Biomechanics
Prof. Varadhan SKM
Department of Applied Mechanics
Indian Institute of Technology, Madras

Lecture - 05
Machines and Mechanical Advantage

Welcome to this class on biomechanics, we have been looking at introduction to mechanics, specifically statics and dynamics. So, we will continue our introductory sessions on statics and dynamics.

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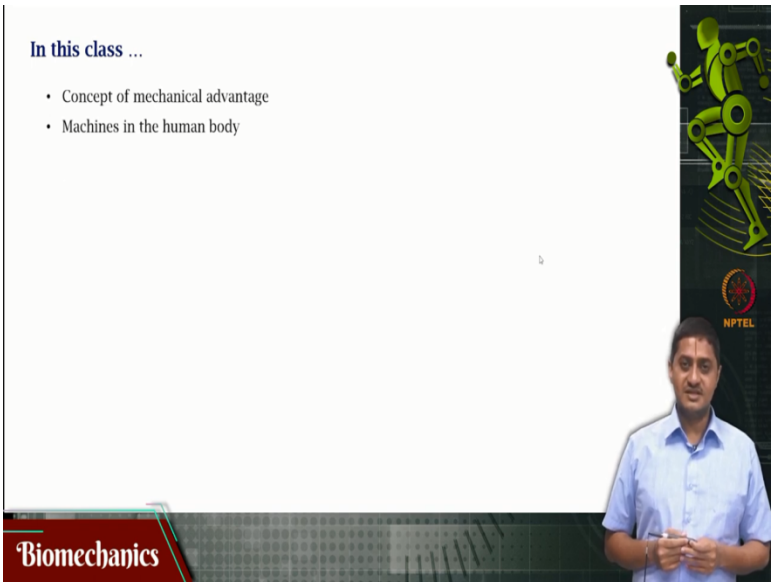

So, in this video we will be focusing on the concept of mechanical advantage and give some examples of where mechanical advantage is used in the human body and will also be discussing machines that are in the human body.

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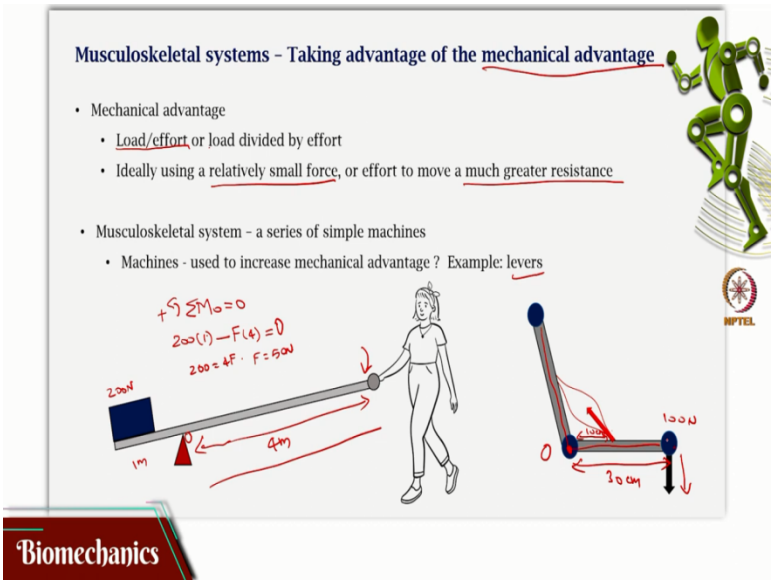

Essentially the human body; not just the human body, animals also sometimes exploit the so-called mechanical advantage principle. What is this mechanical advantage principle? See when you have a room let us say for example you are sitting inside a room and there is a door. And the door is attached to one side and whereas the handle is on the opposite edge of this door, why is this? Because the handle is the place where you apply a force either to pull or push.

But the work itself is happening at the axis about which the door is rotating and that is on the other edge. In this case what happens the width of the door acts as the momentum and it is a moment that will have to be overcome are produced to open or close the door. And because the moment arm is greater or is the greatest when it is closest to the opening edge that is where you keep the handle because force that will need to be produced will be small.

So, the effort that a person will have to incur or put to open or close the door can be minimized for the same system. Now consider that you are trying to open the same door by pushing very close to the axis of rotation in that case you will have to produce a very large amount of forces that is a very unnatural door, this kind of door you do not see right just saying. So, what is this mechanical advantage?

It is the load or the effort load divided by the effort right that is the mechanical advantage. Ideally what we want is using a small amount of force, we want to have a great amount of effect

this is always the case we are always looking to optimize or minimize the amount of effort that we put in while maximizing the output that comes from our effort that is very normal. So, ideally this is not just true for human systems this is also true in many biological systems.

So, ideally our aim is to use a relatively small force to move a much greater resistance this is same that means you will need some sort of amplification or some sort of an unfair advantage that comes. This advantage is called the mechanical advantage. So, consider this lady who is pushing this load about this pivot, let us say this is some 20 kg load let us assume that this is about 1 meter for the sake of discussion.

And that is about 4 meters, for example the point where she is applying the forces 4 meters for example. So, because this is happening here in planet earth so essentially you will have an acceleration due to gravity that will be taking this load down. But the job that is given to this lady is to keep this in equilibrium at level for example. For example, keep it in horizontal equilibrium for example.

In that case what she will have to do is she will have to put an effort to overcome the effect of gravity on this 20 kg mass let us say about 200 Newtons will be the force that will be produced due to this load due to this mass. But will the force that will be required by this lady be 200 Newtons, the answer is no. Now it will be much lesser, why is that? Because in this case the rotation is happening closer to the load.

The lady is having a much greater momentum these are example numbers. So, I could write out that equation that balance that that is required to be let us assume that this is not 20 kg instead I am saying that this is actually 200 Newtons. What is the difference? There is a slight difference 20 kg well actually some to you know ah slightly lesser than will be about 196 Newton, so I am here I am assuming that this is 200 Newtons.

So, if I am taking let us call this point where the pivot is as o if I am taking a moment about this o and I am saying this moment about this o is maintained at 0 is balanced that means that sigma M about o is 0 this is what it means. Now let us write out all the counter clockwise considered

positive. What is the counter clockwise moment? One counter clockwise moment that is present is 200 times 1 meter.

Then the force that is produced by the lady on this bar will cause a clockwise moment not a counter clockwise moment. So, that will be minus we do not know how much is the force that she will is producing we will call that as you know some force F times 4. What is 4? 4 is this moment arm that she is using is it not so that is 0. So, that that means 200 is 4F are the F that this lady is producing to keep this object in equilibrium is 50 Newtons.

So, 50 Newton force is sufficient to overcome a 200 Newton weight. So, essentially this lady is having an advantage, this advantage is the mechanical advantage because she is having operating through a larger momentum. That does not necessarily mean that this is what is always desired in the human system this is an example of what happens in the human system. So, the human musculoskeletal system is essentially a series of many simple machines.

For example many times our human body uses levers, these machines are used to increase mechanical advantage. But there are also cases in which mechanical advantage is not that actually in some cases there is a clear mechanical disadvantage. So, you cannot have it in all the directions you cannot have it which way whichever way you want it turns out that in some places it is a mechanical advantage in some places it is not a mechanical advantage.

Consider this case there are two boards for example there are two rigid bodies and they are connected by a muzzle here this is the muzzle whose line of action of forces given in the direction this is overcoming a load. In this case you see that the rotation is happening about that point o the moment arm for this force is let us say for the sake of discussion 30 centimeters. Let us assume this is the elbow joint about which this is happening is approximately one foot is the distance between my elbow joint and my wrist, for example.

So, I am assuming this is about 30 centimeters. Let us assume that this is the biceps muscle it is attaching at some point actually let us give it 10 centimeter momentum distance this is actually not true actually the distance is much smaller but that is okay let us say that this is 10 centimeter.

In this case to overcome a weight of 100 Newton the system the muzzle will have to be producing a force that is much greater than 100 Newton.

Why is that? Because in this case the resistance that needs to be overcome is having a larger momentum or the force is between the axis and the resistance. So, remains us of the high school physics that we have studied there are three classes of levers and depending on which class of lever that you are operating with you might either have a mechanical advantage or a disadvantage.

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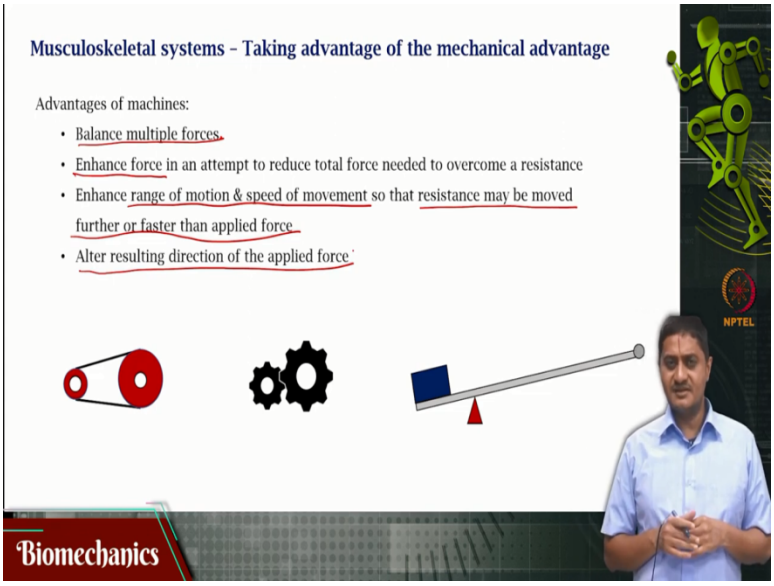

So, we will be seeing what these types of levers are in a future class, future video. Some advantages of machines, one is that these are used to balance multiple forces so many forces may be applied and machines may be taking care of these. So, that is one and sometimes these are used as force amplifiers. So, like the example that I gave sometimes depending on the momentum configuration that you are working with there might be an amplification of force.

That is happening or an enhanced moment of force in an attempt. That is used to reduce the total amount of force that is needed to overcome relations. Again remember I said the human system or any biological system is attempting many in many cases attempting to optimize or minimize the amount of effort that a particular organism is putting in but this is not always true. There are

of course counter examples of cases where effort is compromised or more effort is put to favour stability and this but those are special cases.

But I am giving an example the general case or in some cases the need might not be an amplification of force but rather an enhancement in the range of motion and the velocity of movement. In these cases force that the system will be producing will be much greater than the resistance but this trade-off is practiced. So, that the system has a greater range of motion and a greater velocity.

So, this helps that the resistance may be moved further or faster than the applied forces very critical. So, depending on the application depending on the situation depending on the particular case there might be an amplification of force or there might be an amplification of range of motion and speed of motion. The other might be to alter or slightly twist or tweak the direction of applied force.

This is done using many muscles depending on the situation depending on the case there might be a need to alter the direction in which the force is separate. This will result in some crucial changes in mechanics that will affect the outcome.

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So, with this we come to the end of this video. So, in this video we saw what is mechanical advantage and with some examples of some machines in the human body. Thank you very much for your attention.