Mechanics of Human Movement
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Lecture - 24
Static Analysis of the Knee

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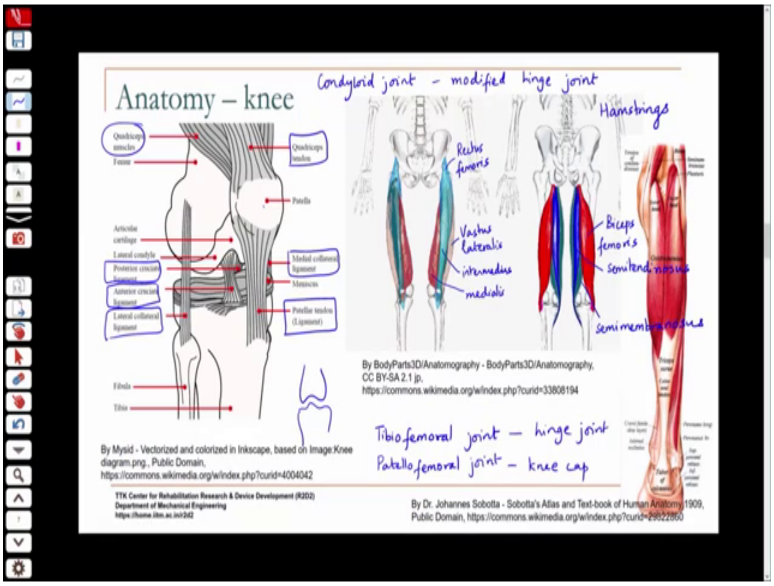

So, now we move on to the knee ok, we have looked at we have been coming down the skeletal system and we looked at the loading at the hip. Now we will look at because there are a lot of activities where the knee has to be stabilized by the muscular forces and the joint forces can also get to be pretty high at the knee. And activities can result in pain in the knee they can be you know destabilization that could be and we will see how to do simple analysis to kind of determine the loads at the knee during different.

So, if you look at the knee structure of the knee you all remember that it is a what kind of a joint is it, it is also a Condyloid joint it is basically a modified hinge joint, for the most part you have flexion extension is the major movement you also have some internal external rotation, but predominantly you have the movements that are possible are flexion and extension, there is some inward outward rotation.

So, it is one of it is the largest joint in the body in terms of size, it is the knee is a large a joint and the muscles that are responsible for controlling the movement about the knee, on the anterior side you have the quadriceps you have the quadriceps muscles.

So, you have 4 muscles that come into one tendon basically the quadriceps tendon and then there is also a small bone the sesamoid bone called the Patella, which is located inside the this tendon and then on the other side you have the patellar tendon follows through to attach to the tibia and that portion is called the patellar ligament because it is essentially attaching the patella to the tibia. So, this patella kind of acts like a pulley over which this tendon moves.

So, you have the various ligaments that stabilize the motion at the knee. So, you can see the knee is basically like and you know you have something like this and you have to control the motion it is not like your regular hinge joint. So, you have ligaments such as the medial and sorry lateral and medial collateral ligaments, these are the ligaments at the side and then you have the anterior and posterior cruciate ligaments.

So, the ligaments are very important for limiting the motion at the joint especially the motion in the frontal plane ok. So, a sign of a joint where you know if you have a knee joint where the ligaments are damaged then you will have too much movement it is called joint laxity. So, when you try to passively move the joint. So, actively you do not have abduction adduction at the knee, but if your ligaments are loose then you can passively move the joint and that is how they test the health of the joint.

Somebody has an injury they will know that there is joint laxity and that is caused by some damage to the ligaments. Again it is a synovial joint you have you also have some shock absorbing many sky you know which is all cartilage between the condyles of the femur and the tibia ok. To cushion the loads that are taken by the knee and the joints also, have the lining of Articular cartilage just like all synovial joints do there is a joint capsule this synovial fluid inside the capsule etcetera ok.

So, the knee basically the join between the tibia and the femur the fibula does not have a part in the knee joint, the fibula is a bone that is attached to the tibia, but it is not part of the knee joint, when you talk about the knee joint there are 2 joints that we talk about at the knee. One is the Tibio femoral joint so, that is the main joint the hinge joint and the other joint that you talk about is the join between the, what are the 2 bones are in contact at the knee, you have the Patello femoral joint.

So, there is a groove in the femur and as your knee flexes and extends the patella moves inside that groove your kneecap you can feel it move as you bend your knee it moves on the femur in the groove on the femur. So, there are 2 so, this is really the hinge joint and that joint is the kneecap that we talked about. So, if you look at the muscles you have the Quadriceps, you have the Rectus femoris, 4 muscles make up the quadriceps. Then you have the Vastus you have the media sorry this would be the lateralis this would be the medialis and underneath is your intermedies.

So, these 4 muscles are essentially your knee extensors, the quadriceps muscles are the only knee extensors and they are a very important group of muscles for that reason because you have this articulated system that needs to be stabilized as you are applying loads to it and these muscles are very important play a very important part in the stabilization of the knee.

On the posterior side you have the, what muscles do you have, the hamstrings group and you have this would be your biceps, femoris and the semitendinosus and semimembranosus, this is the semitendinosus the blue is the semitendinosus and the green is the semi membranosis. So, these muscles are by articular muscles. So, they connect to the pelvis the hamstrings. So, the long head of the biceps femoris, the semitendinosus and the semimembranosus actually connect to the pelvis. So, they are crossing both the knee as well as the hip joint.

So, they are the by articular muscles and we saw in the case of by articular muscles you have active and passive insufficiency. So, when you have when they are at their extremes they may not be able to perform their function because they are then functioning at the short end of the muscle length or at the long end of the muscle length not at their normal length when they are most effective.

So, these are a group of muscles they exhibit, if your knee is extended for instance if the knee is extended then what will happen if you try to let us say knee is extended.

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If you try to.

Student: Hip flexion.

Hip flexion if you try to do hip flexion you are limited the hamstrings will resist that. So, that is an example of passive insufficiency when the knee is extended. So, that is see and similarly if the hip is flexed your ability to extend the knee becomes limited same the other side of the coin.

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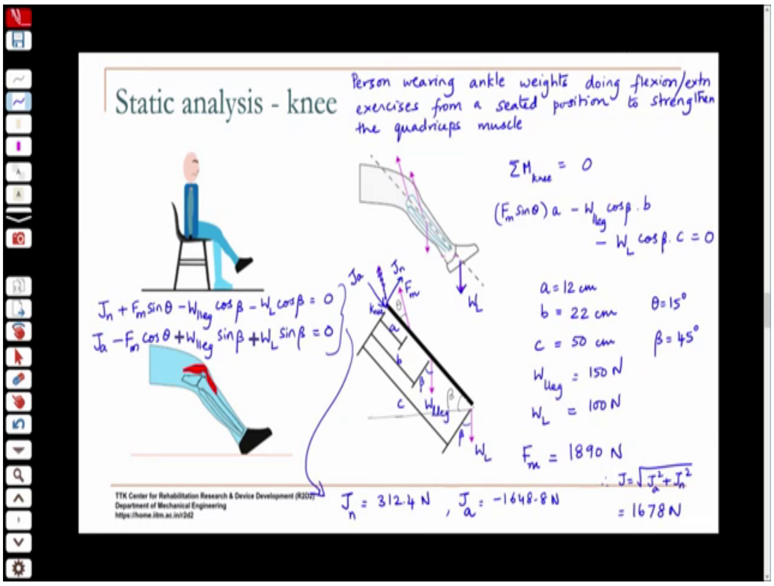

So, for strengthening the quadriceps typically you are given knee strengthening exercises and those are essentially quadriceps strengthening exercises. So, that would be a case where you can do a static analysis at the knee. So, people typically wear some kind of a weight boot or they would have ankle weights and then you would do the extension and flexion to strengthen your quadriceps muscles.

So, if you have to do an analysis of this, let us say to hold it at a certain position, then it is very similar to what we have done so far. So, if you take the free body diagram. So, let us let me just stay the problem. So, you have a person wearing ankle weights doing flexion extension exercises from a seated position to strengthen the quadriceps muscle.

So, if this is the weight, at the weight of the boot or the ankle weights and so if I draw a free body diagram. So, this is my knee, this is my load, this is the weight of the lower leg. So, we will call it l leg of the shank ok, then say this is my F m, K is the knee. So, I may have some force J the instead of because I do not know the direction I will represent it by it is components. So, I will say I have a J axial and a J normal ok, F m I know where it acts let us say this is a, this is b, and this is c.

Let us say that the intonation of this leg at this particular instant is beta and F m acts at an angle theta to the tibia actually I could call this well tibia would mean only the bone. So, I do not want I will just call it weight of the lower leg l leg. So, again what are my unknowns, I have similar to your because I am assuming there is only one muscle, which in I am assuming there is no antagonistic muscle acting here which would be the hamstrings, I am assuming only the quadriceps are acting on the tibia I assume I know where the insertion is for the quadriceps. So, that is my a, I know that I know the direction of action of this muscle the only thing I do not know is what is the magnitude of the muscle force.

I know the external load that I am applying to the leg W L from anthropometric data I would also know the weight of the lower leg for a person of a certain body weight. The other things I do not know are J a and J n. So, I have 3 unknowns 3 equations I should be able to solve for the forces.

So, I have let us say sigma M about this knee equal to 0 then I get F m sin theta into a minus W leg, if this is beta then this angle is also beta right. So, cos beta into b and minus W L into cos beta into c equal to 0, a equal to say 12 centimetres, b equal to 22 centimetres, c equal to 50 centimetres and I will give you W leg sorry l leg lower leg 150 Newton's and the load so it is like a 10 kg boot so about 100 Newtons. And I get F m from that equation for these set of values theta is 15 degrees and beta is 45 degrees, what is F m 1890 Newton, that is a large load right.

And then if you find for these same values if you do sigma fx equal to 0 sigma fy equal to 0. you will find J a equal to 312.4 Newtons, J n equal to minus 1648.8 Newtons, therefore, J equal to square root of J a square plus J n square will give you get 1678 Newtons the magnitude of the joint force. So, these are large loads at the knee.

F m sin theta now so this is J n this is J a. So, here equation would be J n plus F m sin theta minus W l leg cos beta minus W L. So, here again this angle is beta cos beta correct and then J a minus F m cos theta sin beta sin beta equal 0. So, these are here other 2 equations so, these give you this.

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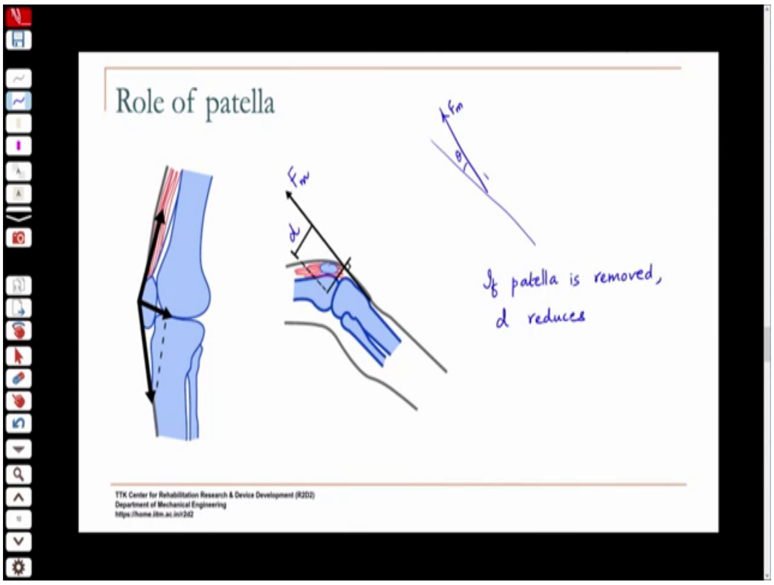

So, the patella plays o an important role I will just mention this say if you look at the patella is if you look at the muscle force ok. Because of the presence of this patella you are increasing that angle theta to the tibia at which this muscle force acts and this is F m because of the presence of the patella you have that pulley effect this is increasing this angle theta. Now if you look at F m, the F m sin theta is your rotational component that is what is resisting the torque of the.

So, if you have a small theta then F m has to be higher in order to. So, if suppose somebody has an injured patella and they remove it then that person has to exert much larger forces to maintain the knee at a certain angle, because the rotational component now becomes smaller and instead the component that is compressing the joint is going to be higher because that is F m cos theta.

So, the patella acts to increase this moment arm at the knee joint and so, it gives you it gives this muscle force a mechanical advantage with respect to the rotation and reduces the compressive force because that is F m cos theta. If the patella was not there, then you would have this closer this distance d, if patella is removed d reduces. So, making it less effective for d so, F m has to increase to compensate for so, the person has to exert greater forces muscle forces and the joint forces correspondingly will also increased ok. So, that is the function of the patella, it acts to improve the mechanical advantage at d ok, we will stop here.