Mechanics of Human Movement
Prof. Sujatha Srinivasan

Department of Mechanical Engineering
Indian Institute of Technology, Madras

Lecture - 22
Static Analysis of Hip- Part I

So, far we have looked at the statics of the upper extremities then we look at the statics of the spinal column. We looked at various tasks like bending, lifting, etcetera with respect to the spinal column and we analyzed the loads on the body. Now, we move on down to the lower extremities.

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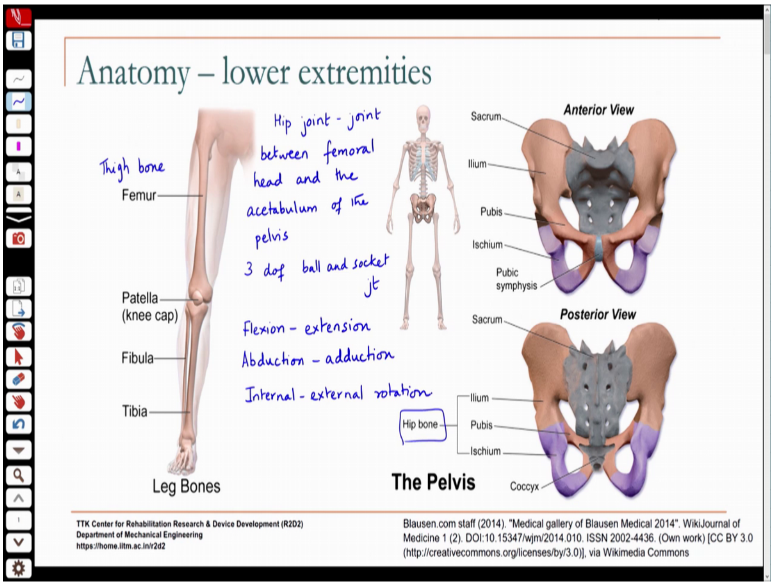

So, the spine connects to the pelvis and then from there on to the legs and to the ground. So, the lower extremities play a very important role. You know they are weight bearing structures, but also highly mobile. So, there is a lot of muscular action that is necessary to provide this combination of stability as well as mobility, ok. So, we will look at some of the major bones and muscles in the lower extremities and then we will go on to do some analysis static analysis of the lower extremities.

So, as you all know should be familiar by know the thigh bone is your femur and the hip the hip joint is the joint between the head of the femur and the socket is what is called the acetabulum of the pelvis. This is a ball and socket joint, and actually at the head of the femur you have a very nice ball covered biarticular cartilage. It is a very mobile again it is a synovial joint, very mobile and its shaped, so it is a 3 degree of freedom ball and socket joint. So, the socket is the acetabulum and the ball is the femoral head.

So, you have, so this is the structure of the pelvis you have the anterior and the posterior view. You can say this is the sacrum the last analysis that we did was at the top of the sacrum, you know where the fifth lumbar vertebrae, vertebrae sets. So, we were looking at loads at this level here, ok. Now, we move, now you look at the sacrum, the sacrum actually consists of multiple bones which are all fused together in adults like the ilium, ischium and the pubis, ok. They are all fused together in adults and that is your hip bone, ok.

So, this, about the hip joint the movements it is a 3 degree of freedom joint so the movements that are possible are you have in the sagittal plane flexion extension. In the frontal plane what do you have? Abduction, adduction and in the transverse plane you have internal external rotation. So, all 3 motions are available at the hip. And the extent of the movements as always is constrained by the other structures like the ligaments, the bony structure of the hip, and the muscles surrounding the hip joint. So, they control how much of the motion is available.

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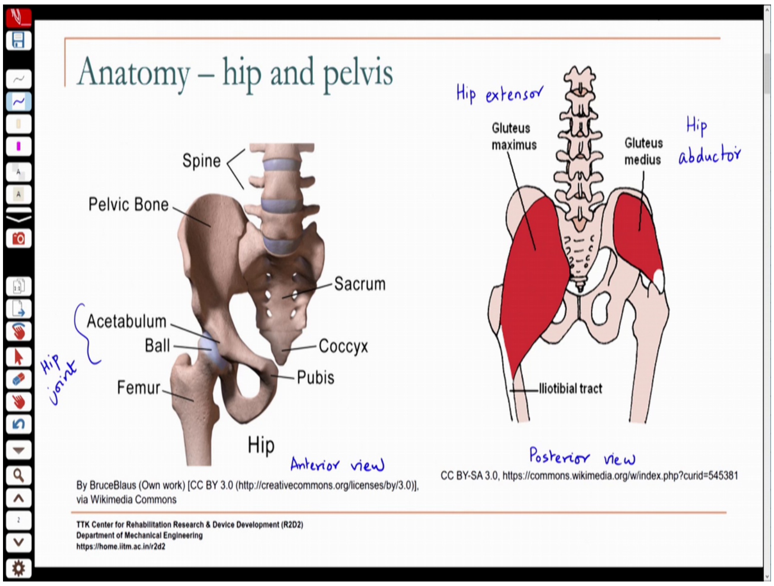

So, let us look at some major muscles at the hip. So, you can you can see here this is a nice picture showing the hip joint here with the ball and the socket. This view is the posterior view, this is the anterior view and muscles that two major muscles in the posterior side one is your gluteus maximus which is a hip extensor, and the gluteus medius is a major hip abductor. So, the pelvis is stabilized in the frontal plane mainly by the gluteus medius the hip, abductor.

We will see this when we do the analysis shortly and you will find that the gluteus medius is majorly responsible for stability in the frontal plane, keeping the body erect.

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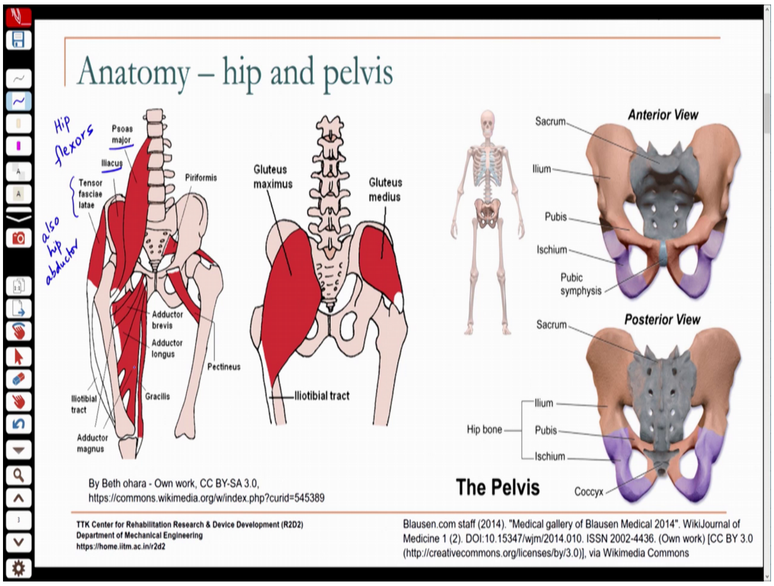

So, more muscles you have these muscles the psoas and the lliacus which are hip flexors, ok. They are flexor muscles of the hip and then the tensor fasciae latae also a hip abductor, but more of a minor hip abductor. As you can see its cross sectional area is considerably lower than that of the gluteus medius. There is also gluteus minimus that is hidden in this, but so those 3 are the hip adductors then you have these muscles here which are the adductors of the hip. So, they would be the antagonist when the hip is being abducted, ok. By now, you should be familiar with this terminology that you know you are not wondering what I am talking about when I say this, ok.

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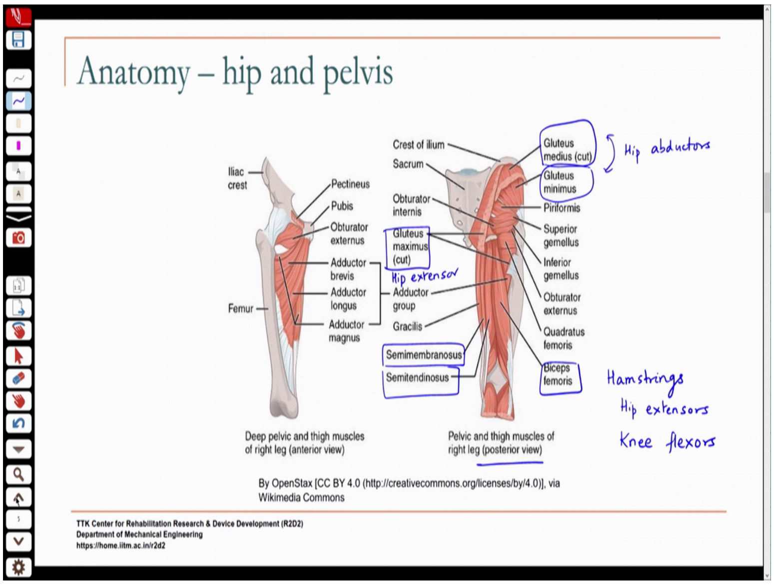

So, you have the other hip extensors are your hamstring muscles. So, this is the sorry before let us here you can see the hamstring muscles. So, this is the posterior view if you look at the pelvic and thigh muscles. The hamstrings consists of the biceps femoris, the semimembranosus and the semitendinosus. So, these muscles together form the hamstrings.

So, when we talk about the hamstrings we are talking about this group of muscles and these are hip extensors, they are also the this is what kind of a muscle these are biarticular muscles, ok. So, actually the biceps femoris is a biarticular muscle. So, these are also knee flexes. The hip extensors and knee flexes. You can see here only when you cut this is the gluteus medius, when you cut it you can see the gluteus minimus which is also a hip abductor, both are hip abductors and gluteus maximus you can see when its cut this is a hip extensor and then you have the adductor group of muscles, ok.

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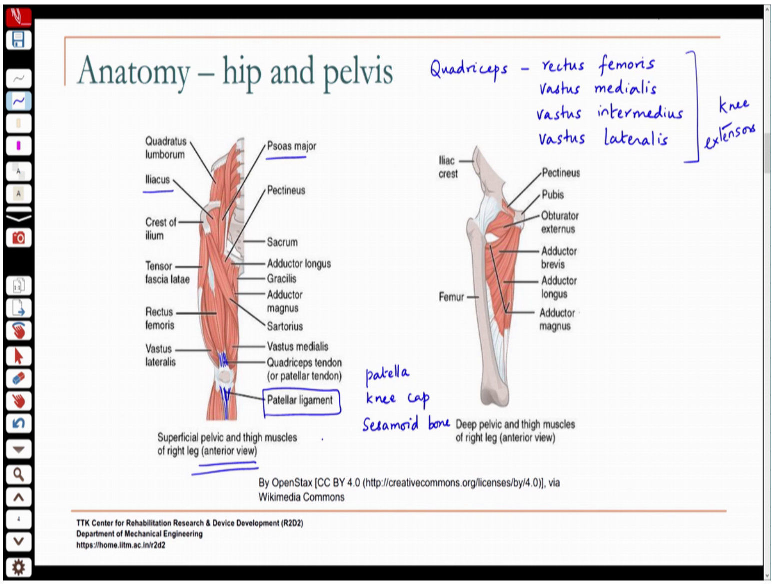

So, if you look at the anterior view then in the anterior view you have at the hip you have the iliacus and the psoas which are hip flexors, and then you have the quadriceps femoris. So, this is the 4 headed muscle. So, it is called because all 4 come together to a tendon at the knee. So, in the front of your thigh are the quadriceps which consists of these 4 muscles you have the rectus femoris, rectus femoris, you have the vastus medialis, the vastus intermedius, and the vastus can you guess; lateralis. So, these 4 muscles they are responsible for knee extension. So, these are the knee extensions

These are also a very important group of muscles, because you have this mobile you know two link system if you just take the thigh and the shank connected by the knee joint and for it to be able to bear weight and not you know collapse, ok. These muscles are very important because that is what keeps it that is what straightens out your leg, ok. So, I mean if I can you know simulate say if this is my thigh and this is my this thing to when you are bearing weight the tendency will be to collapse. So, but for the action of the knee extensors, this stability during walking or any standing activity would be compromised. So, the knee extensors are very important group of muscles, ok.

So, and then you have all these stuff it is called the quadriceps because these 4 muscles come together into this tendon which is called the quadriceps tendon or the patellar tendon. And then you have the sesamoid bone you remember the patella your kneecap ok, your kneecap is your is a sesamoid bone. So, it is embedded in the tendon and that tendon is called the quadriceps tendon or the patellar tendon, ok.

And the other side of this tendon, because the insertion of this is on the tibia ok, the quadriceps muscle in order to be able to straighten the leg, inserts into the tibia, ok. So, the portion of the tendon that is below the patella which connects to the tibia, that is called the patellar ligament it is basically the tendon that comes down this some people still refer to it as the patellar tendon on either side of the patella, but because we refer to structures that connect bone to bone as ligaments the correct name would be the patellar ligament for that, ok. So, these are some of the major muscles you need to remember when we are doing analysis of the lower limbs. Hip flexors, hip extensors, knee flexors, knee extensors, right.

Student: (Refer Time: 14:17).

And the abductors, abduction, adduction.

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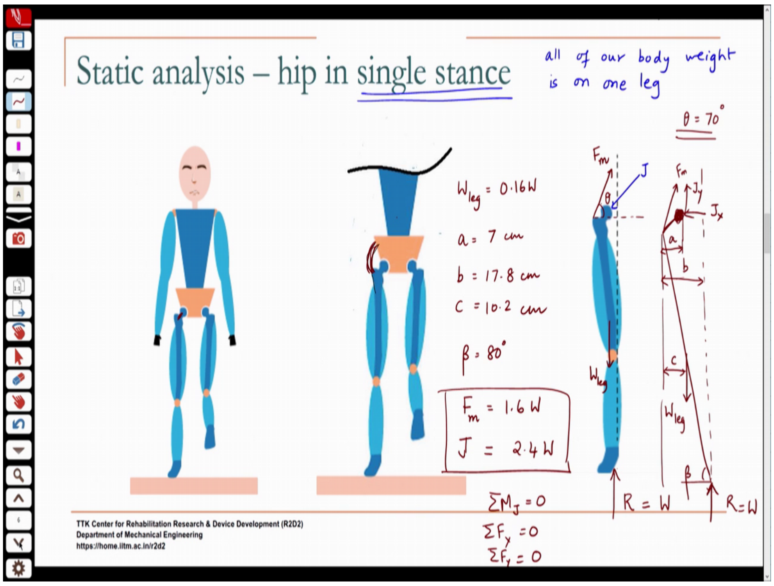

So, we will move on to; now, during walking, one of the critical periods is when you are supporting your entire body weight on one leg. So, you have alternating faces when you are walking, you have alternating phases where you are supporting your body weight with both legs and then part of the time you are supporting it with only one leg. Now, we will look at a quasistatic analysis because we are freezing, now walking is actually a dynamic activity, but we are just going to freeze at a particular instant when one leg is off the ground and all the weight is being supported by the other leg, and then look at you know what is the influence at the hip of this kind of a of this phase of the gate. So, this is called single stance, when all the body weight is on one leg. So, in this case this is the right leg you have.

So, we want to analyze what is happening at the hip joint in this single stance. So, when I am looking at the frontal plane. So, I am doing this analysis in the frontal plane, I am looking at what is happening at the hip and you can see that the muscle of interest. So, if I look at the hip joint, this is the, so there will be some joint force at the hip and the hip abductors will be the muscles that I am going to be looking at, ok. That is my that is the muscle that is acting to kind of prevent the pelvis from going down. See because when this is lifted off the ground, you have an articulation here at the hip, this you have this body weight acting like this, and you have the this hanging leg also and the tendency would be to do that what prevents that it is got to be the hip abductors here, ok. So, that is the muscle that we would be looking at as acting to prevent the tilt. So, let us say I have F m act, ok.

Then before I do that when I look at the whole body, in single stance for my body to be in static equilibrium, the entire body weight has to pass through the foot, right. So, my ground reaction acts opposite to that and this would be equal to simply the weight of the body, ok. So, if I draw the free body diagram of this leg which is on the ground then I would have the ground reaction is there anything else I am missing the weight of the leg itself.

Student: Weight of the leg is coming included in the weight of the (Refer Time: 18:53).

So, you have that is the ground reaction, ok. So, I have the weight of the leg. So, the assumptions now would be I am doing an analysis in the frontal plane. I am assuming I am clubbing all the hip abductors together and saying its acting as this muscle force and let us say I know the angle of that as some theta and let us say theta equal to 70 degrees.

Student: Mam, if (Refer Time: 19:36).

So, if you look at the speeds that are involved, here first of all what are you considering as rotating here.

Student: When the legs will be flexing, so there will be some (Refer Time: 20:00).

When it is you are talking very low speeds first of all, that you have to consider inertial forces in cases where the masses are very high or the and it is.

Student: Omega is (Refer Time: 20:18).

Omega is high, right. So, here we are considering a quasi static case which means we are saying omega 0, I am freezing it at a particular instance and the speed is very low. So, omega square will be very low, ok. So, I do not need to consider any inertial forces, ok. Plus if I look at the entire leg in a if you are considering rotation about the hip that omega is going to be negligible, ok. So, you it is a static analysis we are doing.

So, let us say we have the muscle may give you some dimensions for this. So, let us say the weight of the leg is 0.16 W, then and you have these dimensions I say this is acting theta equal to 70. So, I need say this distance; let me call it a, then this to this b, c, and the distance between this and this. So, my diagram is not very is not the scale, but let me give you these values a equal to 7 centimeters, because I do not think I have the inclination properly it should be more like this, ok. So, if you look at this then these numbers will make sense. So, I have W leg, I have R equal to W, then I have F m and J, ok.

So, and then and if this is the line of action of the body weight then a equal to 7 centimeters, from here to the line of action of the body weight which is b, b equal to 17.8 centimeters. This distance c is 10.2, I already have b. So, I do not have a d is essentially b. So, c is 10.2 centimeters.

Student: (Refer Time: 24:40).

Sorry this is a. Now, I can write my equations as usual and I can find F m and J Can you find them? What do you mean y is there, only one I can take it as J x and J y. So, I can instead of writing just J I can write it as J, I have taken J like that. So, I can write it as I can split it into the components, I do not know the angle at which, so those are the two unknowns the magnitude of J and the angle at which it acts are the two unknowns I can either express it in that form or I can express it as two unknown components J x and J y.

Student: (Refer Time: 25:55).

Sorry?

Student: (Refer Time: 25:58).

Angle?

Student: (Refer Time: 26:00).

Which angle do you want? The angle of the muscle, 70 degrees.

Student: (Refer Time: 26:09).

You, so I am giving you these dimensions instead I could either give you the angle or I could give you these momentums a b c.

Student: One more dimension will be required.

Which one?

Student: Either the inclination of the of that one (Refer Time: 26:2).

This one?

Student: Or (Refer Time: 26:31) hide from that the joint to the bottom.

What would you need that for? For F m?

Student: The component of F m for talk you will not be able to calculate.

Let me see what if I give you this you can find that, right. So, say this is the angle that the neck of the femur, that part is called the neck of the femur this part, ok. That let us say we know the angle that makes to the horizontal or the whole inclination I can give you the inclination of the leg, from which you can find. Let us say we give the inclination of the leg, let us say this angle is say beta, let us say beta equal to an 80, 80 degrees so the leg is inclined at that angle, ok. It is nearly vertical, ok.

Say if you do this analysis I mean since I picked beta out of the air, but see if you can give me the values because the values that I have may not match, I can I find F m is approximately 1.6 times W, if I solve and I get the joint reaction J the magnitude of that is 2.4 W you get this by doing, ok. So, fairly high loads at the hip when you are in single stance.

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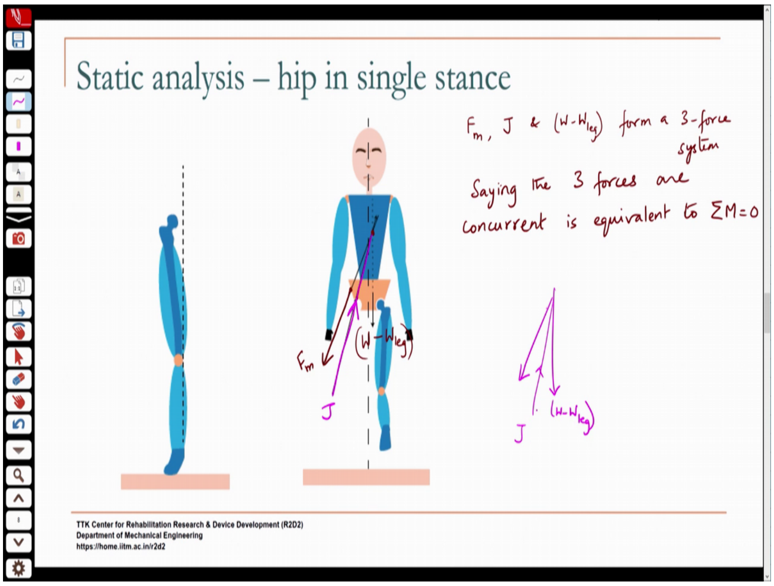

I could also do the same analysis by using the free body diagram of the upper body and the left leg. So, I am interested in this interface. So, instead of separating out this part you know I look at the free body diagram of that, ok. Then there is no ground reaction because it is suspended, it is in the air and so there is no ground reaction you have the weight of the body minus the weight of one leg that is what will be. And the reason say if this is the midline you put it slightly to that side of the midline because you removed. So, if the right leg removed your cg is going to be closer to the more on the left side of the midline, ok. So, this is the weight minus the weight of the leg that would be acting there and it would essentially be a 3 force system. So, you have this is wrong, so now, this is way.

So, if I look at this I have F m acting on the pelvis, acting on the upper body then I have the joint. So, how can I then find the angle of the joint force? So, again this is there are only 3 forces acting now, I have F m, J and W minus W leg, they form a 3 force system. So, saying the 3 forces are concurrent is equivalent to sigma m equal to 0, right. So, I am using one equation like that. So, if I have I know the direction of F m, I know in what direction it and I know the direction of W. So, that point of inter section and my joint wherever I pick my joint if I join those two that gives me the line of action of that gives me the line of action of F J, J would act such that it would also pass through that point.

So, now the direction I know the angle at which this acts, ok. So, I have F m, I have W minus and I know that F J has to or J has to act like this so I can determine the angle at which it acts and then using the components I can find J x and J y and hence the magnitude of J, ok. So, direction of J is determined and then the only thing left to do is find the magnitude of J, ok. So, this is using the upper the other portion of the body as the free body, because the ground reaction does not come into play so it becomes a 3 force system.

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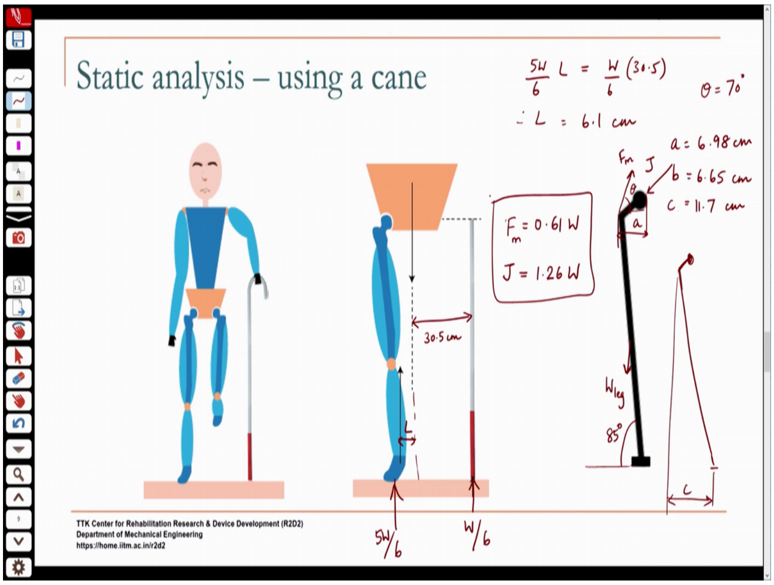

Now, you know that sometimes people who have trouble walking, use a cane, right you have seen how a person may use a cane while they are walking. Typically happens when a person is aging or you know they have had some injury or and it is usually caused by weak hip abductors they have trouble balancing. So, balance is a big reason why a person may want to use a cane, right.

So, what happens is when you have let us let us look at single stance when you are using a cane. How does that change things? Let us say the cane in this case takes up one-sixth of the body weight, let us see. So, the person presses you know puts about one-sixth of their body weight on the cane and they are holding the cane say about this distance is

35.5 centimeters about a foot away from the midline of the body, ok. So, they are using a cane, let us look at the same single stance when you are using the cane.

Now, what happens to the inclination? Ok, now, you are earlier in single stands your body weight had to pass through the foot, ok. Now, your foot is somewhat away from the midline of the body, ok. So, and first we need to compute the reaction here, ok. So, what if this distance is we want to compute what would be this distance L. Now, what is the value of this reaction?.

Student: 5 W.

5 W by 6, the remainder of the body weight, ok. Where is it going to act? If you take moments about the midline then what is L?

Student: 6.1.

6.1 centimeters; because I have if I have some moments 5 W L sorry, 5 W by 6 into L equals W by 6 into 35.5, so I have L equal to 6.1 centimeters, ok. So, now, my foot is away from the midline so that also changes the inclination of my leg. Earlier it was 80 degrees, now it might be something else, ok. So, it is probably let us say 85.

And if I now do the analysis, so if I look at I will give you some distances. So, this is 6 point, I called this a, right. So, a equals 6.98 centimeter now, then W leg acts at a distance b equal to 6.65 centimeters and again I should draw this more exaggerated, this distance from where the foot is due this, this distance c equal to 11.7 centimeter. Earlier it was 17.8, now it is 11.7. Earlier it was at the midline, now that is been shifted by 6.1, ok. So, the main difference is that the, right foot is no longer at the midline and then the reaction on the foot earlier it was the entire body weight, now it is only five-sixth of the body weight.

So, if you do the analysis now, you will find for this case F m equals 6 time 0.61 times the body weight and J, so I have J and F m. And let us assume that it may not it may not be true, but we kept we could assume that theta still remains 70, ok. We can make an assumption that theta the angle at which m F m acts with respect to the horizontal is still 70 degrees in which case I get J to be equal to 1.26 W. Yes.

Student: Should not be the; should not we calculate the case where the, for the leg which is near to the stake like for the critical analysis.

That leg this off, so we will come to that. So, that leg is off the ground now.

Student: That means, like we are doing the analysis for the leg which is fine, not the one which is like damaged or this.

So, you are making the assumption that you are going to use the stick on the side that there is a problem.

Student: But in the random case

In the case of weak hip abductors it is the opposite. So, if you have weak hip abductor muscles you use the cane on the side opposite the bad side, because the aim is to reduce the or if you have a painful hip then you use the cane in on the side opposite to the painful hip. In other cases where you know where you do not want to bear the full weight and so you use the cane on that side that is a different case.

Here we are talking about at the hip joint when if you have weak hip abductors or if you have a painful hip, you will get the benefit of using a cane only if you are using the cane on the side opposite the bad hip, ok. Because that is what helps to reduce the; so even though the cane is only taking one-sixth of the body weight it makes a significant difference in the muscle force that is required to stabilize the body in the abductor muscle force and correspondingly the joint forces are also reduced. Because anytime you have the muscles around a joint contracting your joint contact forces are going to increase, in the net joint reaction force is going to be more.

So, the idea is that you use the to compensate for weak hip abductors or a painful hip you use the cane on the opposite side. So, this is sort of counterintuitive to what we normally think, ok. We all always think if there is a problem I am going to use a cane on that side, but in the case of this because in while walking you need the maximum effort or the maximum loading at the hip joint happens in single stance, and so that is when you require this assistance, you need to reduce the loads and that therefore, you use.

So, this moment arm of help you know of the ground reaction force is what has changed, right and that has played a big role in reducing the moment that has to be counteracted by the hip abductors. So, that is what you are doing with this. Same thing if you the reverse of it in instead of using a cane, if I am carrying a load on one side then this is going to be the case where when I am on single stance on the opposite leg that is when the loads will be the most on my hip. So, what do we tend to do normally? You will tend to lean more towards the side you are trying to reduce the moment arm, that has to be of the external force that has to be counteracted by the hip muscles, ok; so that is the effect of the.

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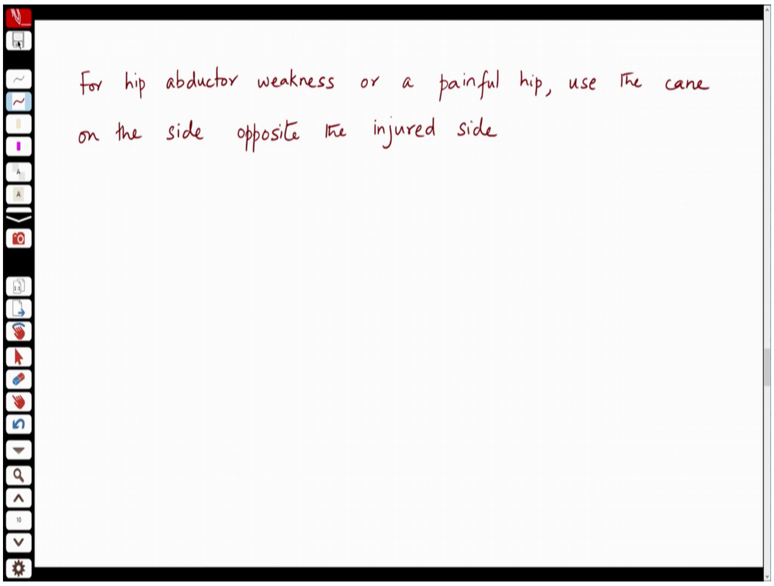

So, using a cane you use a cane on the side opposite the affected side so for injured side.

Student: Mam, in the previous slide.

Yeah.

Student: Mam, position c.

Yeah.

Student: Equals to 11.7 centimeter, previously it was the momentum for the leg (Refer Time: 45:34), instead of the leg. Just before this.

Just before this, ok. Let me see.

Student: Here c is the W you know.

Sorry, ok.

Student: (Refer Time: 45:55).

Here also. Now, here I have b is 17.8, right. I have switched b and c in the other one, ok. So, this should be b.