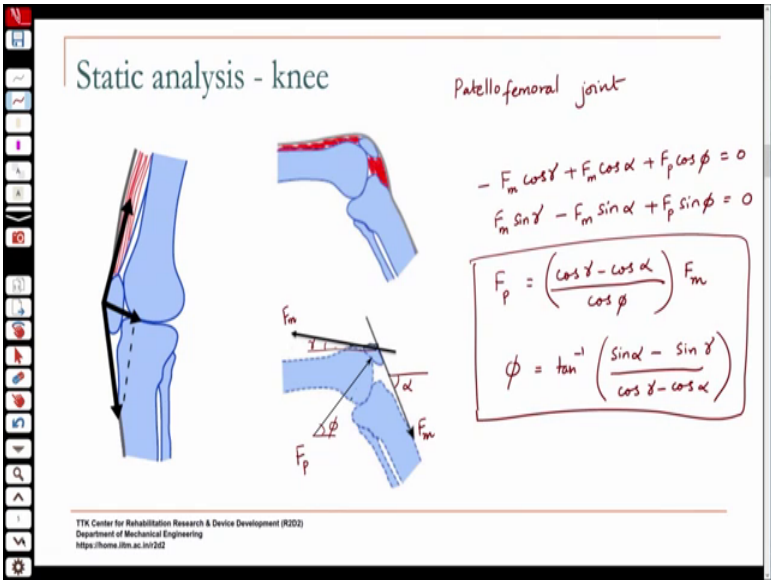

And as I mentioned at the knee there are 2 joints, one is what we traditionally refer to as the knee joint which is your tibia femoral joint, which is responsible for the flexion extension of the knee, but you also have another joint between the patella and the femur because the patella moves on a groove in the femur. So, there are contact forces that are also generated at that joint. So, if you look at the patella, it is subject to let us assume it is like a frictional frictionless pulley so, that F m is you know the same on either side then the resultant of these 2.

So, this would essentially be the resultant of those 2 would be the force between the patella and the femur. So, if I look at. So, if you look at this and this, then those 2 create a force, which results in the contact force of the patella ok. So, you can find so, if this makes a an angle gamma with the horizontal, let us say this makes an angle let us say this makes an angle phi with the horizontal and this makes an angle alpha with the horizontal. Then you can find the magnitude of F p and the angle phi or essentially the 2 components of F p, which is basically the compressive force.

So, when you experience pain in your knee cap it is because this force it is because of this force this compressive force because as the muscle force increases this force also increases the compressive force on the in at the patella femoral joint.

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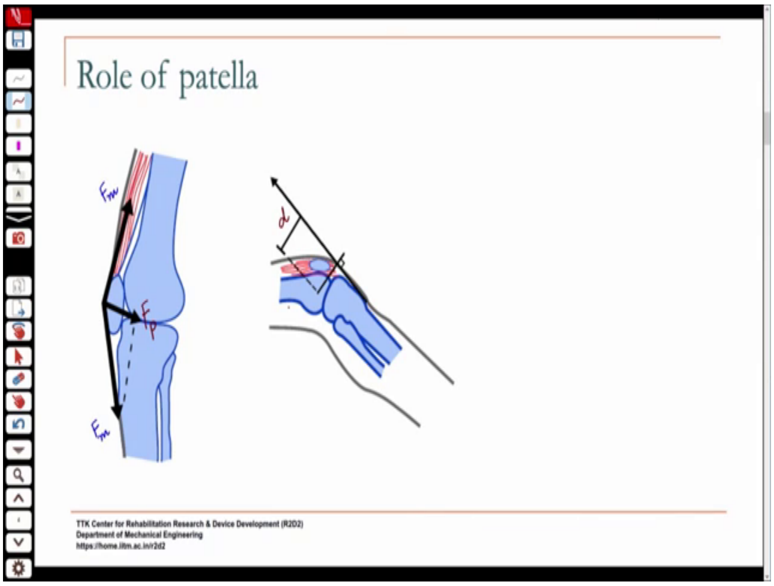

That is especially true like we saw earlier if you know the patella creates this lever arm for the muscle force and if that is damaged and has to be removed then d decreases which means to perform the same activity the muscle has to exert a larger force, which you know if the patella is damaged then in that case if there is you know osteoarthritis or you know problems with that junction then because of the increase in the joint force there a person could experience a lot of pain if that joint gets degenerated ok.

Sometimes the cartilage between the 2 will wear off and that could cause the movement arm also to decrease for the better now for the muscle force there. So, if we do a quick you have F m cos gamma plus F m cos alpha plus F p cos phi equal to 0 and then you have F m sin gamma. So, F m you would determine from your previous analysis right where you did the where you looked at the loading and you found F m here.

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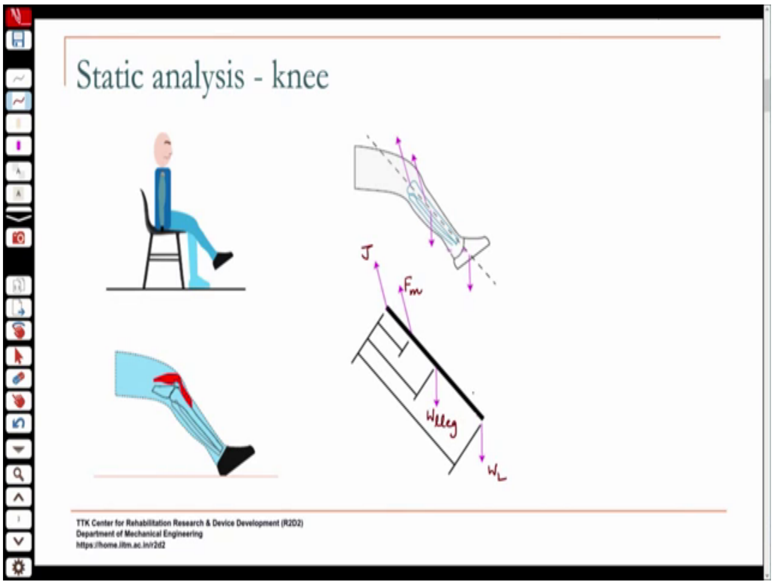

So, this was the joint force at the tibia femoral joint and then for that particular loading and the weight of the lower leg be found F m. So, then once you find that you can do an analysis at the patella femoral joint and you get F m sin gamma plus F p sin phi minus F m should put this first, since I put that minus F m sin alpha plus F p sin phi equal to 0. This gives you F p the force at that interface between the patella and the femur to be this and this angle phi is tan inverse of sin alpha minus sin gamma by cos gamma minus cos alpha.

So, some of the activities that load the knee are activities like step climbing ok.

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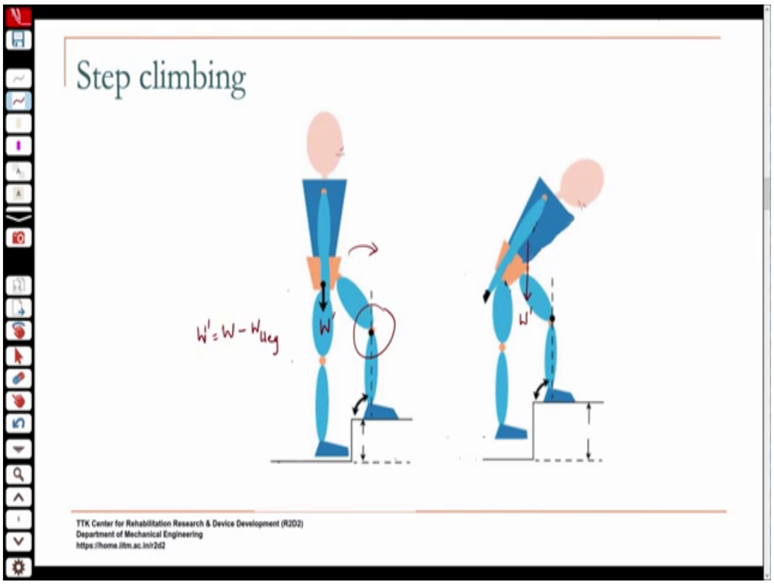

If you look at step climbing you put once one leg on the step and now you have to raise your entire body over that and the loading on the knee can be quite high. So, if you notice people with knee problems will have trouble climbing steps.

So, for instance if you have so, if let us say in this case, we assume the body weight is acting some better than. So, the person has lifted this leg off and is now trying to climb over the step. So, if they are erect again as with all the other loading conditions your moment arm is large. So, the muscular force that has to be developed in this region to straighten the knee is going to be high and if the muscle force is high the joint reactions are also high.

So, a strategy that people who have trouble climbing adopt is that when you place your foot as you are climbing you lean forward ok, that helps you do that task easier and loads the knee less. Because here if the entire not the entire weight, this should be W dash equal to the entire body weight minus say the weight of you know there is some support. So, if you draw a free body diagram of this up to this then it would be minus weight of the lower leg right.

Student: Lower leg.

In this case part of the you moved the when you lean forward especially your trunk has a large mass. So, when you lean forward you moved the W dash closer to the joint centre and therefore, you reduce the moment about that and hence the muscle force that is required to be generated is reduced and it helps you climb the step more easily, especially even you know so, able body people if you have a high step you tend to do that right.

So, you may not have any knee problems, but if you encounter a step that is higher than normal then the tendency is to lean forward in order to climb the step. So, these are some strategies we use and now you know how to actually look at the forces said that knee interface.

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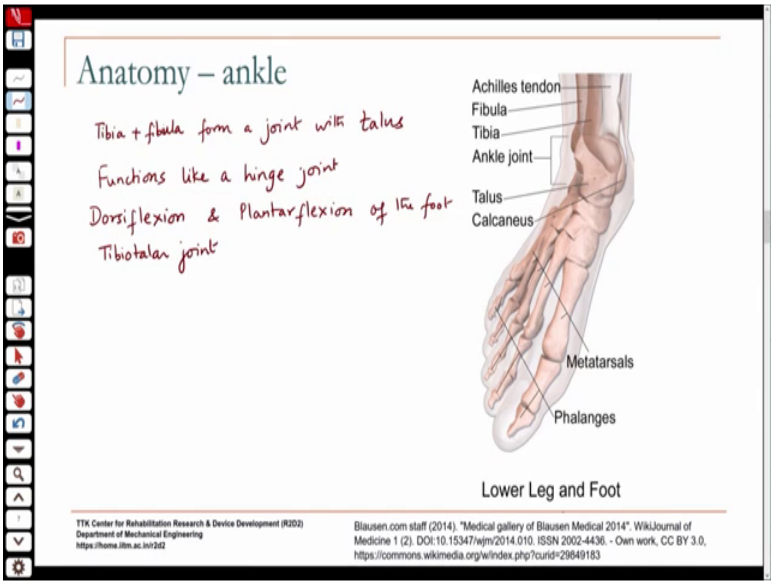

We will now move on to the lower leg below the knee and the joint that is there below the knee the one that we will be looking at is the ankle joint ok.

So, the ankle joint is actually the joint between the tibia and fibula of the lower leg ok, the tibia and fibula come down and they form a joint with what is known as the talus ok. So, you have the talus here, the tibia and the fibula form a joint with the talus and that essentially functions like a hinge joint and this is responsible for the what movements of the foot.

Student: The dorsiflexion.

The dorsiflexion and.

Student: Plantar flexion.

Plantar flexion of the foot these movements occur in the sagittal plane.

So, this joint actually primarily the joint between the tibia and the talus that is the larger joint, between the fibula and the talus it is a smaller contact area ok. This is the main load bearing joint at the ankle, the joint between the tibia and the talus. So, this is the joint that is responsible for the dorsiflexion and plantar flexion of the foot.

So, the other movements at the foot occur because of movements between other bones in the foot ok, not because of this tibia and the tibia fibula and the talus ok, this is responsible only for the dorsiflexion and plantar flexion.

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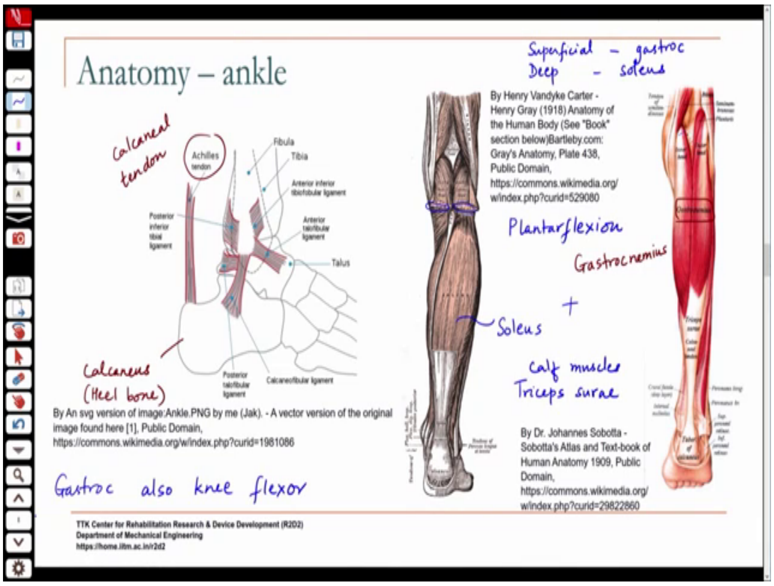

So, if you look at the muscles that are responsible for this you have you are aware of this large tendon right at the back of your foot. So, the bone the heel bone is called the calcaneus that is the heel bone. And the tendon that inserts into it is called the achilles tendon from or the calcaneal tendon, biological name is the calcaneal tendon, but the historical name is the achilles tendon. And the achilles tendon there are actually 3 sorry 2 muscles that go into it, one is the Gastrocnemius which is a 2 headed muscle gastrocnemius.

And below that so, here you can see the gastroc muscle has been dissected it is been cut and deeper you see the, what is known as the soleus muscle. The gastroc muscle again is a bi articular muscle it actually crosses the knee as well. So, it inserts into the femur the condyles of the femur the 2 heads insert into the condyles of the femur and it comes down to the calcaneal tendon and the soleus muscle also comes to the calcaneal tendon. So, together this plus this you know the gastroc has 2 heads and the soleus has 1 so, together they are known as the Triceps Surae. So, the calf muscles are also referred to as the triceps surae it is a combination of these 2 muscles.

The superficial muscle remembers like we talked about relative superficial and deep, superficial is closer to the skin, the superficial muscle is your gastroc in the calf, the deeper muscle is the soleus. The soleus only inserts into the tibia and the calc and then on the other side into the heel. So, it is a uniarticular muscle it is only responsible for. So, what motion will this be responsible for do you think?

Student: (Refer Time: 15:01).

The calf muscles through the calcaneal tendon cause plantar flexion of the foot, they are responsible for plantar flexion of the foot. The gastroc muscles also can cause knee flexion because it is a by articular muscle. So, gastroc also knee extensors sorry knee flexes. The soleus muscle is important it is when you are standing it is what is preventing you from falling forward. So, it is activated even when you are simply standing ok, because it keeps the tibia erect and prevents you from prevents it from falling forward. So, it pulls on the tibia and keeps it erect.

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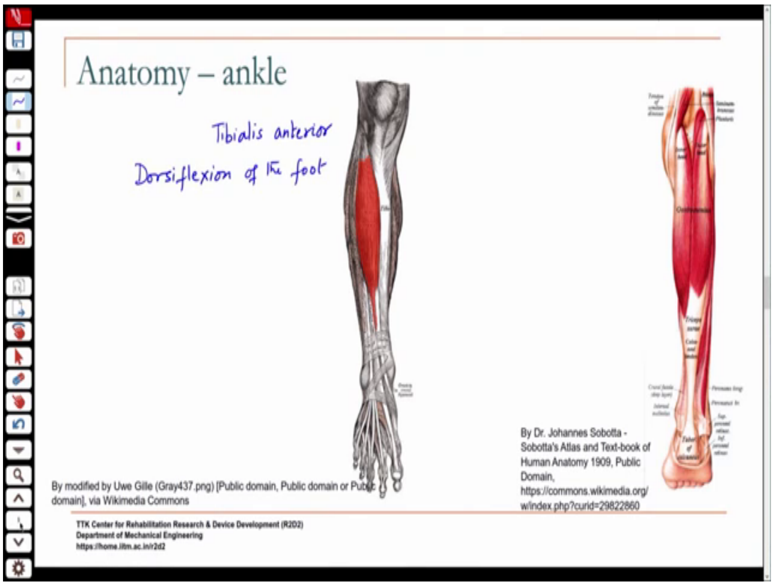

On the anterior side an important muscle is the Tibialis anterior this muscle here and it is responsible for dorsiflexion of the foot ok. So, now, let us look at so, you also have other flexors of the toes that originate in the lower leg, but we will not go too deep into those muscles which cause those motions.

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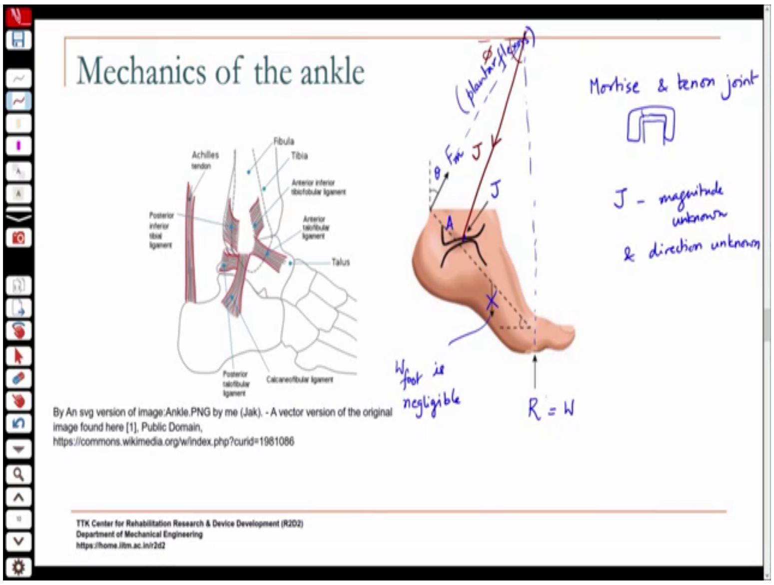

So, if you look at say a person is standing on tip toe we want to calculate the loads on that ok.

So, if you look at the foot, say this is the ground reaction which is equal to the weight of the body, let us say the weight of the foot is negligible compared to the weight of the body just. So, we can form a 3 force system. So, then I have this force would be the force due to the calf muscles the plantar flexes through the calcaneal tendon muscle force of the plantar flexes and this at the joint would be your joint reaction at the joint between the talus and the tibia or the tibia fibula.

So, you can see here the tibia is here and the talus is here they said the side is the fibula. The fibula acts more like you know in carpentry we talk about the mortise and tenon joint. So, this joint the so, it is like this, it spans that like that ok. So, it kind of stabilizes it in the frontal plane. So, if this is the talus, this is the tibia and the fibula together form this kind of a structure around it. So, again this forms a 3 force system.

So, I could similar to the previous analysis I can join F m I know the angle of angle at which it acts, J I do not know, J magnitude is unknown and direction is unknown. So, I can use join R and F m that point of intersection. So, if I know the location of the joint a then if I join this point to the point of intersection that gives me the direction of J ok.

So, this would be what I so, I could solve for J in that manner. So, essentially using the moment equation then I can do. So, I can I now know the direction of J. So, let us say this is at an angle phi I can compute the magnitude of J X and J Y which will give me the magnitude of J.

So, now, we have gone through pretty much you know from head to the ankle and we have looked at some of the key muscles involved in the joints and muscles involved in various static activities that we perform or activities that we look at from a statics perspective. Because some of the activities are actually dynamic activities, but we assume that we can look at it from the statics point of view at a particular posture for instance.

And then we have analyzed what kind of loads are there how you can compute the internal loads at the joints that you are concerned with using these kind of models for the body, for the joint under consideration we looked at we look at what muscle may be the primary acting muscle to perform that particular task and we have also looked at ok. If you have more than one muscle that in your module, how we can deal with that ok, by either looking at you know muscle relative muscle cross sectional areas, the ratio of the cross sectional areas of the muscle.

So, we try to ready you can solve for from the statics equations, we can solve for 3 unknowns, if we have more than that that is why we always take only one muscle into consideration because the joint reactions have 2 components in our plain error analysis. So, those are the 3 unknowns if we have more unknowns if we consider more muscles in the analysis then we bring in other relations in order to be able to solve for the muscle forces.

So, we have looked at some of the anatomy that is required for these purposes in order for you to create a somewhat accurate modern, mechanical model that you can analyze using the principles of statics. We will move on now to analyzing some of the kinetic activities.

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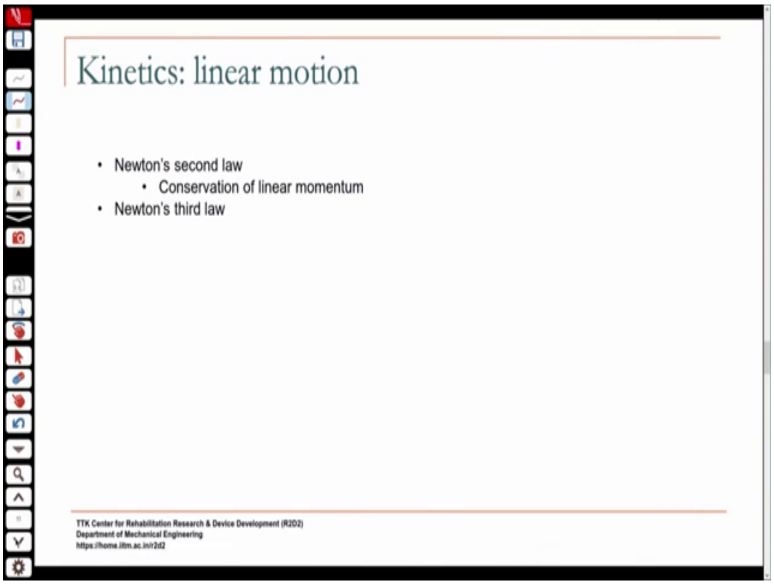

So, let us look at motion ok, we look at how we can apply the principles of dynamics in order to analyze some basic human movements, how would you model that will go from some simple cases.