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

Lecture – 25
Elbow Problem 1: Biomechanical Analysis of Joints of Upper Limb

(Video Starts: 00:17) Welcome to this video on Biomechanics, we have been looking at joints of the Upper Limb, specifically they saw in the previous video, the elbow joint. **(Video ends: 00:35)**

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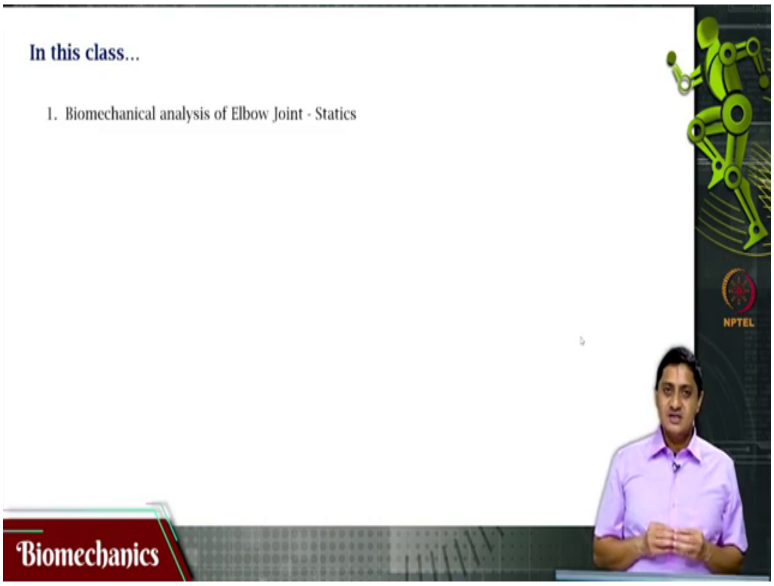

In this video and in the next couple of videos, we will be looking at static equilibrium of the elbow joint. And we will solve some simple numericals using principles of static equilibrium applied to elbow joint.

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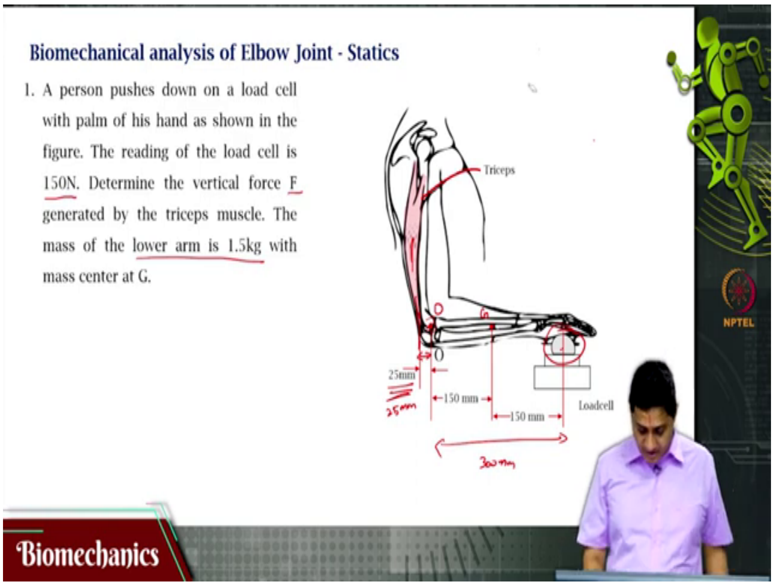

It is a simple problem, a person pushes down on a load cell with the palm of his hand as shown in the figure. The reading that is measured on the load cell is 150 Newton's, the question is, find the vertical force F that is generated by this muscle, triceps muscle that is responsible for producing this moment or action? The mass of the lower arm is 1.5 kg with the mass centre at G.

It is not given but that is the point G, I am marking it for you that is the point G. Let us study the situation before we start solving the problem this is the elbow joint, the muscle is attaching to the left of the elbow joint here. This is the triceps muscle, I am not doing flexion, I am doing extension I am doing that I am pushing on the load cell. So, suppose this is the load cell, let us assume my left hand is the load cell.

And I am pushing on this that action, suppose this load cell was not there stopping this that will lead to extension that is performed by the triceps muscle. And that triceps is attaching at a distance of 25 mm perpendicular distance, is 25 mm from the elbow joint which I am going to call as say ER or let us say O, I am going to call as O for that. And the centre of mass of the forearm itself is at resistance of 150 mm from the elbow joint for the purpose of this problem.

And the measurement of force that is found on the load cell is 150 Newton's. The question is find the force produced by the triceps muscle this is the question? Before we start solving as usual, let us try to understand what is likely the order of the solution? How which scale is going the solution going to be, it going to be units of Newton, tens of Newton, hundreds of Newton's, thousands of Newton's which one is this?

We have not yet started solving the problem, I am aware of that but it is useful to get that intuitive understanding. Remember the joint itself is here, the distance that we are looking at is 300 this distance is 25 mm. The measurement that you are seeing under load cell is 150 Newton, roughly there are about twelve 25s in 300 and not, 300 has twelve 25s. If all goes well if everything is fine assuming that there is nothing else there are other things.

So, we will rigorously solve this. The solution should be close to 1800 Newton's, why is that? 150 Newton's is what I am measuring here that must be then it must be that this one must be able to produce 1800. Not exactly this is not an exact calculation this is a back of the envelope calculation that I am doing. Approximately 1800 Newton are in the vicinity of 1500 to 2000 Newton is there I am expecting the solution.

It is useful to develop this sort of intuitive back of the envelope approximate solutions before we proceed, why? Because many times when students solve problems using calculators they will find the solution to be 18 Newton's and they will just say mark and move on. It is likely that you have made a mistake somewhere in the numericals and because you may be writing the exam in a computer one of the choices may be 18 Newton's for you the other one may be 1800.

For example, this is likely this may happen and you may choose 18 Newton you will get zero points for doing this or maybe even get negative points for doing this. Remember this always have an idea of the scale at which you are expecting a solution. In many problems it is possible to do this back of the envelope computation arrive at some intuitive expectation of the solution, remember that solution will not give you the exact answer.

Because if you are indeed solving the multiple choice questions one of the answer will be 1750 Newton, one of the answer will be 1950 Newton. Then you will be stuck you cannot do this guesswork, you must solve this rigorously but you must also have an idea of the scale that you are looking at. Let us erase all this because it does not confuse you. So, my back of the envelope calculation tells me that the solution is somewhere.

The vicinity of 1800 Newton's are at least between 1500 Newton's and 2000 Newton's. If I am not getting that answer, I am going to recheck my solution this is how I am working. We have not yet started solving the problem.

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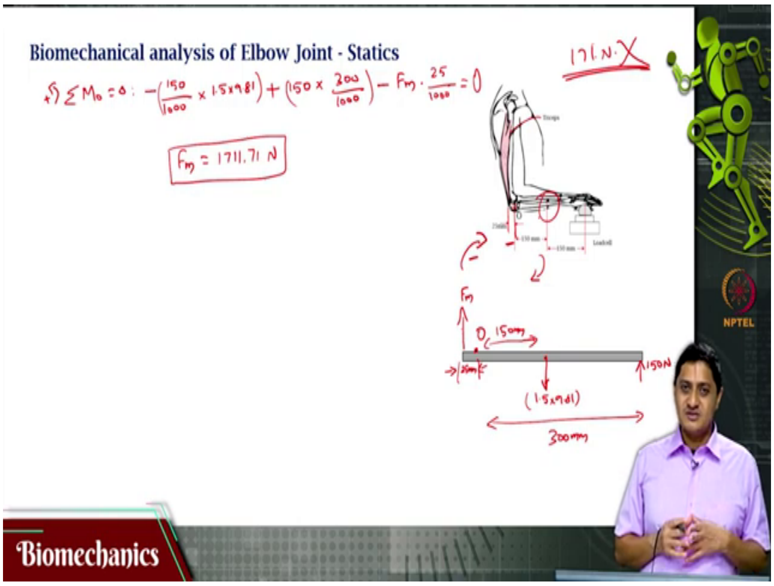

But let us now proceed rigorously this is the situation I am drawing the free body diagram, the muscle is acting here that force is what I am interested in finding. I am going to call this Fm and this is O the origin or the elbow joint that distance is 25 mm very important. The distance between the elbow joint and the point of attachment or the point of insertion remember, the distal attachment of the muscle is called insertion, the proximal attachment is called origin.

So, the point of insertion of the triceps muscle is at a distance of 25 mm from the elbow joint. Remember this is something that might vary, as a function of a joint angle, as a function of configuration, as a function of many different things. But for this problem this is already given, how do I know this? Here it is given, the problem statement says that this distance is 25 mm and I am just trusting this.

Now, at a distance of 150 mm, the weight of the arm is acting and that weight is given to be 1.5 into 9.81, 1.5 kg is the mass this is the weight in Newton's. On the load cell, the force applied by the person is 150 Newton's but since the load cell is not going down it is probably kept on a sturdy table that means that the load cell itself is applying a force of 150 Newton's.

Remember, I am drawing a free body diagram of the arm system not of the load cell. So, the force that I am applying on the load cell is not relevant here. And I know because the load cell is not accelerating in the vertical direction or in any direction for that matter. I know that this load cell is perhaps applying a reaction force of 150 Newton on the arm and I am drawing the free body diagram of the arm.

When I remove this contact, I will get this reaction force of 150 Newton and that is happening at a distance of 300 mm from the joint. Let us go back and just check if we have missed out any detail, we are done 150 Newton nothing we are good. So, this kind of problems it is usually more difficult if a reaction force is asked or maybe it is the easier one to solve. But here because I have to find the unknown force may be more useful for me to immediately write out the moment equation.

So, sigma M o = 0 counter clockwise considered positive, I am writing out this this equation. So, the arm is applying a force of 1.5 times 9.81 Newton and that is going to cause a clockwise moment. So, I am going to write minus, why minus? Because this is a clockwise moment minus 150 by 1000 or rather 0.15 is the momentum times 1.5 into 9.81. Remember to include the 9.81 explicitly, otherwise you will forget.

Otherwise, you will assume this as 1.5 Newton's. 1.5 kg is not 1.5 Newton's it has to be multiplied by 9.81 and not 10, it is not 15, 1.5 times the acceleration due to gravity is not 15. It is a number less than 15 perhaps 14.7 remember this. Then this reaction force from the load cell is going to cause a counter clockwise moment. So, plus 150 Newton's this is in Newton's now, I can simply write it as Newton's, the previous one was in kg so, I had to multiply it by 9.81.

150 Newton is the load cell reading and that is given in Newton's to me so, the load cell is also applying the same on my arm. So that is 150 times 300 by 1000 or 0.3. Then what else? Of course, there is this muscle there is this muscle force. And that will cause a clockwise moment, is it not or rather it will be negative minus Fm into the moment arm is only 25 mm, 25 divided by 1000.

Before I write equal to 0 let me check if there is any other force or any other thing that I have missed, have I missed anything? No and then I am writing equal to 0. This is one equation in one variable all I have to do is simplify this equation to solve for Fm. I requested to spend couple of minutes trying to simplify this after some algebra or as they say in advanced textbooks.

They will write this and then in the next step they will write after some algebra, we get Fm is equal to 1711.71 Newton that. Now, does our intuition match our rigorous expectation? That matches. So, I was expecting around 1800, it is about 1700. I am not expecting an exact answer with my back of the envelope calculation. But I want to make sure that the order with which I am working makes sense.

It should not be that my answer is in 100s of Newton's or 10,000s of Newton's. It better be in 1000s of Newton's and it is likely in the vicinity of 1500 or 2000 Newton between 1500 and 2000 is there my answer and that matches. So, now if you get an answer like this it is likely that it is correct then there is no need. And if needed, you can cross check but likely there will be no other answer that will be there and you might be in a position to give the correct answer.

But if you are getting an answer as 171 Newton's this is likely wrong, how do you know this? Because earlier I calculated, the distance between the load cell and the joint is 300 mm and the distance between the muscle and the joint is 25 mm. The answer is approximately twelve times the load cell reading approximately this is my expectation and that is correct.

Of course, there are other things that come into the picture which is why it is not exactly twelve times. Because there is also the mass of the arm and there are other things that come into the picture. So, we have not included that in our back of the envelope computation. So, in this class, we saw a simple problem involving the elbow joint solving for static equilibrium of the elbow joint.

We will see some more simple problems in statics of the elbow joint in the future videos. Thank you very much for your attention.