Mechanics of Human Movement

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Lecture – 12
Static Analysis of Spine- Part III

So, last class we looked at bending and lifting a load and what kind of loads that puts on the, the base of the spine where it transfers the load from the spine to the pelvis and to the ground. So, in some cases in some work areas this also has an impact not just when lifting loads, but also when say in work areas; so, say a person is working in an assembly line for instance and the work area is not designed properly which causes this person to perhaps bend more than required to do the job.

So, we will look at a situation like that to see what kind of load so, even if you are not carrying an external load, there can be significant loads on the spine which can cause long term damage if that versus. So, say for instance a person has to do something with these books you know maybe he has to put labels on them or you know do something and it is located in such a way that.

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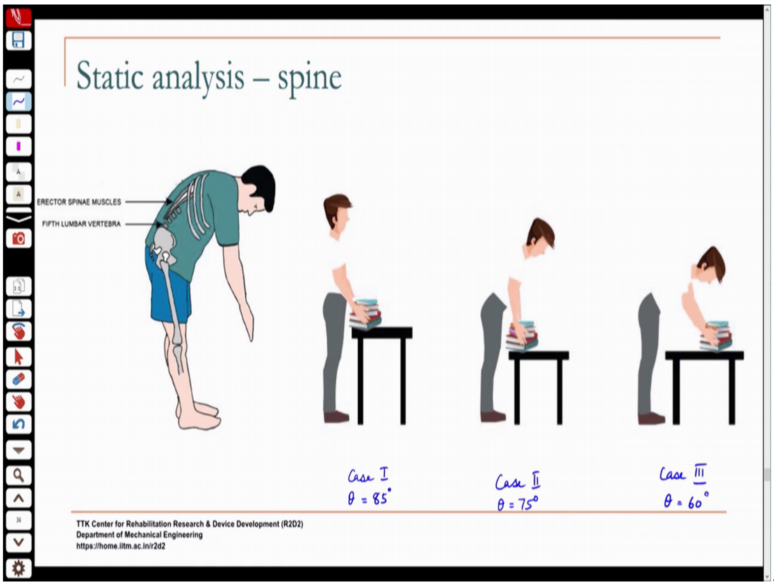

In one in the first case, case one it is a fairly correct position, the second case the stool on which those books are is a little shorter and the person has to bend to do whatever task he is doing and in the third case it is not only you know it is it is located in such a way that they have to reach forward even more.

So, there is even more bending of the trunk that is happening in this third case and. So, we will look at the loads on the spine in this case, last time we took a free body diagram of the lower half of the body and we solved it. So, now, let us look at how we would do it if we took the free body diagram of the upper part of the body. So, you have so, these are the 3 cases we will look at.

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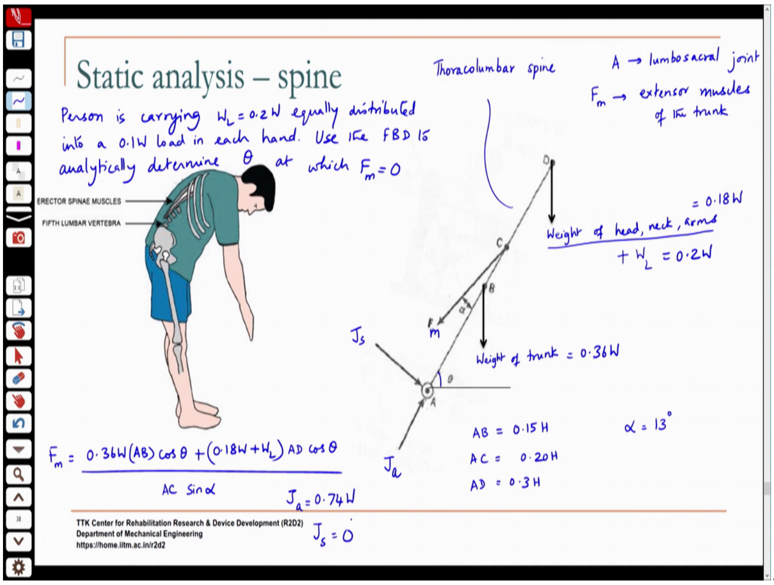

So, let us look at let us say the person this is an exaggerated bend of course, but let us say theta is the angle this part I am drawing the free body diagram of the Thoracolumbar spine so, the base is still that same joint the lumbosacral joint. So, it denotes the location of the lumbosacral joint, join between the fifth lumbar vertebrae vertebra and the sacrum.

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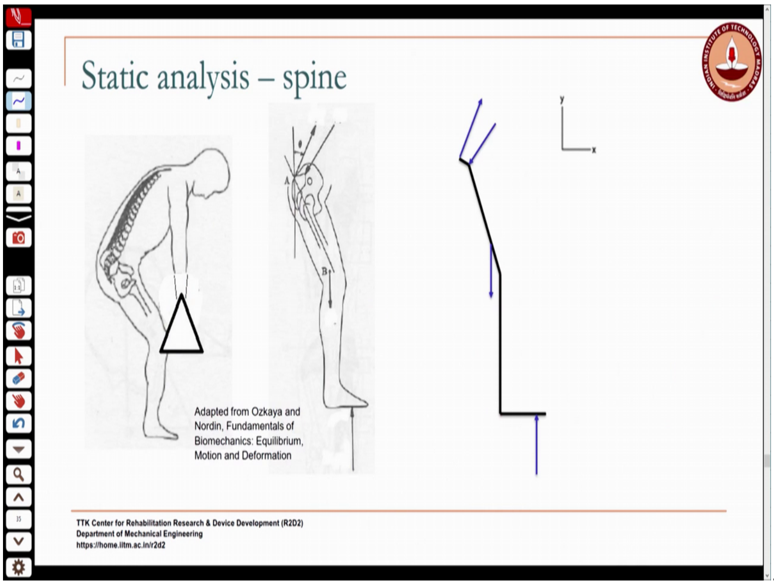

And then let us say that whatever when the person is all the load of the head and arms acts at the base of the cervical spine ok. So, at the top of the thoracolumbar spine; so, let us say that this is equal to weight of let me call it head, neck, arms, acting through the endpoint of that spine ok. So, that is the weight of the head neck and arms this is the weight of the trunk itself ok, the portion that we are considering the thoracolumbar spine with all it is. So, this is the weight of the trunk that we are considering and it is acting let us say through the center of the thoracolumbar spine and the muscle that is acting.

So, let us say the, what kind of muscles are these, these are the what muscles are this the erector spinae or essentially these are extensor muscles for the trunk. So, these are so, F m this could be the erector spinae and perhaps some additional muscles extensor muscles we are clubbing them all into one extensor muscles of the trunk and at the joint you have a J axial and a J shear the J axial is what causes compression of the spine perhaps compression of the discs compression of and could also cause fracture of the discs.

And the J shear is what could cause them to displace or slip right that is your shear loading. So, this is the axial load and the shear load that acts at the joint the lumbosacral joint ok. Is there anything suppose, suppose the person is carrying a load then this would you would also add that to this you know if you had in this case let us say they are not really carrying a load, but W L equal to 0 you can basically do the same analysis by adding that load to thee arms ok.

So, now we are looking at and let me give you some values. So, let us say this weight of head neck and arms equal to 0.18 times. So, from anthropometric data I say that that is equal to 0.18 W, weight of the trunk I take it as 0.36 W and distance AB equal to 0.15 times the height, AC equal to 0.2 times the height, AD equal to 0.3 H and let us say that the muscle the line of action of the muscle makes an angle of 13 degrees with alpha is 13 degrees with the thoracolumbar spine.

So, now we will perform the analysis for the 3 different positions that we saw here let us say case one is theta equal to 85 degrees the spine is nearly erect, case 2 is theta equal to 75 degrees and case 3 is theta equal to 60 degrees let us look at what they Fm ok.

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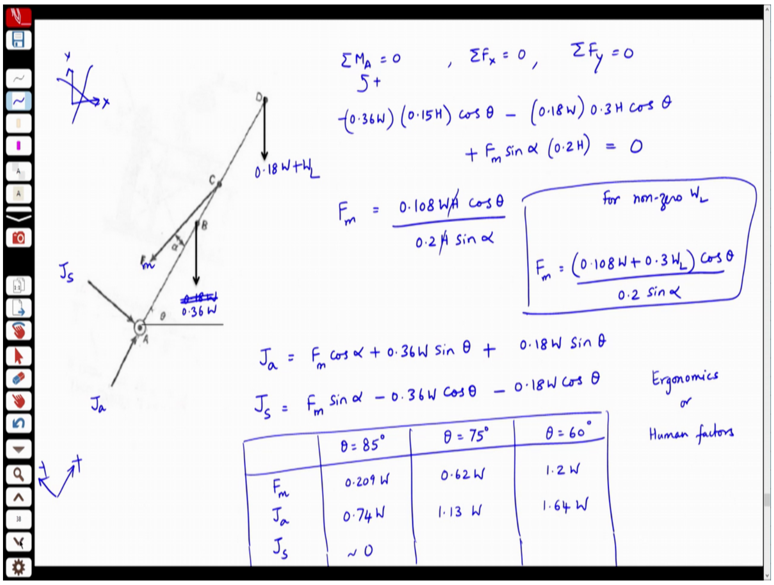

And I have J a and J s now I can do my 3 equations sigma M A equal to 0 sigma F x. So, if I take this as x y, I could also take or in this case it may be more meaningful to take my x y like that along the spine and verbally. So, sigma F x equal to 0 and sigma F y equal to 0 so, go ahead and compute in terms of theta. So, I will get if I do sigma M A equal to 0 I get minus 0.36 W minus of. So, if I take counterclockwise positive minus point cos theta F m sine alpha into 0.2 H equal to 0.

So, I get F m equal to 0.108 WH cos theta by 0.2 H sine alpha if I included for nonzero W L I would get this expression as F m equal to 0.108 W and you can verify this here also the H and H will cancel. So, now, if I take sigma F x equal to 0 then I get J a equal to F m cos alpha plus 0.36 W sine theta plus sine theta and I get J s cos theta cos theta.

So, now I can plot so, theta equal to 85, theta equal to 75 degrees and theta equal to 60 degrees. So, tell me what F m, J a and J s are go ahead and work it out Fm.

Student: (Refer Time: 11:52).

0.209 W.

Student: (Refer Time: 11:58)

209 and for theta equal to 75.

Student: 0.62 W

0.62 W and.

Student: 1.2.

1.2 W for theta equal to 60.

What about J a?

Student: (Refer Time: 12:24)

0.74 theta equal to 75.

Student: 1.13.

1.1 3.

Student: 1.13.

1.13 and for theta equal to 60 1.64 and the shear force in most cases is almost 0 it is pretty close to 0 for all 3 cases. So, you see here with no external load at all just the change in posture can make a significant difference in the loads on the spine for instance this tablet that I am using ok. If it was not at the right height and I have to bend down to right, over the course of the lecture I am imposing more loading on my spine than if it were located at the right configuration ok.

So, this is the importance of you know designing workspaces. So, that you are not putting excessive loads of the spine. So, there is a whole branch of a biomechanics that looks at the design of workspaces and all that and that is called and. So, this area is called ergonomics or also called human factors in design ergonomics or human factors. That is the term that is given to ensuring that works erg goes you know it is for work workspaces it is a trial designed drop in so, as not to impose excessive loads on the body.

So, because when a person is doing the same thing for hours on end, the cumulative effect of the damage can be quite high. So, you will notice that some people who have to work they will develop back pain sooner or later you know and they will not be able to function. So, the posture say same way when you are sitting if you sit with incorrect posture sooner or later you're going to develop back problems ok.

So, it is important that because the muscle the extensor muscles have to keep your body in that position against the force of gravity because a large part of your body mass is concentrated yeah in the top portion of your body. So, to keep it from falling down the extensor muscles have to exert high forces which in turn lead to high joint reactions ok. So, that is the importance of correct posture.

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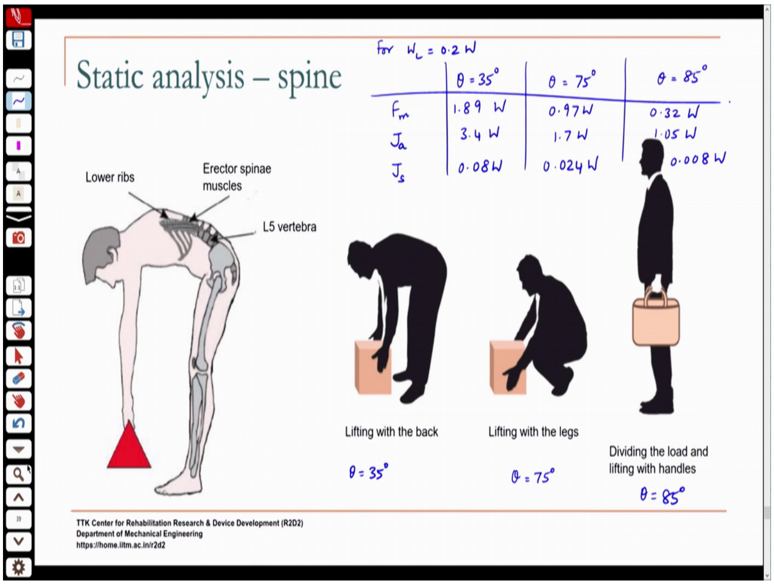

Similarly when you are lifting a load ok, we saw so case one is you bend your trunk and then lift the load. So, you can analyze this similar to what we did just now except that in addition to you also have the W L, that is the case where you have this plus D load and you have theta I will just I let you do the analysis, but I will tell you 3 cases for which you can analyze this ah.

So, you have theta equal to 35 degrees theta equal to 35 degrees, then you have if you if you bend down keep the load closer to your body and lift with your legs then your spine stays more erect I can either bend down and pick up a load like that or I can go down you know bend my legs go down pick up the load. So, that my back is straighter than what it was earlier.

And that would be the case the second case where theta equal to 75 and then the third the optimal way of doing this load lifting is if the load itself was say divided equally I bend I keep my back straight and I lift it with handles. So, I do not have to do any bending at all to lift a load from the front, say the load is provided with handles and divided equally. So, that I can use my 2 hands to lift it then that is the most optimal way of doing this load lifting of course, it is not always possible because loads are tend to be bulky sometimes it is not always easy to divide a load and provide it with handles.

But if possible that should be the way to go otherwise you should always sit you know you bend your legs hold the load close to the body and then lift it or get help you know more than one person to help lift the load because you can do a lot of damage yes tear spine.

Student: (Refer Time: 18:43) lifting with legs more erect posture because there (Refer Time: 18:48).

There is friction at the hip.

Student: (Refer Time: 18:52) so, if there is a (Refer Time: 18:54)

If you look here if you look at the loads at the base of the spine the thoracolumbar spine how much it has, what is the inclination of that if the you are looking at theta with respect to the horizontal here if you look here this theta is measured with respect to the horizontal it is not the relative angle between the thigh and the truck ok.

So, theta is measured the absolute angle with respect to the horizontal is what we are talking about when we are talking about an erector spinae ok. So, you would do the analysis in the same way. So, this is say theta equal to 90 degrees or dt yeah this would be from the point A yeah these because the CG you know it is you are giving the distance in terms of the length of that spine.

So, these locations will not change, but the contributions to the moments and all that will change with theta the less yeah the points B and D will not change we will not change with respect to the thoracolumbar spine, on the spine A B and D with respect to the global system it is going to be different because the theta plays a part in that.

Student: (Refer Time: 20:36).

Yes.

Student: In the earlier question you said that J as shear joint forces negligibly (Refer Time: 20:45)

Hm

Student: Is coming out from (Refer Time: 20:47).

What did you get.

Student: Because 85 degrees I got 0.50 W H.

Hm I got.

Student: (Refer Time: 20:59) triple 0 1 8 yeah it is less

Yeah it is 10 to the power minus 4.

Student: (Refer Time: 21:06)

Yeah it is of the order of 10 to the power minus 4 or minus 5 something like that, there must be some mistake in your calculations you can check that.

Student: In the last case what is a alpha.

In the last case also we are assuming. So, we are assuming alpha is always acting at 13 degrees with respect to the thoracolumbar spinae that is here from the back because your spine has a curve right. So, we are assuming that the line of action is at 13 degrees.

Student: (Refer Time: 21:38) we have straight like that (Refer Time: 21:42)

Yeah so, you will have yeah.

Student: Then the muscle force

Force muscle force will be at an angle to that vertical.

Student: (Refer Time: 21:52)

Third join forceful will.

Student: (Refer Time: 21:58).

So, the joint force will balance that out know. So, there will be there will be yeah there will then be a horizontal joint force in order to balance out that ah. So, that in that case you will probably have.

Student: (Refer Time: 22:11) moment also so, that will also be applied (Refer Time: 22:14)

Now, we are assuming it is a pin joint so, it cannot support a moment. So, the forces have to be such that those all 3 equations have to be satisfied if it is an equilibrium you cannot have a residual moment.

Student: (Refer Time: 22:30).

For 90 degrees.

Student: (Refer Time: 22:34).

Then we will have to see what let me work that out and I will ah.

Student: At 20 degrees (Refer Time: 22:51).

Everything will be this thing now ok, I see then you can just take alpha equal to 0, then you know that is it is going to act because it is almost along the spine. So, here I think I computed oh I took 85 degrees that is why that is why I did not run into that ah. So, if you take nearly erect. So, I computed these 4 and you can work that out and check I took W L as 20 percent of the body weight and for the 3 cases theta equal to 35, theta equal to 75 and theta equal to 85 degrees I got F m as 1.885 W, let us go just 0.97 W and 0.32 W.

So, you can see the drastic change in the muscle force, J a 3.4 W, 1.7 W and 1.05 W and the shear 0.08 W, 0.024 W and 0.008 W, that is why people if they have problems with their spine they are advised not to lift loads you have to because the effect of those loads can be quite detrimental to the health of the spine or if they experience pain.

So, you know all this leads to worsening of the condition. So, if so, these you can work out it is the same free body diagram just as a different set of you have some external loads. Now let us look at the case say the person is ok. So, now, once you have the.

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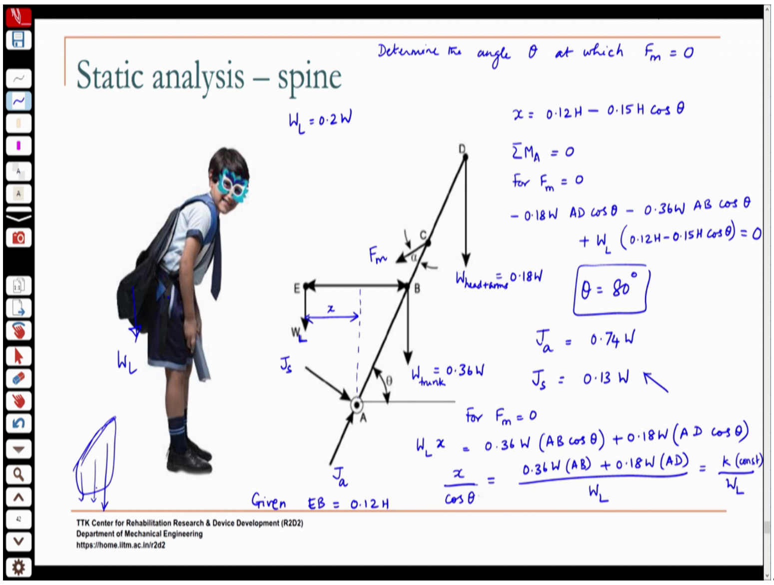

Once you have lifted the load we will look at the analysis using a backpack next before that when a person is carrying the load say they are carrying a load. Let's look at a case now where W L equal to 0.2 W and person is carrying equally distributed into a 0.1 W load in each hand, use the free body diagram to analytically determine theta at which F m equal to 0 ok, at what angle of the spine does your muscle not have to exert any force at all. So, you have the expression for F m which we saw earlier as 0.36 W AB cos theta plus 0.18 W plus W L A cos theta divided by AC sine alpha.

So, when will your F m be 0, theta equal to cos theta is 0 if cos theta is 0 then. So, when you are erect then your F m is likely to be 0, but of course, you have to make you know in that case if alpha is 0 then you have a you end up indeterminate system. So, if we assume alpha acts at an angle to the spine then your solution is so, close to 90 degrees is what you are looking at to minimize the muscle force, analytically it tells you that if alpha acts at a finite angle to the spine then your when the spine is erect at theta equal to 90 here F m will be 0.

And in this case our axial comes out to be 0.74 W sorry J axial and the shear force will be 0 all the loads are F m is 0. So, that is what happens when theta equal to 90. Now let us look at the case where we are carrying a backpack that is something we all do on a regular basis so, let us try to using the same free body diagram.

A similar freebody diagram let us analyze what it is going to look like when you are carrying a load in a backpack ok. So, for this let us see what is the angle theta at which F m equal to 0. So, let me call this as J axial, J shear, this is my W L ok, this is the weight of the trunk, this is weight of head plus arms. So, this is equal to 0.18 W, 0.36 W.

And let me call the distance from this load to this joint as x that is how far behind the load this W L you know how far behind it acts from that joint lumbosacral joint is my x and I want to determine at what angle F m will be 0 when I am carrying this load in a backpack.

So, my E so, this is A, what is this distance x equal to 0.12 H minus 0.15 H cos theta I am given AB equal to know what is 0.12 H.

Student: AB.

Ab EB EB where is EB eb is 0.12 H. So, find out the angle at which this is F m again take you can take alpha equal to 13 degrees and find at what angle theta you will have WL is again 0.2 W all the kids when they go to school nowadays their backpacks are close to their body weight so, 0.2 w is very low.

So, what do you get, at what angle is F m equal to 0, if F m equal to 0 then I have 0.1 8 W they take moments about A WL into if you solve this you get theta equal to 80 degrees ok. So, when you are carrying a backpack not the fully erect, but somewhat bent your muscle force will be 0.

And what is the axial load at this at theta equal to 80 you get 0.74 W and you get the shear force of 0.13 W. So, if I just look at x you know I want to look at what can I play with x ok, what should be there? There should the load be in the backpack. How do I pack my backpack I can look at to do that I can say.

So, for F m equal to 0, let me say W L into x equal to 0.36 W into AB cos theta plus 0.18 W into AD cos theta. So, I can if I look at x by cos theta it is equal to 0.36 W into AB plus 0.18 W into AD by W L, that is equal to this is some constant the numerator is a constant, because it is all based on the this is some constant by W L.

So, if I want F m to be equal to 0 and I increase the load in the backpack what do I have to do, what happens to theta, if I increase the load in the backpack initially for W L equal to 0.2 times W I found theta equal to 80. Now, if I increase the load which way should theta work should I become more erect or do I bend more.

Student: Yes mam

I tend to bend more my theta decreases. So, that cos theta will increase ok. So, if W L increases then so, when you when the load on your backpack increases you tend to bend more ok. So, a simple analysis like this can tell you why that happens, then if you look at x ok. The other way that I could minimize the impact of the bent load is if I maintain theta then I should decrease x right, if I want to keep the same posture then I have to decrease x. So, how can I do that so, if I look at my backpack ok.

So, right you tend to pack the heavier stuff you know if you lay the backpack flat you put the heavier stuff like even your laptop pouch right it is they do not put it in the frontal they put it towards the back. So, that that is your and then you start putting lighter stuff on top of it. So, that you are moving your CG so, that you are making x smaller say you pack it such that x is as close to the joint as possible ok.

So, a simple model like this of the spine can give you insight into why we do that ok. So, we will so, you put the lightest things on top. So, if you and you put the heaviest ones towards thee when you are when you are packing it you put the heaviest ones there ok. So, that is the right way to pack a backpack so, that you do not have to stoop so much to carry the load ok.

Because when we are walking you want to walk fairly erect you do not want to walk like that. So, that is the simple analysis tells you why we do that ok. In the next class we will move on to the lower body they will look at what are some of the loads that happen when you do static analysis of the lower limbs.