Mechanics of Human Movement
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Lecture - 33
Kinetics of Arm Swinging during Walking

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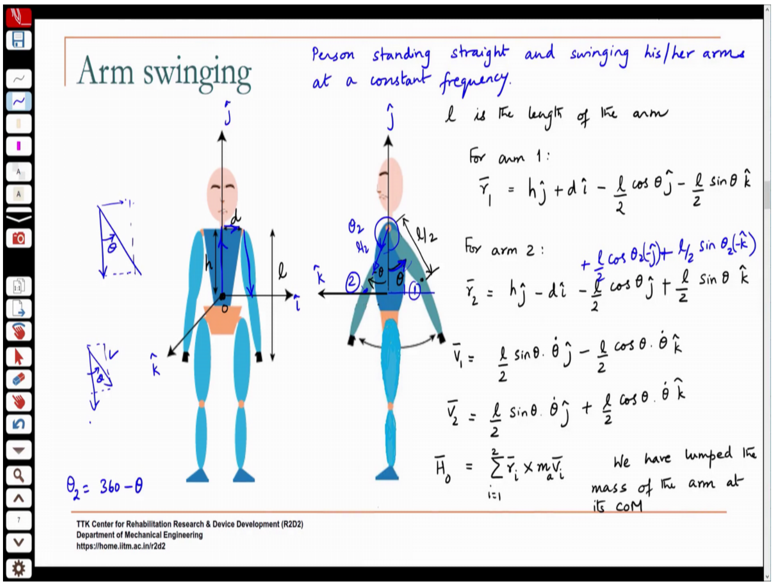

First we will just look at Arm swinging. Say you are standing in one place and you are swinging your arms, what exactly is happening in that situation ok. So, let us look at that. So, you have a person standing straight and swinging his or her arms at a constant frequency. Let us say this distance the center of mass of the person is located at a distance h below the line joining the shoulders.

Let us say d is the half the distance between the shoulders. And let us say the length of the arm this is not depicted very correctly, but let us assume that the arm is stand in a vertical. I am not taking this inclination into account. Let us say the arm is vertical and it is length is l. So, l is the length of the upper limb. So, in the sagittal plane this is theta I can look at it as I have this arm being swung the other way it is called the that minus theta counter clockwise plus theta clockwise minus theta.

Let us say the center of mass of the arm. The mass of the arm is lumped at it is center of mass at a distance l by 2. So, for one arm ok. So, for arm 1 I can write r 1 the location of the center of mass of that arm. As if this is the origin at the center of mass of the whole body then I can write it as. So, let us call this i j and k coming out of the plane of the paper ok. So, I have r 1 equal to can you locate it h along j plus d along i then minus l by 2 cos theta along j minus l by 2 sin theta along k. If I look at this, so, here this is j. If I am looking at it from the side this is k. That is the location of this one r 1.

Similarly, for arm 2, I have r 2 equal to h along j minus d along i the other arm minus l by 2 cos theta along j minus l by 2 sorry plus l by 2 sin theta along k because now it is minus theta cos of minus theta is still cos theta, but sin of minus theta becomes.

Student: Plus.

Plus sin theta. So, I differentiate. I can get V 1 is h d they do not change only the theta l by 2 sin theta along j minus l by 2 cos theta into V 2 l by 2 is dr 2 by dt. So, l by 1 sin theta into theta dot along j plus l by 2 cos theta into theta dot along k.

So, now I can look at the angular momentum because of these moving masses of the arms. So, I can say H naught equal to sigma of I have 2 lumped masses. So, i equal to 1 comma 2 r cross ma V i. So, we have lumped the masses at the center of mass. sin of minus theta.

Student: Yeah, but the l by 2 is a positive k right?

Sorry, but theta is being measured this way I am measuring I am using the same.

Student: Theta is negative.

Yeah.

Student: So, sin theta will be minus.

But let us see this is a long k is like this.

Student: Positive k.

Yeah. So, it is positive k you know overall it is positive k.

Student: Overall it is negative right? There is only 1 minus, sin theta becomes minus.

Let us see; i j k sin theta this is I am looking at it like this and k is going out.

Student: If that was positive.

See this is theta. So, this is l by 2 it.

Student: r 1 due to minus l by 2 because it will going in the negative k direction.

Because theta is positive also.

Student: Yeah.

Yeah.

Student: Here it is going in the positive k direction. So, l by 2 is naturally positive and theta is minus theta. So, it should be minus l by 2 sin theta.

No, I am using the same see the theta value I am using this positive value whatever is this one ok. And I am, so, I could call it theta 1 and theta 2. So, if I call it theta 1 and theta, but I would have to measure both in the counter clockwise direction for me to say it is positive.

Student: (Refer Time: 09:39).

So, let us say that this is this theta value is positive ok. So, for this arm, so, for this arm l by 2 is in the negative direction; for this arm l by 2 is in the sorry the k is in the positive k direction where I am taking theta as this positive value theta. If I did this as l by 2 sin.

Student: Minus sign.

Say theta 2, but theta 2 would have to be measured positive counter clockwise ok. So, I would get say 360 minus that acute angle 360 or 180?.

Student: 360.

360.

Student: That will again become minus sign minus term.

So, let us see this, this, this my.

Student: (Refer Time: 10:56).

I am going this way this way this way right r. So, if I look at this, this is l by 2 theta 2 cos theta 2 plus l by 2, but if the theta is this theta, let me look at just theta 2. And this is theta 1 ok. Then I have to take that as I have to take this as minus l by 2 cos theta 2 minus l by 2 sin theta 2 right I am measuring everything from this.

So, now this is cos theta 2 is. So, theta 2 is 360 minus theta.

Student: Ok.

Fine, theta 2 is.

Student: Theta 2 is the entire from the.

Theta 2 is it is always from?

Student: Yeah.

This, it is it s from this, I am measuring from this.

Student: (Refer Time: 12:14).

Positive in the counter clockwise direction.

Student: Minus l by 2, if you take it in a positive j direction then it is in the positive k it should be plus l by 2 sin theta (2.

If we if I look at if I look at the vectors I have this vector plus this vector plus this vector. I am going in this direction with that vector ok. So, the vector itself is going in the negative j direction.

Student: Yeah.

That is why this is minus l by 2.

Student: cos theta 2, yeah.

Yeah.

Student: That is fine.

Yeah.

Student: If the sin component is along the k positive k direction.

Ok.

Student: Theta 2 is positive that is as it is because we are the 360.

360 minus theta is?

Student: Minus theta minus sin theta.

Minus sin theta, but again in this case also I am going in the negative j direction.

Student: That sin component is for the k.

k part. So, here.

Student: Ma'am, when.

See, if you look at this figure right this is correct this is along the positive k direction if I take theta as an acute angle measured positive counter clockwise from here. It is correct. I am just trying to convince him how that see here also I am taking minus l cross I have to take minus l by 2 minus l by 2 sin of theta 2 because that is what it is for a positive. If I take the angle positive from this axis I have to take minus l by 2 minus.

So, for theta 2 also right. When you do your projections right, so, if this is my angle I am measuring another angle does not matter what that angle is if that is the way I am measuring it. If this is l by 2 from this point ok, so, this let us say in a different coordinate system this is my positive x axis and this is this angle. So, I have this along this along that those are my projections. So, in this case this direction is the minus j direction this direction is the minus k direction.

So, here I would have minus l by 2 cos theta 2 along j minus l by 2 sin theta 2 along k. Same you use this as this is how I am measuring theta. The projections are this and this right for this vector, this and this. So, this is along minus k. Now, theta 2 is minus theta. Theta 2 is minus theta. So, this becomes minus l by 2 cos of minus theta minus l by 2 sin of minus theta.

Student: But the vector is not in that quadrant right.

It is. See look at this. I am measuring I have this as my positive direction I have this vector V and I am measuring theta this way. So the projections are.

Student: (Refer Time: 15:42).

V cos theta V sin theta along here I have taken this direction as the minus j direction ok. So, here it is plus l by 2 along the minus j direction minus l by 2 along the minus k direction. That is the projection when I measure theta in this manner.

Now, theta 2 is nothing but. So, this ends up being minus l by 2 cos theta along j and minus plus l. So, plus l by 2 a long minus k; see that this is the projection, if this is the vector V.

Student: Why is it in a minus k?

Because that is in my in this coordinate system.

Student: First arm right minus.

So, for the first second arm also. Now I am taking theta 2 measured the same way from here.

Student: Yeah.

All the way to there. So, I do not care about the value of theta 2 when I am doing these projections.

Student: Ok.

This is minus j that is minus k; theta 2 now happens to be minus theta. So, I get minus l by 2 cos theta and plus l by 2 sin theta that convincing enough now fine.

It is the way you designate your coordinate system and where you take the projections. Here it happens to be that the projections are along the minus j and minus k directions and so, theta 2 equal to this ok.

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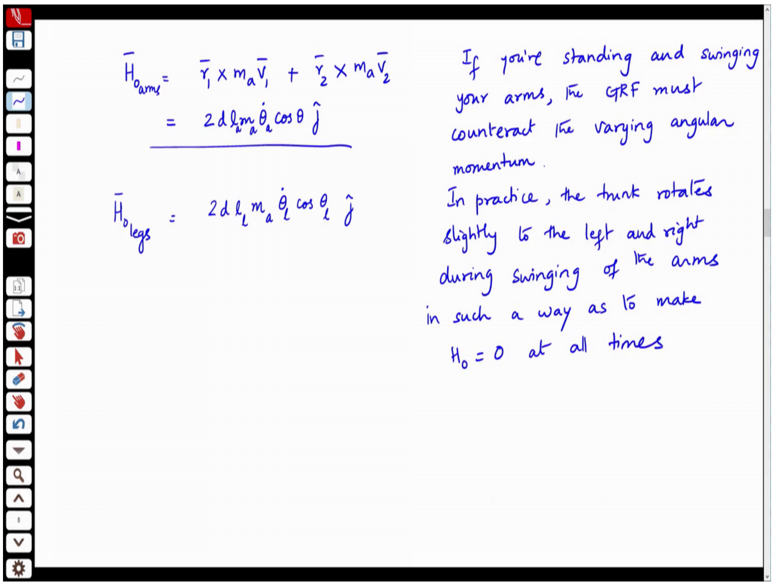

So, that is sorted out. H naught you get r 1 cross m a V 1 plus r 2 cross m a V 2. And you end up with 2 d l m theta dot cos theta along the j direction. So, what this tells you is there is a time varying component of the angular momentum. The angular momentum is varying with time.

So, this means that there is a net torque which has to be compensated by the only other forces acting are it cannot be gravity, but the ground reaction forces have to apply a torque to kind of counter this changing angular momentum because when you have a changing angular momentum, it means there is a net torque on the body right. In reality what happens is that when you do that if you try to stand and just swing your arms. Then you notice that your trunk moves slightly to the left and right to count to essentially make this angular momentum 0 ok. Or you if you only when the angular momentum is conserved then there is no net torque acting on the body.

So, in this case you will notice that if you are standing in a place and then swinging your arms you will find that you have a net your trunk has to now slightly move about this y axis. Your trunk undergoes this rotation to compensate for the angular momentum generated by the swinging arms. And it is not it does not move to the same extent because the trunk is much heavier. So, it does not have to your arms you can if you swing them vigorously you will find that your trunk moves more but not as much as the arms.

Now, what happens when you walk? A similar thing is, so, by a similar analysis this is for the arms I can show that this is similar analysis I can show that the legs while walking will be say 2 d l let us let us call this l a the arms l legs mass of the legs theta dot cos theta of the leg ok. Let us say these generate.

So, now what happens when you are walking? When you walk how do your arms and legs move?

Student: (Refer Time: 20:57).

They move in opposite ways. So, essentially what is happening is this is being counteracted by.

Student: (Refer Time: 21:06).

That the momentum angular momentum of the legs. And because your legs are generally longer and heavier your arms end up swinging more to I maintain the same frequency. So, the amplitude of swinging of your arms is higher than that of your?

Student: Legs.

Legs ok. So, this is how when you are walking you basically counteract the angular momentum of the upper limbs and the lower limbs ok. So, if you are standing and swinging your arms, the G R F Ground Reaction Forces must counteract.

Student: Mam.

Yes.

Student: Should not there be a sin theta instead of cos theta?

Where?

Student: If your proportionality with the movement of the arm will be like the larger you move your arm the more will have to counteracted like the more movement will be created. So, cos theta is opposing that argument right, the higher the theta lesser the theta.

It also depends on the theta dot.

Student: Yeah, but let us say for constant theta dot if you are just moving on the larger you have your deflection has.

Let me think about that counteract the varying angular momentum in practice. The trunk rotates slightly. So, now let us see the other question is the sin theta components cancel out, the sin theta components in the so, you are talking about the angular momentum about the j axis. And for theta measured in this manner right, the sin theta components are basically cancelling out when you do the cross product. You have a net moment which is only dependent on cos theta. So, we also say that the frequency has to be the same. So, theta a when theta a reaches it is maximum theta l should reach it is maximum, only then you have the possibility of those 2 cancelling it cancelling out ok. So, theta a typically has a larger amplitude than your theta l.