Ergonomics Workplace Analysis
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Lecture - 05
Biomechanics in Workplace Evaluation

Good morning, welcome back to one more class; today we will be talking about Biomechanics. So, how we are going to do various Biomechanical evaluation or Biomechanical concept; how we are going to use it, when we are doing workplace evaluation.

So, first we will understand, what is biomechanics and various principles and basic concepts of biomechanics and how these concepts are useful when we are actually evaluating or analyzing the workplace environment.

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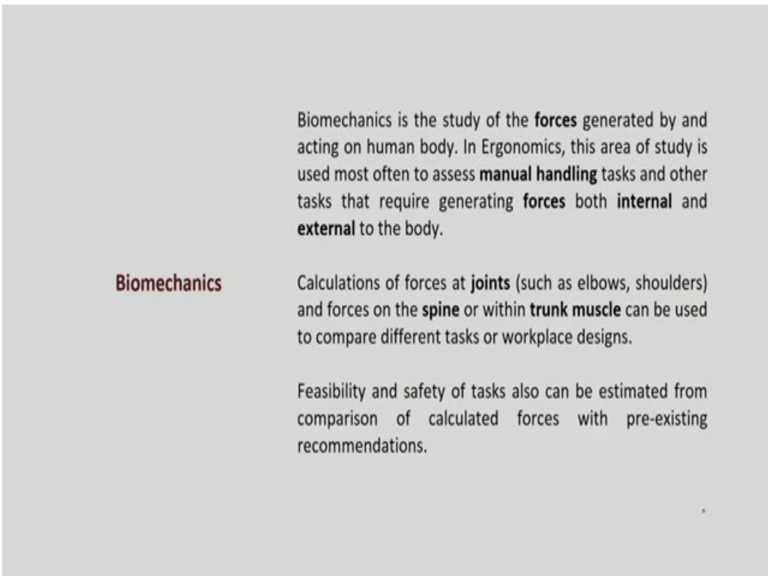

So, let us understand, what biomechanics is? So, as the nomenclature says its bio mechanics. So, what we try to do? We try to understand various mechanical principles which are implemented on our body that is human body. So, force, what is generating through various muscles.

So, we will try to understand all these concepts and how these are associated or when we are using different equipment different tool or maybe we are doing some job maybe it is sedentary or maybe manual job or any type of activity, how these muscles, how these forces are acting and then how those creates different types of phenomena; those we will be discussing today.

So, let us first understand what biomechanics in terms of definition or technically how we define it. So, biomechanics is the study of the force that generated by and acting on human body. So, in Ergonomics, this particular area of study is used mostly often when we are doing manual handling. Manual handling means being a human being when we are doing something using our hand or our trunk or our legs.

So, we are talking about how much required forces we are generating and then internal and external body how those are reacting with each other so, that we will be discussing. So, calculation of forces at joints and forces on this spine or within the trunk muscle can be used to compare different task or workplace designs.

So, just I will give you an example suppose, I am using this particular pen. So, to hold this particular pen, how my the whole posture is like each finger is occupying a specific position specific posture. So, for each individual it is different, it is unique right

Now, when we do hold it and we put it put our hand or we write on against a paper. So, definitely there is a force which is generating over here in this particular part maybe on these joints and all. So, when we are utilizing or when we are handling this type of you know tools or equipment, when we are interacting with those instruments; how the that force is generating and how it is having impact on the human muscle.

So, now how what the example I described it is holding just a pen. So, it is a small component, we are holding it using our hand that to mainly our fingers. Suppose, I am lifting an object in that case maybe my or the whole arm will be used and if it is really heavy maybe I will take help from my trunk muscle.

So, to hold that object or to lift that object or to shift that object, how my body reactions are happening like how the forces are generating through the muscles and how those interactions are happening. So, normally that is the major component we discuss in the field of Biomechanics; so, those will be discussing today.

Now, when we are talking about Biomechanics there are very important three points we should understand and discuss so, that let me explain you first. So, first point is, how valid are the simplifying assumptions and approximation that are made in the analysis. So, we need to understand that, how robust are the result of that particular analysis and what are the criteria of safe level of force and how reliable they are.

So, when we are talking about safe execution or safe lifting, we should understand how safe it is; how much percentage. So, is it safe for the all the whole population who is going to handle that or it is safe for only maybe 90 percent of the population or 5 percent of the population or what?

So, we need to understand that and we have to define it ok. So, without these specific lines, we will not be able to use those data for our design modification. Because once we do the analysis; once we understand the whole structure of the workplace further what we need to do if there is a problem? We need to improvise it and improvisation will happen only through modification or only through design.

So, for that we should understand the level. So, once we understand those levels then only, we will be able to design safely or design for better performance or productivity because from the beginning of my class I am telling that you know Ergonomics actually is successful only when there is an increment in the productivity along with enhancement or increase in the status of the health of the worker or well being factor of the operator, right.

So, whenever we are talking about biomechanics, same concept same goal we need to achieve for biomechanical analysis definitely we need lot of instrumentation. So, we need to understand those techniques. So, to that also we are going to discuss here.

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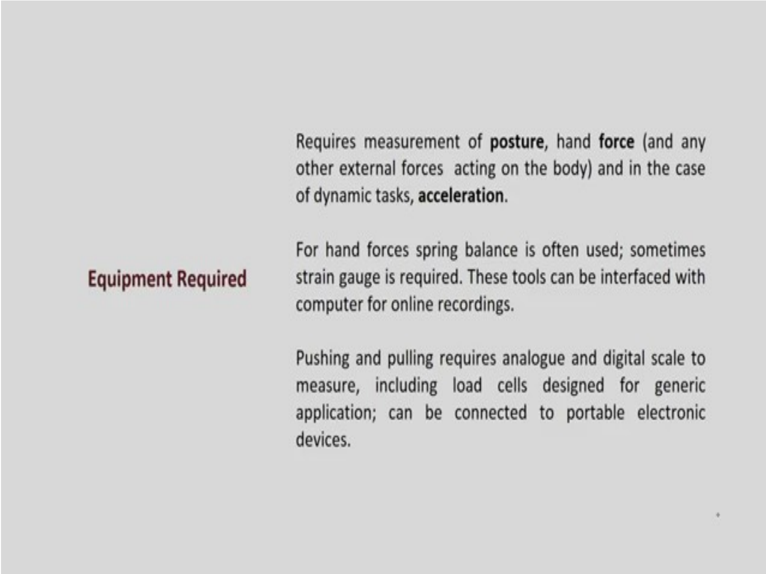

So, what we mainly do over here is posture measurement, postural load measurement, hand force measurement and many cases some dynamic tasks are there in those cases we do acceleration measurement as well.

So, for hand forces, spring balance is normally in use; then strain gauge we may also use and these tools can be interfaced with computer and then maybe we can do online recording. So, those facilities are right now available like there are varieties of instruments, varieties of facilities are available in the market you can buy according to your choice and your requirement and we can use it. So, pushing, pulling all these analogue and digital scales are available so, we can use it. So, if we get some time maybe we can show some of the equipment which is available in our lab.

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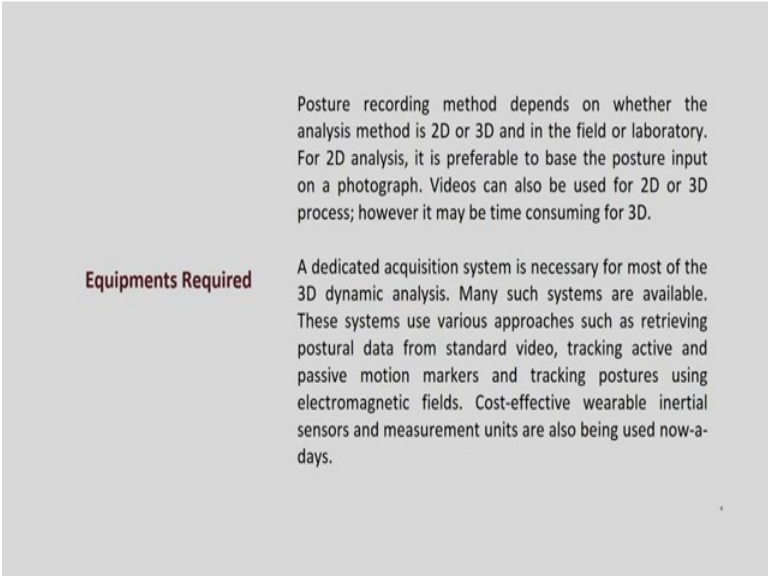

So, what are the other things are required? So, when we are talking about posture recording that can be mainly two types one is 2D another is 3D. So, if we are talking about 2D mainly the photographic technique will be useful. So, we do photographing; photographing also has specific way of clicking the photographs.

So, for that we need to really avoid parallax error, we need to understand what is the angular formation is happening between the joints. Those things so, maybe side view, front view, top view all these are very important when we are talking about 2D photo like 2D posture analysis and through photographs.

So, videos also can be possible and whenever we are doing 3D analysis definitely these are very much time consuming. So, we have other facilities like you know we call it a data acquisition system. Many times mainly what it does is it access or it records various data points of our body using marker and then finally, it calculates the kind of load or force or the angles are generating when people are the subject means that participants are working in a particular job.

So, that is possible; also, active tracking of those markers and their movements need to be recorded and after that we can analyze them. So, that is the way how we do the 3D dynamic analysis.

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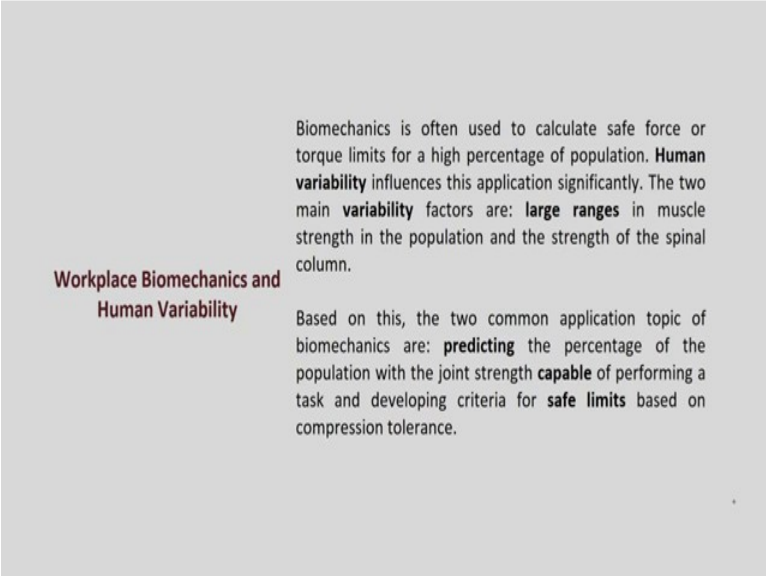

So, when we do all these things, we need to understand that human variability is very important and it plays an important role like it has an impact in the biomechanical analysis. So, biomechanics is often used for calculation of the safe force, what I mentioned earlier also or I can say limit of the torque.

So, take example like for a door handle, I need to open the door. I need to define that what should be the resistance need to be given so, that a kid or maybe a person maybe a school going kid, maybe nursery or class 4-5 till 4-5 should not enter into the that particular room because maybe some very hazardous elements are kept there and they may not understand the risk.

So, what I should do? I should keep such resistance that so they should not push the door and go inside, but for the people who are eligible to go maybe with little has little more hand force, they can push and go inside.

So, now I should understand what limit I should give? Now, it does not ensure that a kid having more force will not go inside, but still we can create some kind of barrier; so, safe execution. So, maybe we can take one more example like we want to create us some kind of latches so, that everyone in the in that particular population or for that target population will be able to use it.

So, what should be the minimum resistance we should give so, that everyone without any difficulties can operate that particular handle. So, this understanding of safe handling; these things are very important.

But here concern is the human variability is huge. So, when these large scales we need to adjust, we need to be very specific as what the context we are designing is or how we are specifying it. So, once we understand that then definitely we can take a decision, what is the limit we should consider for all these type of data? So, based on these maybe two common application, we need to understand one is predicting the percentage of population with a particular joint strain.

So, suppose we are talking that who is having this much hand force or grip force and the percentage or the maybe 50 percent of that we are applying. So, whenever the person is going to operate that particular instrument, maybe they need not to use the maximum force; they can use 50 percent of the maximum.

So, predicting that is important also the safe limit as I mentioned earlier that if it is 10 kg suppose; then the weakest person in that target population should be able to use that 10 kg load or 10 kg force. So, that way we need to understand prediction and the safe handling.

So, one more important aspect in Biomechanics is that understanding the personnel factors as well as gender, age and their specific limitation. Now, it is very common now or we know that you know female trunk muscles or any other body parts muscles are comparatively weaker than male population.

So, when we are talking about lifting a load if I design that lifting device or lifting job in such a way that it is beyond females capacity then female will not be able to do the job within a safe limit or safe zone. So, then there may be a problem or there may be consequences like back injury or maybe reporting of back pain, then other maybe other musculoskeletal disorder issues.

So, what we should understand the kind of susceptibility is like data of that particular biomechanical part like maybe trunk muscle, maybe hand force, maybe neck strength everything. So, these are important when we are talking about biomechanical analysis.

Another important aspect is age so, young adult population always have more strength or power as compared to the elder population and young like children right. So, whenever we are designing something; we need to understand, what is my target population. So, if my target population is elderly people suppose, I am designing a medicine box. So, the medicine box how I should open and close that medicine box. I should understand who is going to use it, is it going to used by a caretaker who is young adult or it is going to be used by the that particular elderly person.

So, if I understand that if I design in such a way that given a condition the elderly person is going to use that that particular medicine box, I should design that that locks system in such a way that with minimal force he or she can open that. Because they are really not having that capacity or capability those days in their fingers or wrist or hand, right. So, we need to understand.

And when we are designing something in the lower limit then of course, who is having more force they are going to use it. So, there will be no problem, but whenever we are designing a risk we want to restrict something then we knew should go for the higher value. So, that is very important concept when we implement all these biomechanical principles.

Now, we should understand some very specific principle that we use for biomechanical calculation.

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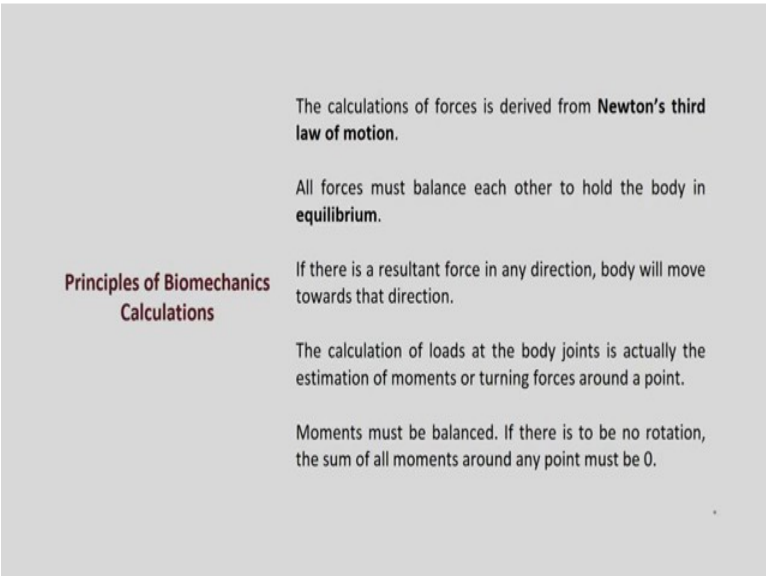

So, normally what we follow here is the Newton's third law of motion. So, whenever we are putting force or exertion on a particular system particular object, there is a reaction force back. So, that principle is always being used in this biomechanical analysis or calculation.

One important thing is that whenever we are applying force, it has to be a balance it is always body always is in equilibrium state. So, if I am flexing my trunk muscle, there will be always a kind of force will be there in my extensor muscle. So, that it try to keep it back in a extended position. So, if there is a imbalance between the strength of the extensors muscles and flexors muscle, there will be a problem in your back or like there will be a back pain.

So, whenever forces are being exerted by the muscle groups, it has to be in equilibrium state; otherwise there will be a problem or there will be a response which says the maybe musculoskeletal disorders are is being reported for that particular body part.

So, the calculation of the loads at the body joints is actually the estimation of the moments or turning forces around that particular point. So, suppose here I am trying to pull it down; so, if it is within body there will be something some force which is trying to push this also down. So, then there will be an adjustment so, this particular concept or principle is always being in use when we are talking about the biomechanical calculation.

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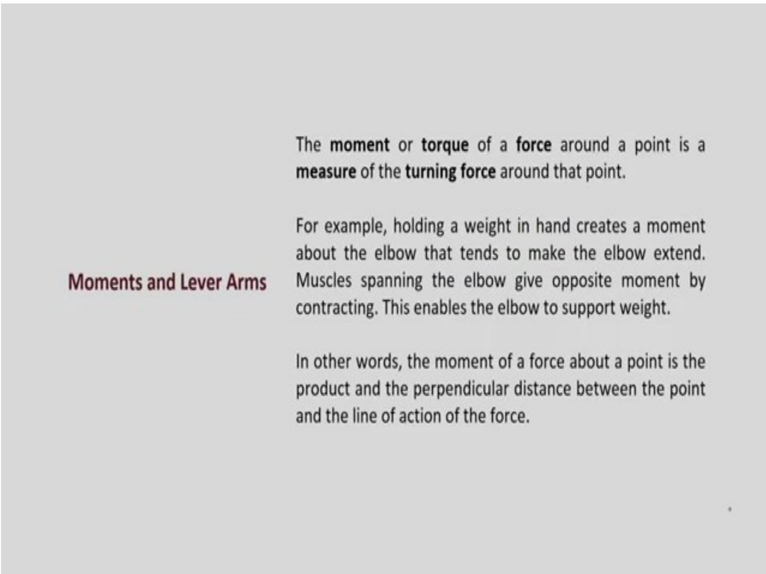

So, let us understand, what is moments and the lever arm. Because for this example also so, these lever arms are very important when we talk about biomechanical analysis or biomechanical calculation within body and the within the workplace. So, what moment and torque is.

So, what it says that when we are doing some job when we are putting some effort or load on some particular object, there is a momentum is generating and there is a torque so, that need to be balanced properly. So, once it is being balanced then the whole state of equilibrium will create and then finally, the work will be in progress like there will be less exertion.

But if that equilibrium is not there or exertion is more then, there will be a response like there will be an accumulation of fatigue or accumulation of like the balance will not be there. So, those muscles will get more exertion and finally, there will be different symptoms of musculoskeletal disorders.

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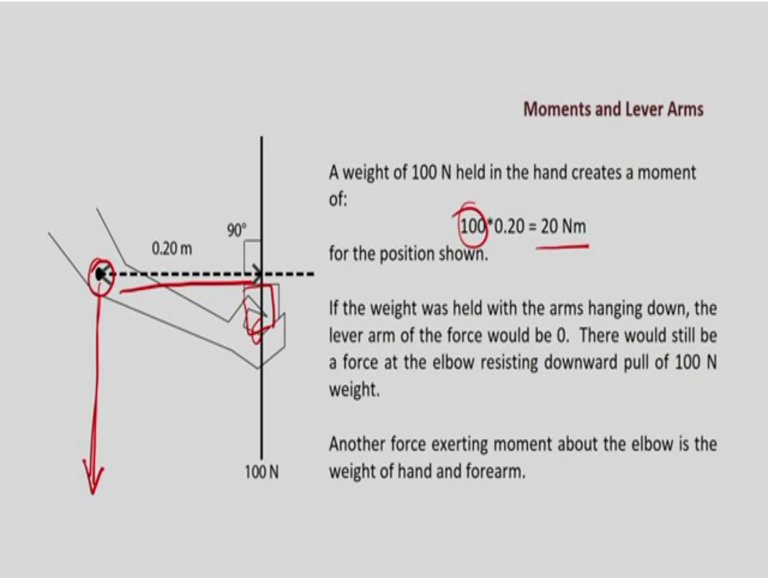

Now, take this example; suppose we are talking about this elbow joint and here I am giving an weight ok. So, what it says that if I am you know holding this particular weight over here, then hand in this particular hand creates a moment of 20 Newton metre. So, this distance we are talking about is 20 centimetre. So, 100 into 20 centimetre is 2200 Newton metre.

So, if this particular weight was held with arms hanging down like not here, if it is here; then what will happen? The lever arm force would be 0 because it is coming like here. Although, this 100 Newton is already there. So, there would be still a force that at the elbow resisting the downward pull of the 100 Newton. So, this 100 Newton will be forcing it down.

So, here it is 200 because it is creating an angle, but here it is direct; it is 0 the angle is 0. So, the distance is 0 not angle. So, it will be 100 Newton. So, this way we can calculate moments or lever arm of a particular for this particular figure.

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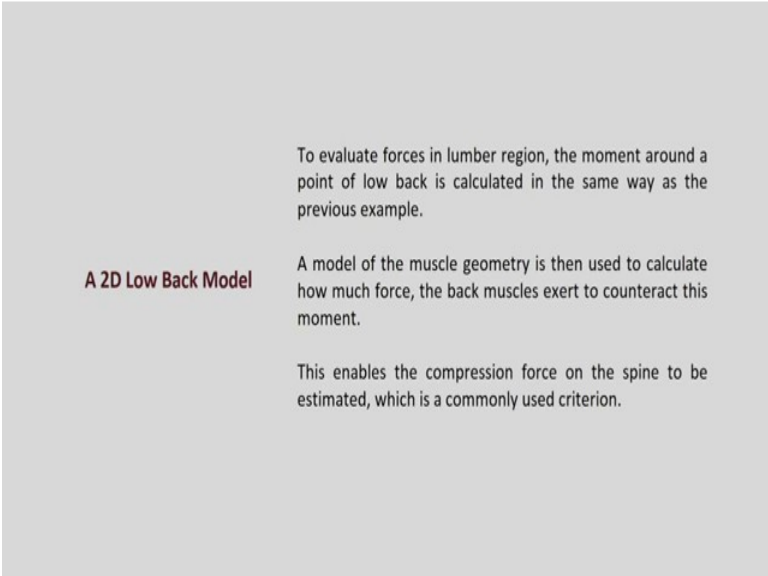

Now, let us understand 2D model of the low back, 2D low back model. So, what is, what it is this? So, it is like to evaluate the forces in the lumber region, in the whole back this lumber region is more susceptible we call it low back right. So, we need to understand the lumber region forces. So, the moment is what generating around a point of a low back that we need to calculate in the same way as we did in this example the same way.

So, first is load, how much load is there and what is the distance then we will multiply it.

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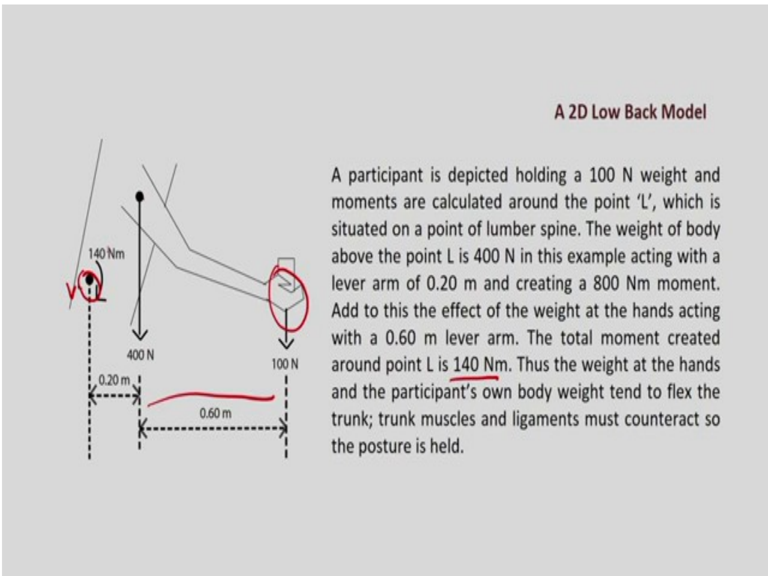

So, let us take example over here, now see this is my lumber region so, I kept it as L ok. Now, I am holding the same weight over here 100 Newton, now what it is saying that here also you have body weight and all those things is coming here as 400 Newton, this distance we kept it 20 centimetre, here it is total 60 centimetre so, total is 80 centimetre.

So, now if we calculate all these so, what will happen? At this L point, we will generate 140 Newton metre force, how? So, if you calculate this, this Newton 140 Newton metre will generate.

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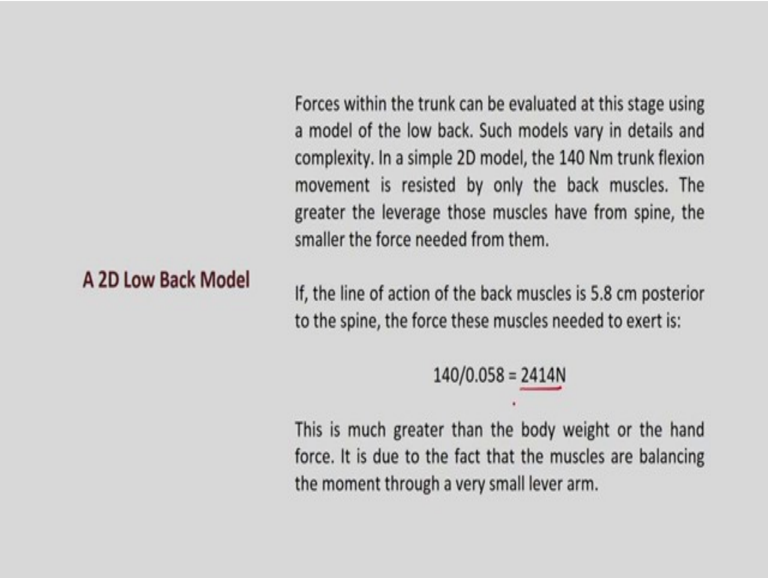

Now, if that happens this 140 now if the line of action of the back muscle is suppose 5.8 centimetre posterior to the spine, then the force of these muscles we need to exert is 2414 Newton because 140, this total is 140 Newton metre at the lumber joint multiplied by 0.058. So, 2414 Newton so that we can calculate.

Now, here this 5.8 centimetre can change ok. So, that is that is an assumption for this particular example. So, you can have your own model you can see, see if someone is holding some object on their on his or her hand and holding this particular posture forward bending with from the lumber joint lumber point and then we are trying to calculate what kind of joint force or moment is getting generated then we can calculate. So, this distance can be changed.

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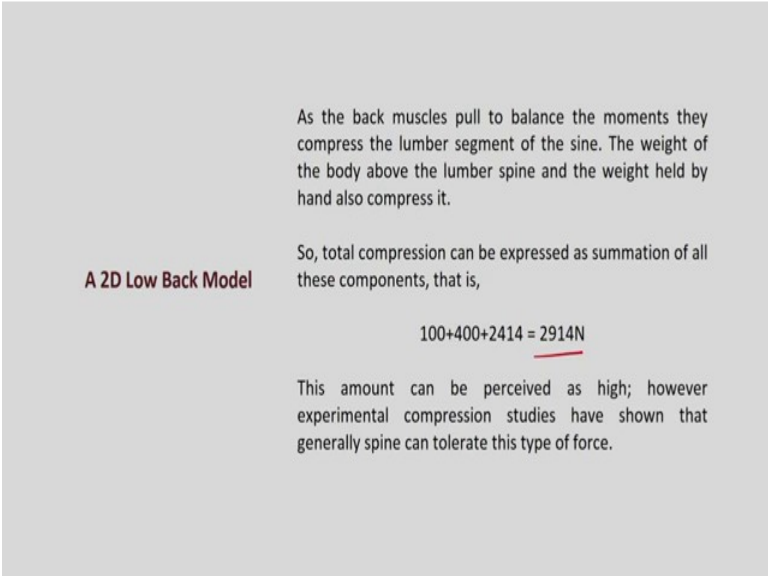

Now, here what I am trying to understand is first in this first example, we have this 100 Newton; then we have 400 Newton and then we have 2414 Newton. So, total we have 2914 Newton at the lumber region. So, this amount can be perceived as very high.

Now, we are saying it is high, but if we see the structure you know our components of the spinal cord, it can bear more forces than this amount. Therefore, if we have such kind of situation at our workplace we may sustain it., But if we continue it for longer duration or longer years slowly what will happen, there will be an small every day accumulation of trauma and over the period of time, it may create a trouble which will be reflected as back pain or it may increase or it may propagate to your upper back and neck and there will be a problem with the whole back issues or back related injury or problem.

So, maybe for that particular point of time, the spine or the whole structure can bear this much load it is possible. So, our body can take this load, but over the period of time it may if we are not doing proper kind of strengthening of our muscle or joint relaxation technique or muscle relaxation techniques; then over the period of time we may have this problem.

So, if we identify right now in the current workplace, the moment or the kind of force is getting generated at the at your back or at your shoulder or at your arm if it is more; if we are not correcting it right now, maybe it will create problem after some year not now. So, we should be careful, we should design the things in such a way. So, that it is much lower than these types of values so, we need to understand.

Now, here how do you know this is high or this is low? We have standard data so, you need to compare that, we need to understand that and then we need to decide that is it can we continue with this or we should modify it to the lower degree.

So, how we are going to use this type of low back model and how we are going to utilize these data?

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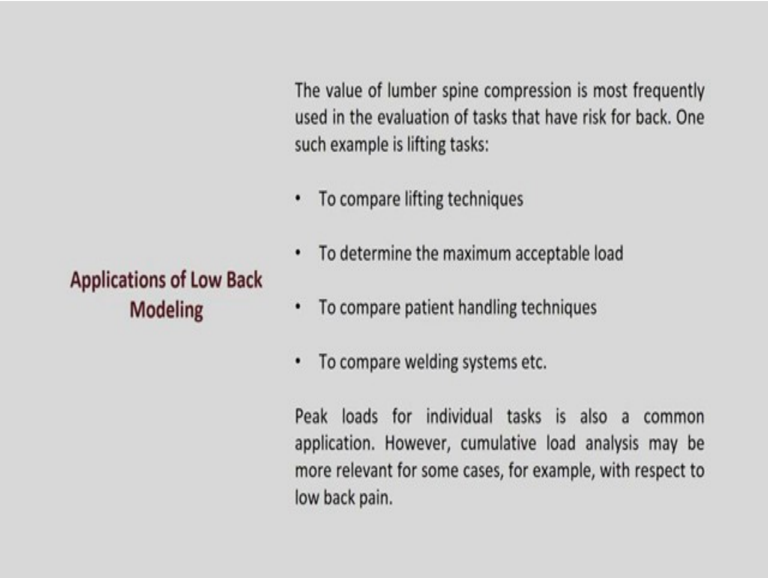

So, first is the when we are talking about lifting techniques. So, how when we are giving the training to the worker? We should tell them how to lift the object. So, comparing different lifting techniques and which is good, which is bad for that, we need this type of low back modelling. Determine the maximum acceptable load; so, many of us know NIOSH lifting equation. So, when we are talking about lifting equation so, what should be the maximum possible load we can lift so, those calculations are purely dependent on this type of model. To compare the patients handling technique is very important, when we are talking about hospital management; so, a healthcare management.

So, when we are shifting a patient from one bed to another bed and suppose we are lifting for our particular operation theatre or many other cases. So, how we should handle that? So, that minimum stress is or minimum force we are getting generated in our back. So, that we need to understand, to compare the welding system in the in the in that particular workplace we need to understand the low back modelling.

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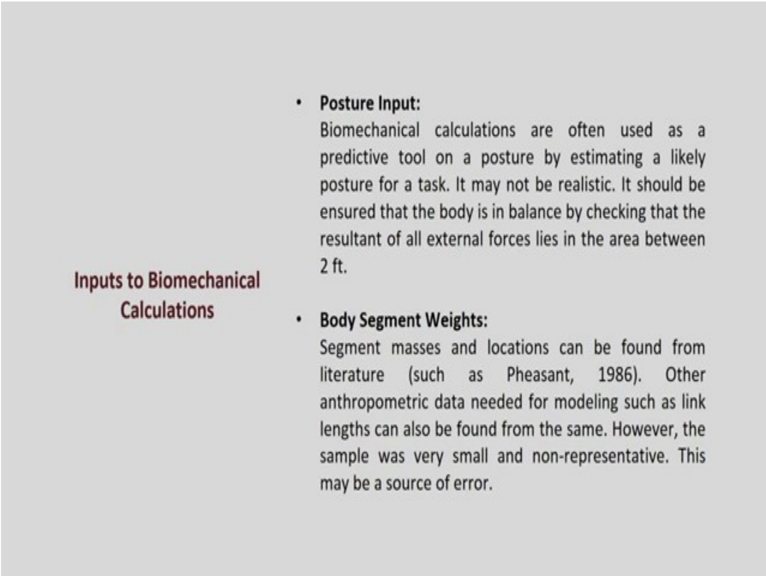

Now, when we are talking about biomechanical analysis, there are varieties of inputs we need to consider so, let us understand that. So, first very important very important input is postural input or posture input. So, biomechanical calculations are often used as a predictive tool. So, it is normally we use it for prediction on a posture by estimating a likely posture for a task.

So, suppose this is my screen so, if I am going to use this screen, how I am going to use it? So, it is a prediction. So, if I am going to use it in this manner so, what kind of body posture is getting adopted and which part of my muscle is having what type of force is getting generated so, these are all prediction. So, that is very important input.

Second is body segment weight. So, each segment has their some proportional weight of the total body like my head is contributing some percentage of my total body weight, my arm is contributing, my back is contributing. So, we should understand the segmental weight distribution so, that how that has an impact in the whole moment generation momentum generation.

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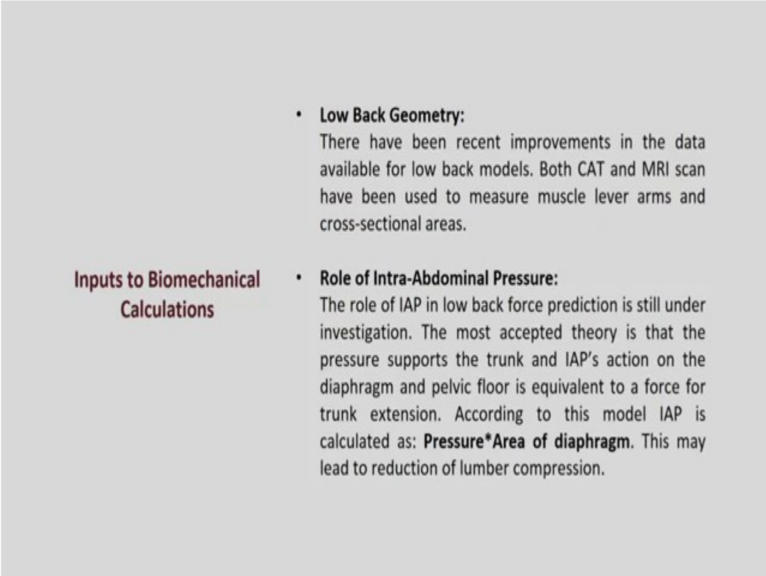

So, again low back geometry very important is intra abdominal pressure. So, what is intra abdominal pressure? So, when we are talking about intra abdominal pressure, it is basically we try to understand the kind of cavity or the space we have within our abdomen because all the internal organs are located over there. So, from whatever the area and the kind of pressure we are having. So, that intra abdominal pressure has lot of impact when we are talking about the biomechanical calculation.

Now, definitely we have some limitation. So, these models cannot give explanation on the repetitive work, it cannot give explanation on fatigue or varieties of inaccuracy source.

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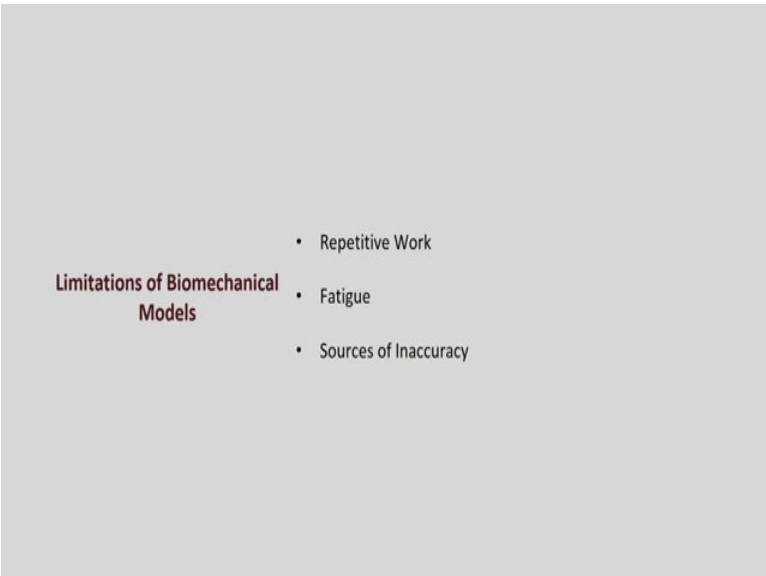

Now first let me explain, the first two is very important so, repetitive work. Now, maybe this particular posture or particular biomechanical load is currently in that particular single episode is not at all hazardous. But the same load if it is getting repeated, if it is getting a static posture; then it may create huge impact on your whole musculoskeletal system, but those biomechanical model cannot explain these repetitive nature also the same way it cannot explain fatigue.

For example, I am holding this particular pen, now if I talk about holding this particular pen and I am calculating the whole strength, the kind of momentum or force is generated over here and all these muscles. If we calculate it, biomechanically maybe it is absolutely correct.

Now, if I hold it for longer hours it will have problem, but biomechanical model cannot explain that problem; so, these are the limitations. So, whenever we are using these models, we need to take consideration of other tools and techniques for explaining these fatigues, repetition and all these aspect as well.

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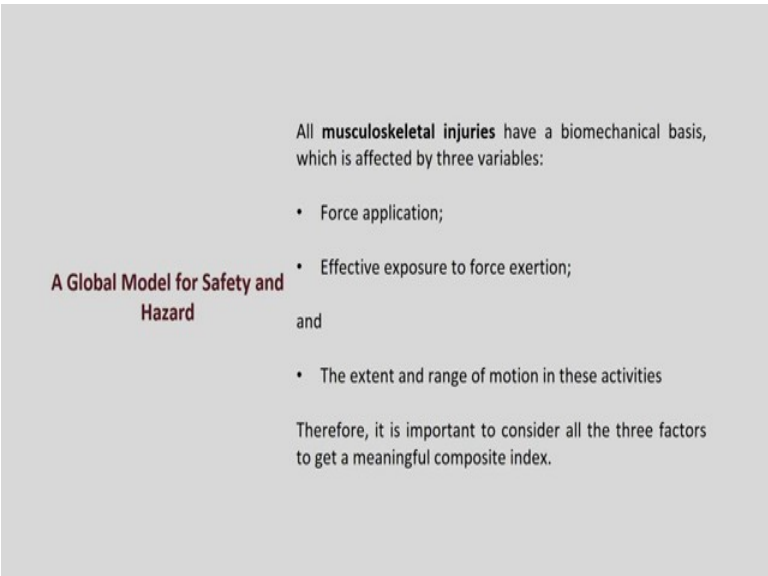

So, we have something called global model for safety and hazard. So, why we do all these biomechanical model or biomechanical analysis at the workplace? Why we do that? We do all these thing to understand or to create a safe environment. So, we have something called global safety like kind of model which try to take care of the musculoskeletal injury.

So, all varieties of musculoskeletal injuries which have a biomechanical basis are affected by three major variable one is force application, second is effective exposure to force exertion and the final one is the extent and range of motion in these particular activities.

So, force, effective exposure towards force and kind of range of motion they are they need to do in that particular activities so, that is very important. So, it is important to consider all these three factors to get a meaningful composite index. So, now, we will be discussing, what this composite index is ok.

So, before I go for that, we need to know there are some terminology we call it margin of safety MOS, another is job mediated risk JMR.

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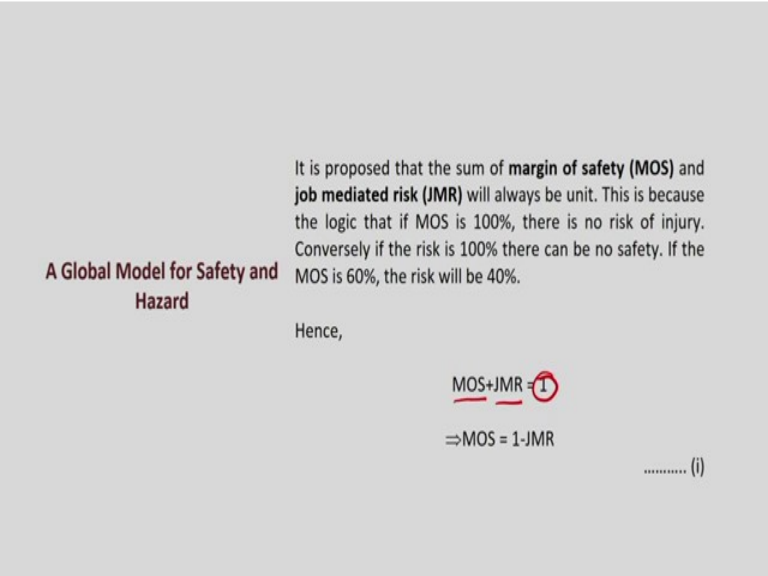

So, you can go back to your textbook and find out details about all these, but I will explain you this particular formula which says MOS plus JMR should be 1, it should not it is always 1. So, if MOS is increasing then like safety factor if we are increasing, risk is decreasing. On the opposite side if risk is increasing, safety is decreasing.

So, whenever it is in balance then we are doing good job because here you can say let me make MOS 1 and JMR 0 then also the total value is 1, is it possible? It is not really possible in realistic situation in the field because it is not cost effective because whenever we are going to apply or implement any kind of intervention, we need to see that what kind of implication is there for that particular intervention.

So, if I do like if I am doing some job definitely I should accept there will be some kind of risk, but I also need to consider that that risk should not be more should not be such big that my health or my well being is getting affected. So, if I can maintain that optimal structure then only we are doing good job. So, productivity also will be high and the well being also be increased. So, always MOS plus JMR need to be balanced for a particular job.

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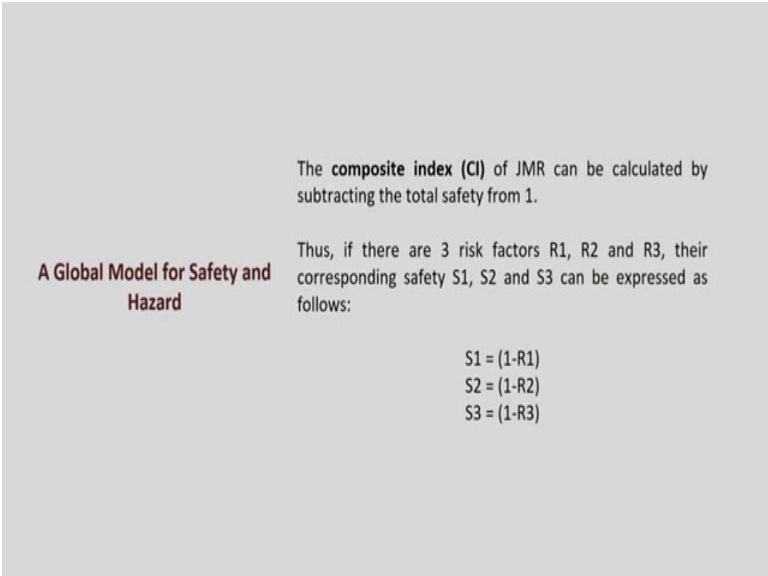

So, what is composite index? So, composite index of JMR can be calculated by subtracting the total safety from 1. So, maybe there are varieties of risk. So, maybe safety 1 is 1 minus R1; then 1 minus R2 something like that.

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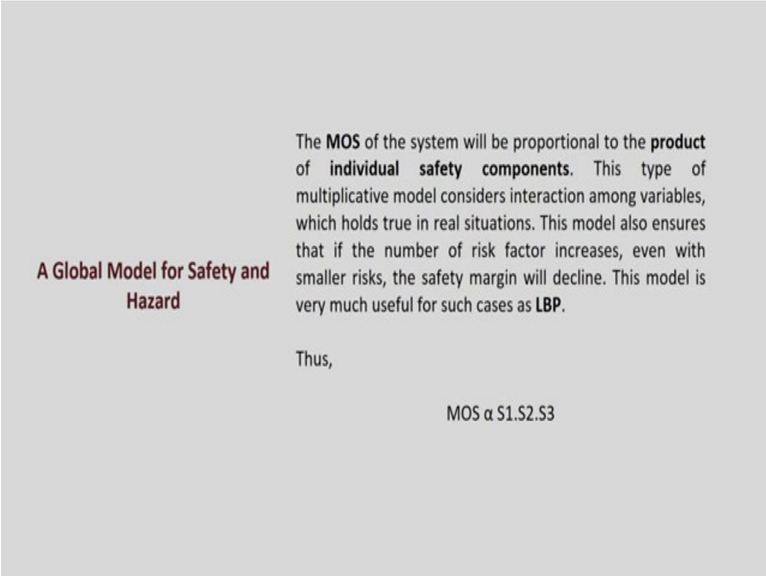

So, MOS we can sum it up as S1 into S2 into S3.

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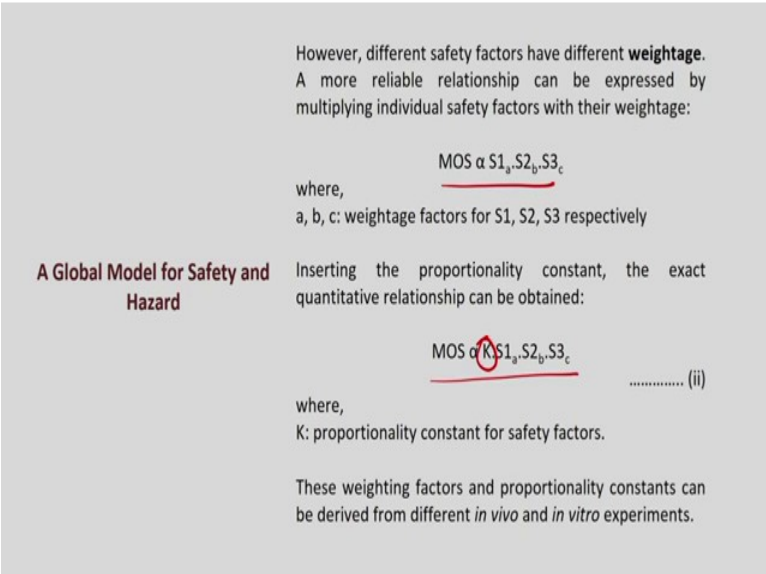

And then we can multiply it like this, what we can say this inserting the proportionately this particular K value the exact quantitative relation can be obtained which is this particular factor K.

So, what it says that proportionality constant for a safety factor? Now, for all your own equation these factors are different, you need to define it from your own value or own variable for every situation it is different you have to give the weightage of it and you have to give the value and then you can calculate this.

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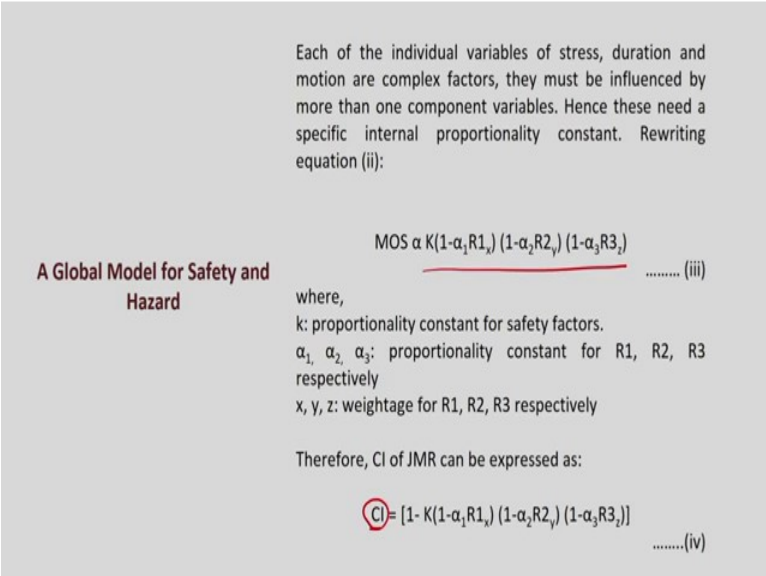

Now, finally, this composite index will come into picture which says that 1 minus all these MOS so, 1 minus K into all these value. So, you are considering all risk factors whereas, alpha 1, alpha 2, these are the proportionality constant for R1, R2, R3. So, this way you can calculate your composite index.

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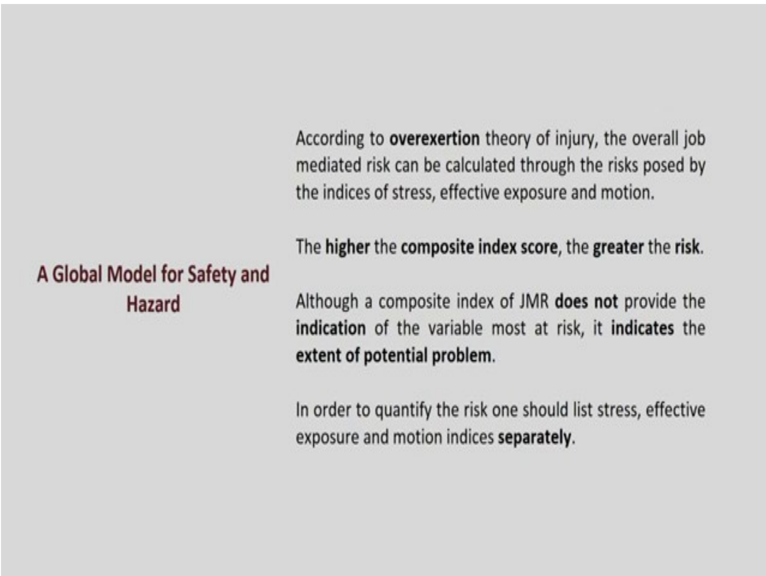

So, once you understand your composite index then you can say that how your risk and your safety factors are balanced. It is balanced or it is not balanced, if it is not balanced to balance that what kind of design modification you have to do or what kind of changes you need to do, maybe it is just an work rotation, it maybe just shifting of this shift, maybe work rest cycle, maybe some equipment design, maybe a tool design so, you can do based on your context.

Now, here one more important terminology that we use for this you know safety and hazard model is the overexertion, by nomenclature itself you do understand when you exerting your particular group of muscle for more than expectation or more than you should do. So, if you are doing that then there will be a trouble and there will be an accumulation of fatigue.

So, if the composite index score is higher, then definitely risk will be more and what it says that composite index of a particular JMR does not provide the indication of the variable most at the risk, it only indicates the extent of potential problem, it does not say so, level is three or level is for or level is five not like that. It only says it may have higher potential or might it may have lower potential or it may have moderate potential something this kind of indication they give; so, that you need to take a consideration.

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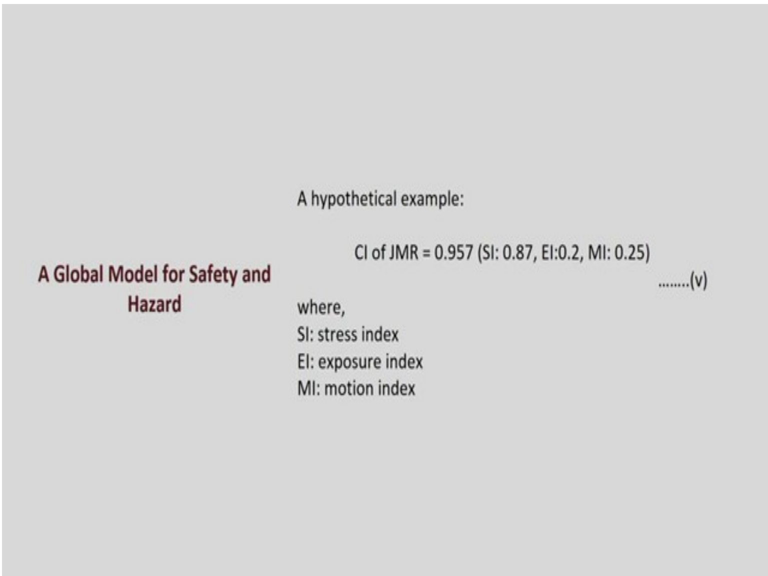

So, if we take an example a hypothetical example where CI is equal to 0.957, what does this mean? So, SI is equal to your stress index, EI exposure index and MI is your motion index.

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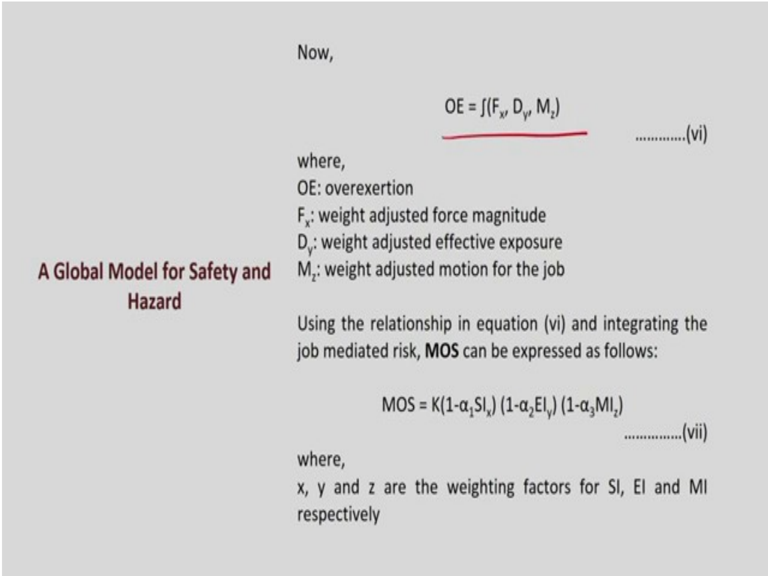

So, over exertion is equal to integration of F x D y M z whereas, x, y, z are the waiting factor of SI, EI and MI respectively so, this way you can calculate over exertion value.

Now, if somebody know all these number, know all these numeric factors or numeric value after that, what? With knowing all these factor, we should understand why this factor are this. Suppose, I got a value of over exertion x now I should check back in the whole system, what are the reason that this OE is x, why not minus x, why not plus x ok.

So, if I can check that, if we can understand that what is the root cause of this particular x value then only we will be able to get a direction to design or modify the whole system. So, getting only these values are not important at all after getting these value, we should check that why this value is this and how we can reduce it, how we can modify it.

So, we need to maybe all these variables whatever we are discussing is not possible to modify because for a particular job, few factors are constant we cannot change them because if we change them there will be an impact in the whole system, whole productivity or the whole manufacturing process or maybe the whole activity.

So, we need to keep them constant, given a chance we need to change the other factor which has less impact in the whole process. So, that is the way how we utilize these values for modification.

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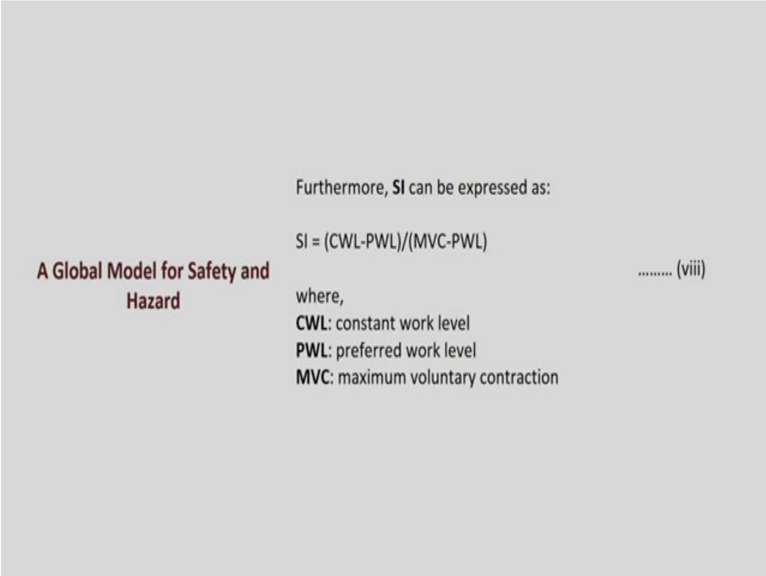

So, SI also we can say CWL minus PWL divided by MVC minus PWL whereas, CW is constant work level, PW is preferred work level and MVC is maximum voluntary contraction.

So, whenever we are talking about whole body finally, how much force I can generate. So, predicting that, getting the percentage of that and implementing that for a particular task. So, for that particular task how much I need and how much my body can generate compare that. So, if the comparison says that it is more how I can reduce it. So, this is the simple understanding of biomechanical analysis or biomechanical utilization of all these biomechanical model.

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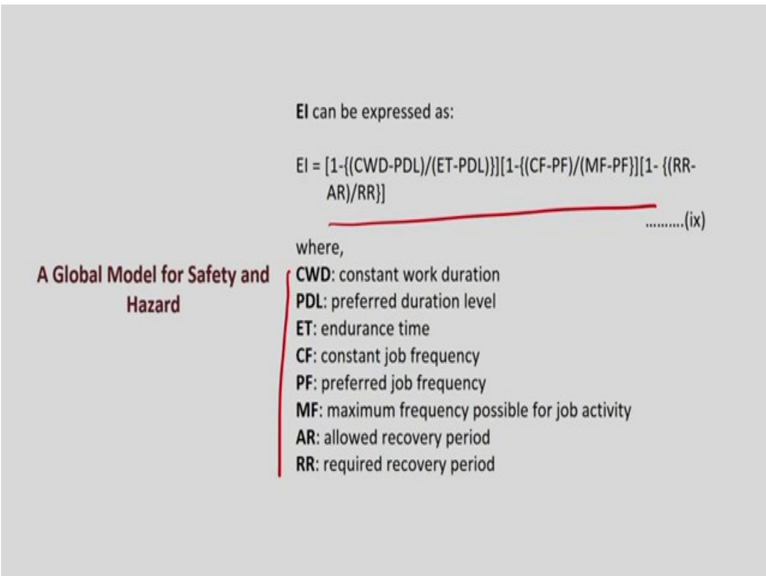

So, here also we can use EI with this particular formula, although this formula looks very complicated because there are so many factors involved. You need to understand the recovery period, you need to understand how much recovery period is allowed to that particular job. So, the whole task analysis we studied it.

So, task analysis, we need to understand the kind of maximum possible frequency is available for that particular job so, we need to understand the repetition. So, what is the preferred job frequency again, we need to consider or relook into the task analysis what is the limitation. So, once we understand all these factor from various aspect then only we will be able to consider or calculate this EI. So, EI calculation formula wise it is looks very complicated because only all these factors, you need to understand separately we need to get those values and implement over here.

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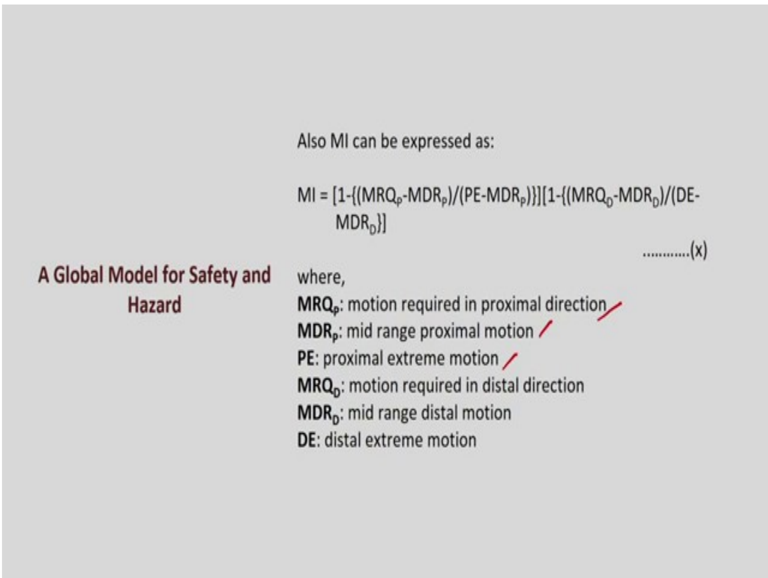

Again for this MI also, its line you need to consider the motion required for the proximal direction, motion mid range proximal motion, proximal extreme motion. All these variable you need to understand, calculate, measure separately and need to put it for MI.

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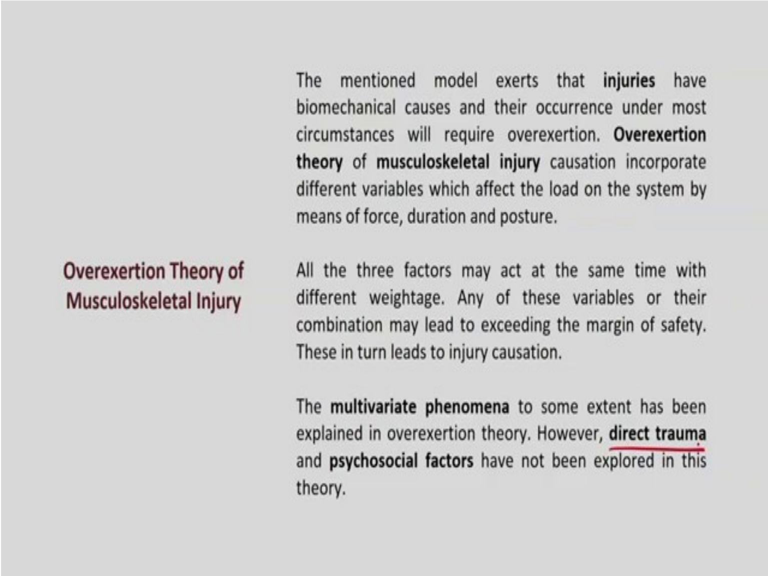

So, that will finally give you the kind of load or safety is available for that particular job.

Now, when we understand the overexertion theory or overexertion principle, what it says in a simplified manner because those are calculation. So, those calculations are important when you are actually trying to identify though the previous setup was giving what and my current setup is. So, giving up for a particular comparison is very important.

But now finally, what it does it says when if there is an overexertion there is a probability of getting pain, getting fatigue or musculoskeletal injury. So, if you find there is an overexertion then there is a prediction that the that particular population may report a prevalence or occurrence of musculoskeletal disorder or musculoskeletal injury.

So, if you see that we need to redesign and then we need to go back and check those report has been reduced or you know changed the pattern or not. So, that way we should use all these all these factors.

So, here one important aspect is psychosocial factor. So, biomechanics definitely is not all the mechanical forces and all those things, but of course, psychosocial factors is you know important because if you have some biomechanical aspect like you know you are having lot of extra forces on your trunk still you can bear it if you are having more positive input from your peer, from your surroundings, from your workplace, but on the opposite side if you have less force, but if your work environment is not psychosocially good enough to give you a boost you will feel low, you may have trauma, you may have injury.

So, both things goes together so, once you technically or mechanically analyze that along with that you need to understand the psychosocial factor to get the these understanding.

Another important aspect is direct trauma; why direct trauma? If there is a sudden impact, sudden trauma that has lot of influence or consequences on the biomechanical, these variables or these loads so, that we need to understand.

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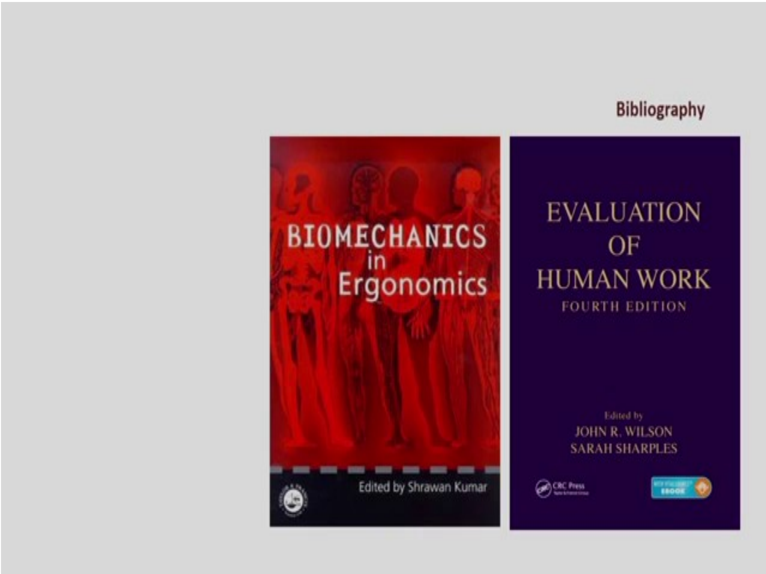

So, again I will tell you these are the two books which you know which is very useful for you whenever you are talking about biomechanical aspects of workplace analysis. So, refer these two books for your more understanding; if you have any query any question, if you find any difficulties to understand all these model. So, get back to us we will wait for you.

Thank you.