Mechanics of Human Movement
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Lecture – 08
Principles of Statics

Now, that we have looked at the structure of the musculoskeletal system and we know about how some of the components operate, let us move on to applying the Principles of Statics first. So, we are going to apply the principles of mechanics in this course.

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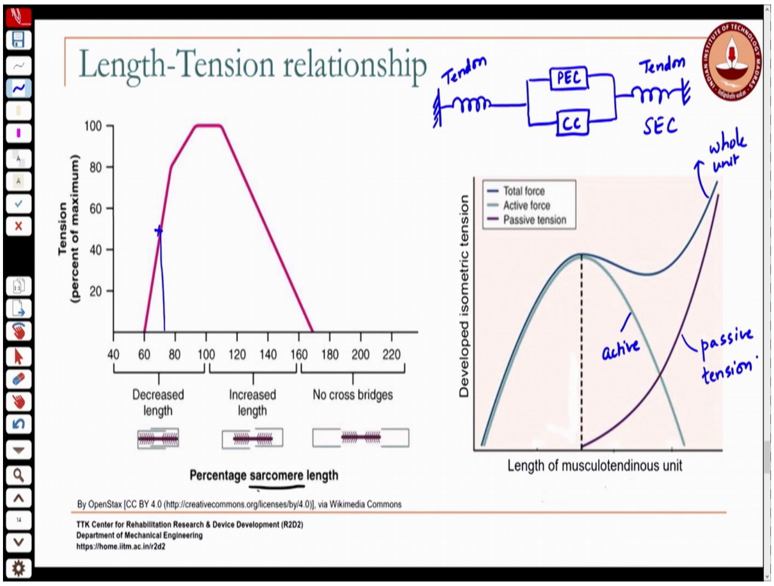

We will start off with principles of statics applied to the human body.

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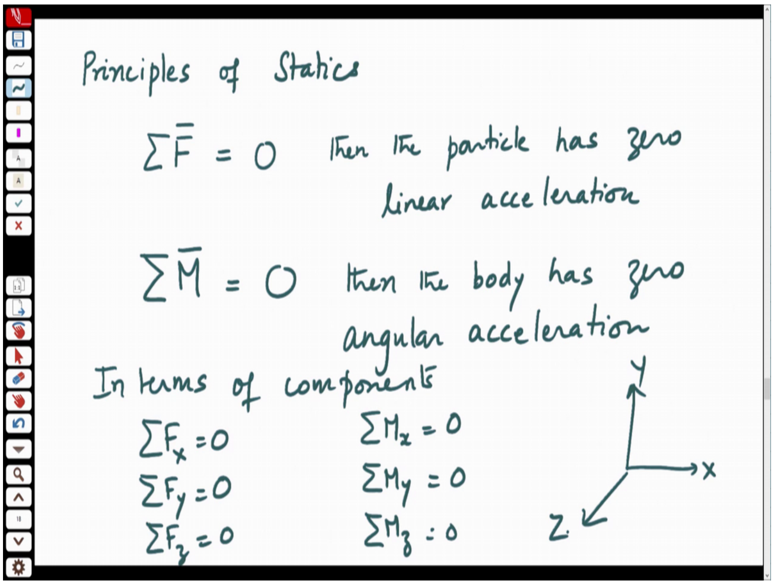

So, we all know that the condition so, if there are a bunch of forces acting on a body then we know that if sigma of F equals 0, then the part the particle or the body has 0 linear acceleration and for a rigid body if the sum of the moments about any point on that any point is equal to 0, then the body has 0 angular acceleration, a particle does not you cannot apply a torque about a particle. So, the body has 0 angular acceleration angular acceleration does not have any meaning for a particle, you have you can talk about angular acceleration angular velocity only for a rigid body right.

So, in terms of components typically we use a Cartesian coordinate system. So, in terms of components you would have sigma F x equal to 0, sigma F y equal to 0, sigma F z equal to 0 and similarly for the moments M x equal to 0, M y equal to 0, M z equal to 0 this is for a standard Cartesian coordinate system.

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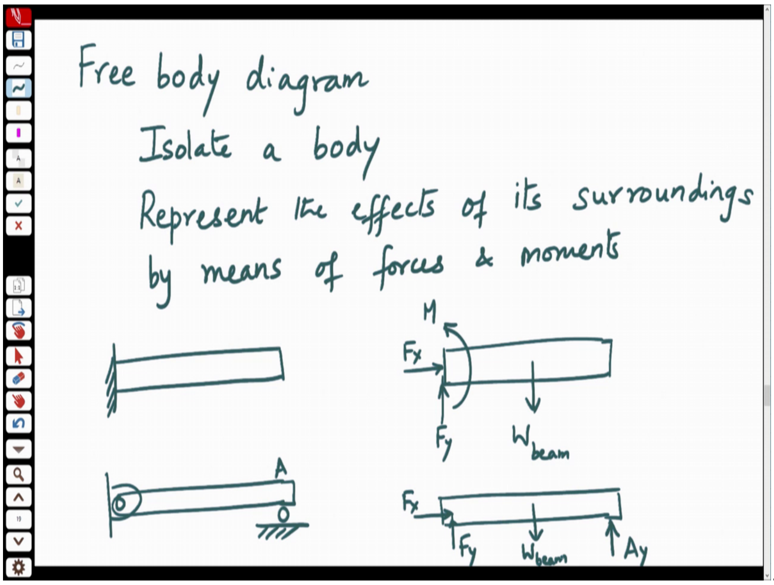

And then we will also you use free body diagrams as you should all be familiar with this concept, you basically isolate a body and then represent the effect of it is surroundings on it. So, you isolate the body of interest and you represent the effects of it is surroundings by means of forces and moments example if you have a beam sorry that is fixed at one end.

Now, if I isolate this beam let us say it has some weight. So, you could say that the weight of the beam acts at it is centroid. So, that is one effect of the external environment on it and then because of the fixed support the fixed support is equivalent.

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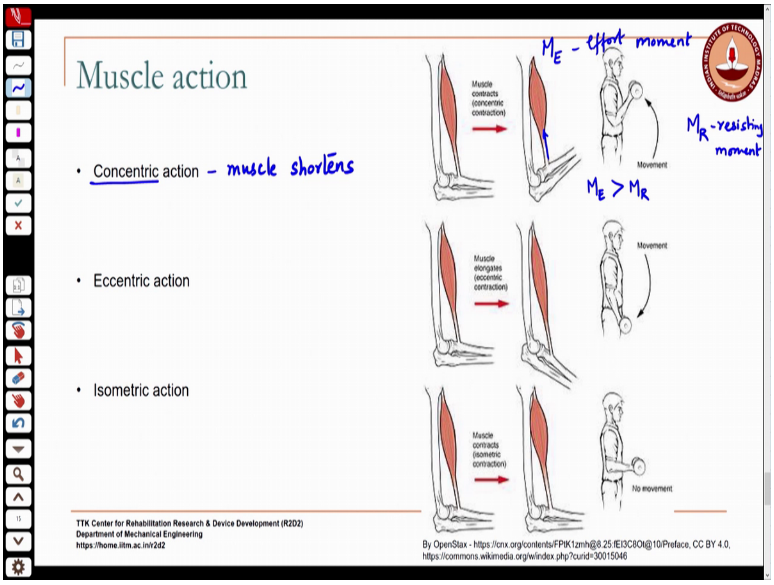

So, let us as a 2 D equivalent F x F y being applied to the beam to prevent translation of the beam in both directions some moment that is applied at the substitution of the beam and that support if you had a pinned beep which was then say supported on a roller then you look at if I isolate the beam now what does the roller do, the roller allows motion along the x motion along the y so; that means, there is a force at this. So, let us call this point A there is a force in the y direction which is being applied by the support to prevent the movement of that and then if you look at the pin joint the pin essentially prevents x and y it will allow rotation. So, it does not provide a resisting moment.

So, this is how we draw free body diagrams right we isolate and also in this case again the weight of the beam is an x represent all the forces and moments everything the interaction of the beam with it is surroundings in terms of forces and moments that is what we do in free body diagrams and. So, you show and then you use the principles of statics in this case principles of statics, but if it is a dynamics problem you would use the principles of dynamics to basically statics is basically just a special case of dynamics where your accelerations are 0 linear and angular accelerations are 0 you would use those equations then to saw unknowns.

So, in when we draw a free body diagram if we do not know the directions of the unknown forces you either express it in terms of the components own direction be your x and y or whatever else that you take as a known direction 2 orthogonal components on the loading of the beam whatever unknown forces the signs get determined based on the overall equilibrium. So, you do not have to worry about the signs of the forces or moments you assume something and then if what you get is negative it means the force is directed or the moment is directed opposite to what you assumed.

So, these are some basic principles that you are all familiar with and we have seen that we have looked at the various joints in the skeletal system we have also looked at the various muscles and how they are go along and we also know that muscles can only apply tension. So, muscles are like cables that can only apply tension to the body that they act on.

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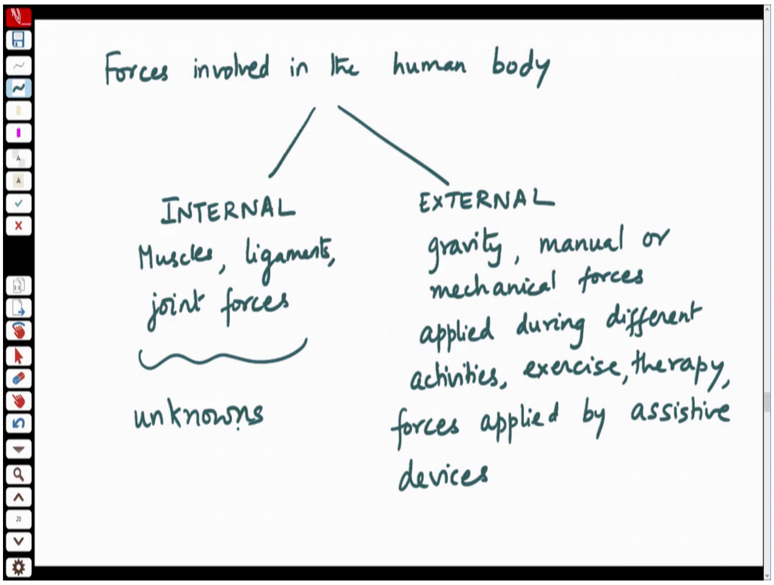

So, if you look this in the human body come across you have what are internal forces and you have external, examples of internal forces would be forces due to muscles, the ligaments, points at the joints, the joint forces, these are all internal forces within the human body and then the external forces the most common one that we will encounter is gravity. Then you could have manual or mechanical forces that are applied external forces applied you know, it could be during different activities exercise stretching etcetera therapy these are all have devices forces applied by external devices like assistive devices.

So, if you see somebody wearing a braces that are applied because of the interaction of the body with the external device. In general because they cannot be the internal forces are your unknowns in general these forces are unknowns because them because sometimes they do put transducers inside they can actually surgically insert to measure internal forces etcetera, but in general we try to estimate the internal forces through modeling because they cannot they are not easily measurable directly.

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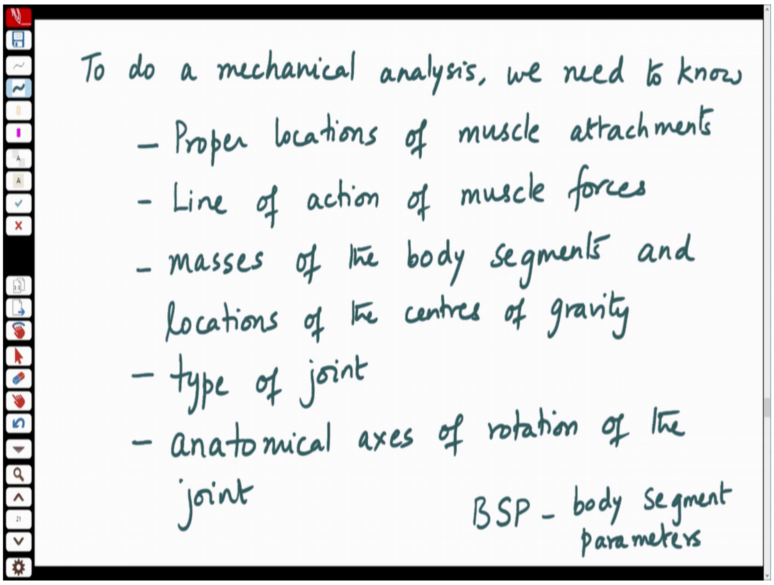

So, there are some things that we need to know when we do this analysis build a model or to do a mechanical analysis to know the following we need to have some idea of the proper locations of muscle attachments because the muscles are the primary actuators in the system, when we are applying and in on any part of the skeletal system we need to know we also need to know the direction in which the muscle is applying the force. So, this is where some knowledge of anatomy comes in you need to know what the muscle what is going to be the muscle that is going to cause this movement or keep it stable and you need to know how it is going to act.

So, the line of action of the muscle forces is also something we need to know, we need to know these parameters, we need to know the masses of the body segments and the locations of their c d s because again the weight is an external force that you need to apply it and because of the irregular shape you cannot always assume that the mass is going to be at the centroid of the body because most of these bones are irregularly shaped. So, we need to know the masses of the body segments and where their c d s are located, we also need to know what kind of a joint.

So, the type of joint that we are dealing with so, that you know what is it like we talked about the beam that is fixed versus a pinned you know what motions are allowed by the joint. So, that you know to apply the appropriate reaction forces and moments at the joint. So, you need to know the type of joint that you are looking at and you need to know the axes of rotation, it could be more than one axes of rotation that you are considering. So, where is the joint axes because you again with the bones you have 2 irregularly shaped bodies that are moving with respect to each other it is not your mechanical hinge joint for instance where there is no question where your axes of rotation is.

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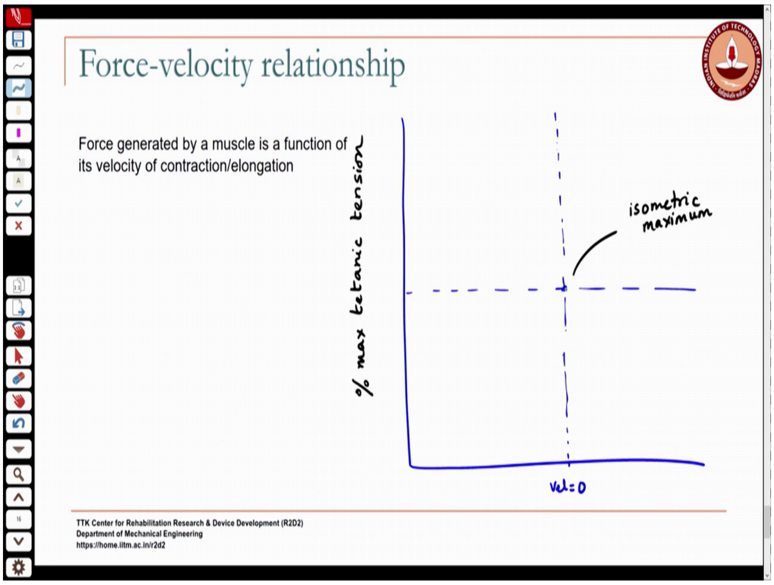

So, skeletal system some of these axes actually move as the segment the for the posture that you are considering or for the movement that you are considering, what would be the appropriate anatomical axes that you need to consider at a particular configuration.

So, these this is information that you need to know in order to do proceed with the mechanical analysis. So, these are all parameters that are, parameters are quantities that you would know these are not unknowns you know these are you may have they are unknown problem, because the mass you know if you are considering a particular segment that has a specific mark mass for the person that you are reactivity the person is doing right.

They call body segment parameters like the masses and so, these are some things that we need to know. So, these are typically known as BSP and of course, when we go to the dynamic problems we will also need to know the moments of inertia of these segments. So, these are called body segment parameters and then we will talk about where we can obtain this data.

So, typically the unknown joints and usually we will make some assumptions to simplify our analysis because if you look at the body about any joint you have a variety of interactions happening, you have multiple muscles that act about that joint, then you have other soft tissue, you know like you have ligaments you have. So, we make certain assumptions when we do our analysis in order to simplify our analysis. So, like I said a model is only an approximation of the actual system.

The more refined your model the more things you include in the model the complexity increases you have a chance of you have a better chance of approximating the real situation in a more accurate manner. Although that is not always true because the more you know if you may also have to make more approximations as you increase the number of unknowns in your model. So, first for some of the things that we do in this course we will make fairly will have fairly simple models and these are some of the assumptions we will make for we will stick to a planar 2 D analysis.

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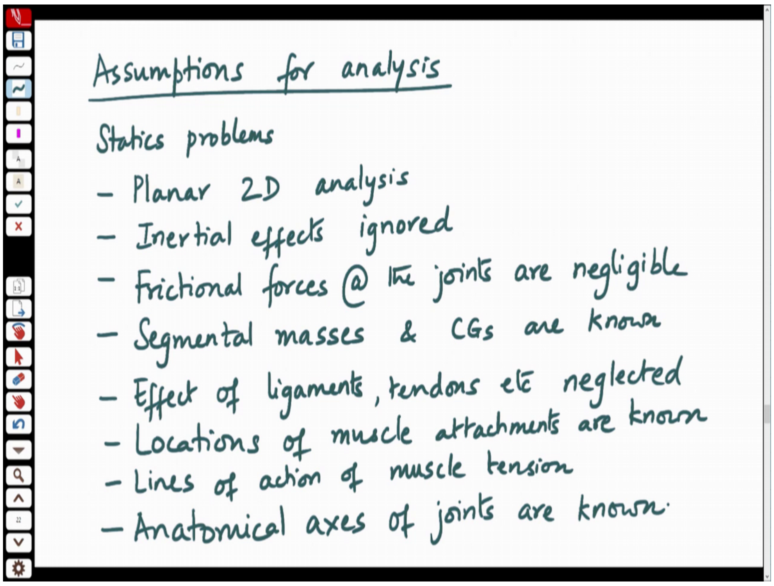

So, we will either look at will so, we will say well we are restricting our analysis to what is happening in a single plane and for the statics problems we are basically ignoring inertial effects. We assume that the frictional forces at the joints are negligible, we know the segmental, we know all the parameters that we need to, we neglect the effect of ligaments, tendons juice, the locations of the muscle attachments are locations of we know, the lines of action of muscle tension and we know the anatomical axes. In most cases also we will make the assumption that only one muscle is acting for that particular case that we are considered because if you go to a 2 D analysis.

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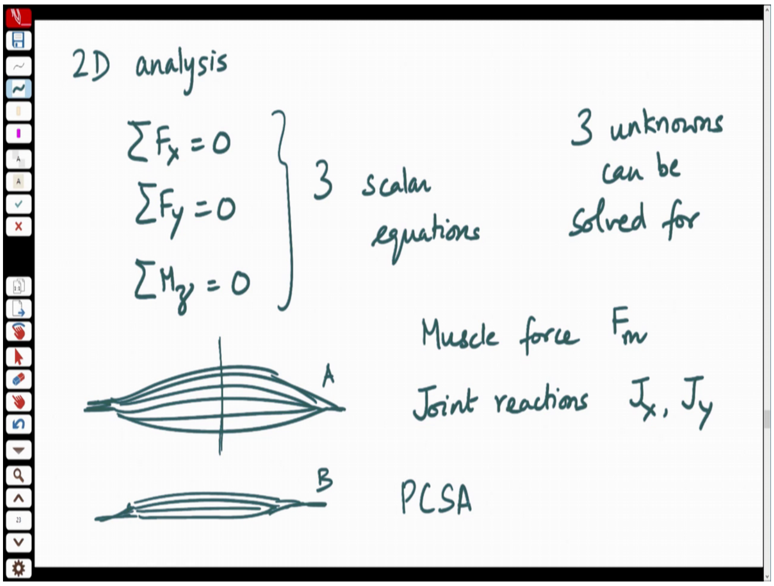

How many equations do you have, in the 2 d analysis you will have basically 3 equations and sigma of M about some point is perpendicular to the plane. So, you have 3 scalar equations and therefore, you can only solve for 3 unknowns 3 unknowns can be solved for solved for are the muscle force and we will solve for the joint reaction forces the joint reactions which will be some J x and J y. So, these are typically because these are the once you cannot direct the kind of assumptions we make there because one of the things that you know about muscles is the reduction is proportional to length.

Student: Velocity.

Student: Velocity.

Um now we are looking at statics problems we are looking at isometric forces in most cases.

Student: (Refer Time: 22:54).

Ah that is at the, if you look at you know one muscle.

Student: (Refer Time: 23:08).

One muscle like this and one muscle like this let us say they are the same length same resting length suppose they say they are the same which do you think will produce more force A or B why do you say that.

Student: Was much the.

Student: The number of

The cross sectional area right the cross sectional area the muscle bellies cross sectional area is something that tells you how much force they muscle is capable of producing. So, a muscle with the greater physiological cross section area can produce more force. So, sometimes when we use multiple muscle we will make an assumption based on the cross sectional areas of the muscle to say this muscle may contribute you know something proportional to it is cross sectional area.

So, we will.

Student: Directly translate to the number of.

Sorry.

Student: (Refer Time: 24:26) direct (Refer Time: 24:28) number for the.

Yeah it translate, but you cannot see what can you measure , for a muscle the cross sectional area can be measured you cannot go to the sarcomere level 2 properties that , relaxes does not change, but we will come to that when we do the. So, in a sense these are idealized problem know idealized models for the body, that we will use, but we will still be able to gain some insights into what is happening and maybe a related to some of the things that we see in our day to day life that is sort of the purpose of doing such an analysis.

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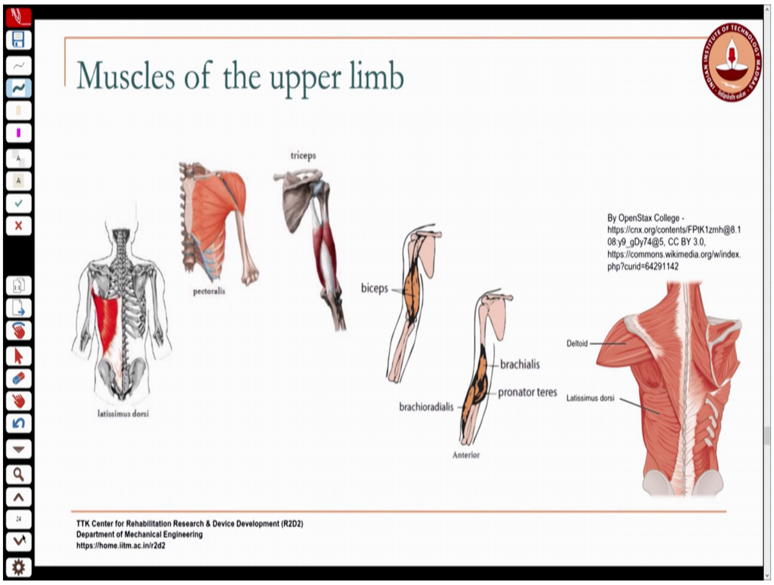

Okay before we go to that.

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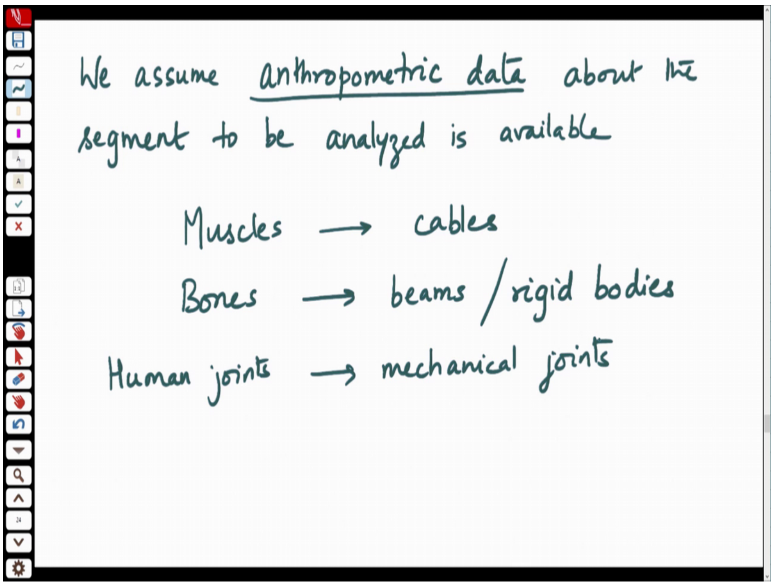

So, we assume that anthropometric data, welcome to what that is about the segment to be analyzed is available. So, based on measurements taken on calibers and statistical analysis of those what we were talking about the mass of body segments, mass of different bones location of their CG moments of inertia about the CG, these are all data that have been compiled for various populations, but mainly Caucasian populations.

So, we will NASA for instance has a huge database of this kind of anthropometric data. So, this anthropometric data is very essential for any kind of biomechanical analysis because you need to know and a lot of a height h you can say that the forearm is a certain fraction of that height h. So, this is so, there are tables available of this anthropometric data which is what we will use for some of this analysis.

So, this is where you get those body segment parameters for this for this analysis and we also make the assumption that you know being mechanical and engineers we say muscles function like cables they can only apply tension, bones when we look at the analysis we will treat them as either beams or rigid bodies and the human joints we will correlate to mechanical joints that we are familiar with. So, muscles, ligaments etcetera would be like cables and if you look at.

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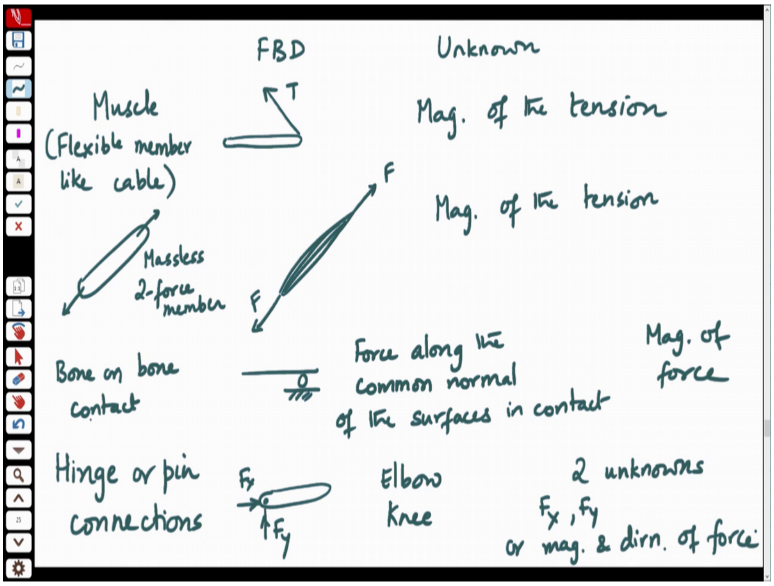

So, in the free body diagram if you had a muscle or tendon or a ligament that would be expressed in terms of a tension if I have a body the action of the muscle on the body would essentially be a tension and the only unknown, would be the magnitude of that tension right because I will know this from the anatomical data I know at what angle that muscle is acting on that particular member.

Student: The muscle will provide a tension pull.

Yes muscles can only.

Student: Compress.

Muscles can only pull, muscles can only pull then again if you know that something is so, muscle is basically a flexible member like a cable. Then if you have a 2 force member again if a member is only subjected to 2 forces and if it is massless you have a massless 2 force member what do you know about the forces, they will be equal and opposite they will be along the line of that diagram you could assume that you can always assume a direction, but it would be basically along the member, then of course, rollers simple support so, the equivalent would be if you have bone on bone contact.

Student: Mam.

Yes.

Student: Already bring to this muscles to member also the muscles.

So, we would the muscle would be that is right so, you basically say that and the unknown would be the magnitude of the force because we are not really taking into account the mass of the muscle when we do this analysis. So, we say whatever tension is developed at one end is the same tension that is developed at the other end.

In some cases bone on bone contact may be modelled as a roller so, you say that the forces normal to the surfaces of contact let me put it as forces along the common normal in contact and so, again if you know the direction of the force only the magnitude of the force will be the unknown, then the hinge connections that we model as actions now, we talked about the knee, knee joint we talked about the elbow which are akin to hinge joints.

There you will have 2 unknowns F x and F y because the hinge prevents movement in 2 directions , now you know that in the actual structure with the condyloid joints you are like a pure hinge, but it is the surrounding. So, you have examples or the elbow or the knee and basically the magnitude. So, you can either think of it as 2 unknowns in terms of the magnitude and direction of the force or 2 components so, you have 2 unknowns or magnitude and direction of force yeah.

Student: (Refer Time: 35:14) where is some hinge order hindrance some joints will be there.

So, in some joints you could say that at that instant so, you have something rolls that at that particular instant. So, it is like this I have a fairly flat surface and the other joint is moving like that I could also treat this as a contact similar to a roller.

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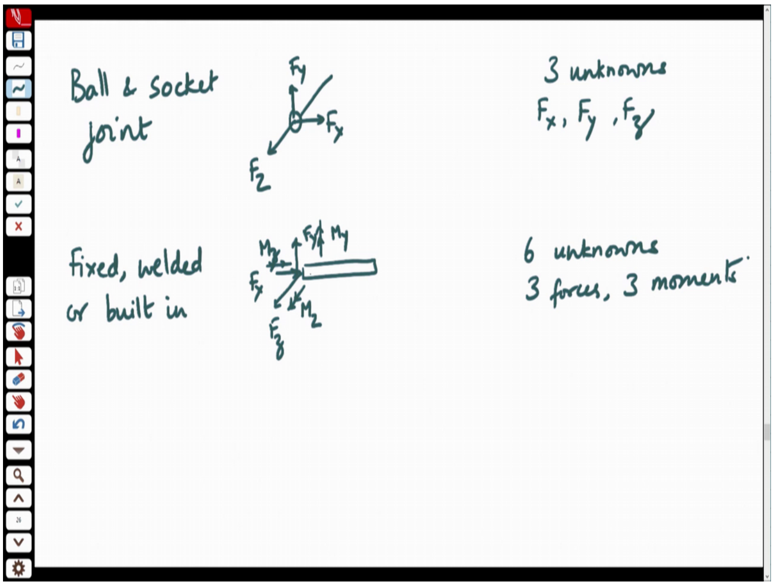

Then you have the ball and socket, joint like your hip or your shoulder and in that basically what is the situation you have F x, F y and F z movement is prevented linear movement is prevented. So, force resistive force prevents a linear movement right the case of the ball and socket it allows it does not support moments in all 3 planes so, you have no resisting moment.

Student: Mam we are talking about only 2 D.

Will yeah this is just for completeness you know this is how we map it to what we know in mechanics.

Student: Mam (Refer Time: 36:52) bone to bone contact is it really bone to bone contact or there is some fluid or soft tissue in between.

There will be yeah except in cases where there is degeneration in the joint which is then you know like after osteoarthritis or something like that then if there is direct bone it is very painful, direct bone to bone trying that becomes very painful most of the joints the movable joints are synovial joints, which have like we talked about the capsule and they have synovial fluid and all that acts to distribute the forces and when we talk about a net force at that joint we are talking about the resultant of that distributed force because that is what we can measure we cannot really measure the actual force distribution across the joint so, you will have 3 unknowns here F x, F y and F z.

So, if you look at joints which are more or less fixed like the joints in your skull right the fibrous joints where there is little or basically no movement, then that is equivalent to the fixed or welded or built in, similar to your beam or the join between the tibia and the fibula where there is no at the proximal end tibia and fibula you there is practically no movement there if you were to model something like that and if you were interested in that then you would use a and you would also have 3 moments.

So, I will mark it as with the double arrows, but right hand roll we are talking about so, at the moment is like this then M z is mark like that. So, you have 6 unknowns here 3 forces, 3 moment so, this is basically just a quick review of your statics you know how you represent different joints how you represent different kinds of members.