Mechanics of Human Movement
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Lecture – 40
Characteristics of Normal Gait Part I

As I mentioned in the last class, this picture of the gait cycle is something that you should really become familiar with ok.

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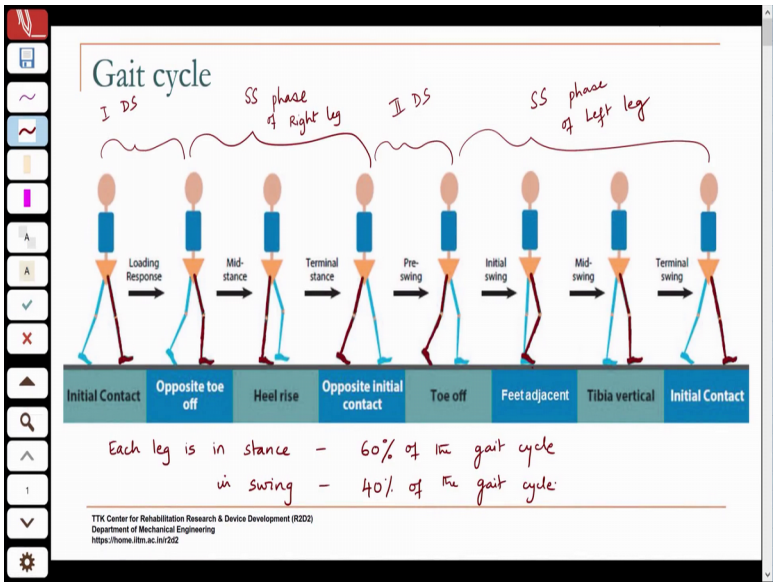

So, just as a quick recap: the key events in the gait cycle. One day cycle is from say initial contact to initial contact of the same leg, then you have initial contact the. So, the events various events are initial contact the opposite leg toes off ok, then slowly the stance leg the heel rises in the stance leg and then, the opposite leg the other leg contacts the ground because that has completed its swing. Then you have toe off of this leg the leg of interest and then as it swinging through the two feet are adjacent and after that you have the tibia becomes vertical and the legs swings through to attain the posture for the next contact with the ground.

So, heel contact or the initial contact of one leg to initial contact of the same leg constitutes one gait cycle and then we identified the phases. So, initial contact is an event, but that is an important event to indicate the start of gait. And loading response is the phase between initial contact and opposite toe off; then opposite toe off to heel rise,

then only one leg is in contact with the ground now. Because once the opposite leg lifts off the ground, you have only one leg; the brown leg is your stance leg single support leg and that first attains mid stance when the body kind of roles over that and then from heel rise to opposite initial contacts. So, this phase is your single support phase where only the brown leg is supporting the entire body weight. And then say this here is your first double support this is single support of in this case right leg.

Then you have the second double support which is mapped by the stance leg going into pre swing going into the going through the pre swing phase from opposite initial contact to toe off of this leg. And then when this leg is an swing, the leg of interest the brown leg that is the time that the other leg is in single support phase of the left leg ok. So, two double supports, two single supports each leg goes through one single support and two double supports. So, it is in stance; so, each leg is in stance for about 60 percent of the gait cycle and in swing for 40 percent of the gait cycle ok.

So, this setup coordinated movements; we find that among human beings, there is a fairly definite pattern in which the movements at the joints occur causing this. So, even though you know you can tell a person you can recognize a person by that gait you know, you can see a person far away and I can say I know who that is by that gait. So, there are enough distinctions you know among human beings where you can even use it for recognizing a person, but at the same time there are some broad patterns which are uniform across you know uniform in the way that we walk. And that is the reason we are able to actually study this in this manner because, you will see that these patterns are repetitive and these patterns lie in a fairly narrowband for most people especially in the sagittal plane.

You see much more difference in the frontal plane motions because, those motions are also small and that sort of characterizes some of their differences. But in the sagittal plane if you look at the motions of the different at about the different joints there is a fairly narrowband in which are especially if you are looking at like an age range of say 25 to 40 you know adult adulthood; if you look at that you will see that the patterns are quite similar.

Of course a lot of the data that is available is mainly for Caucasian populations ok. Hopefully one of the things are lab is also trying to do is we want to collect data for say

the Indian population and look at how it fits in with the data that is available. But there is reason to believe that in most cases the patterns will be more or less the same so, that is the. So, these events and these phases are recognizable across the board. So, in most cases of what is termed normal walking you will be able to identify this kind of a pattern.

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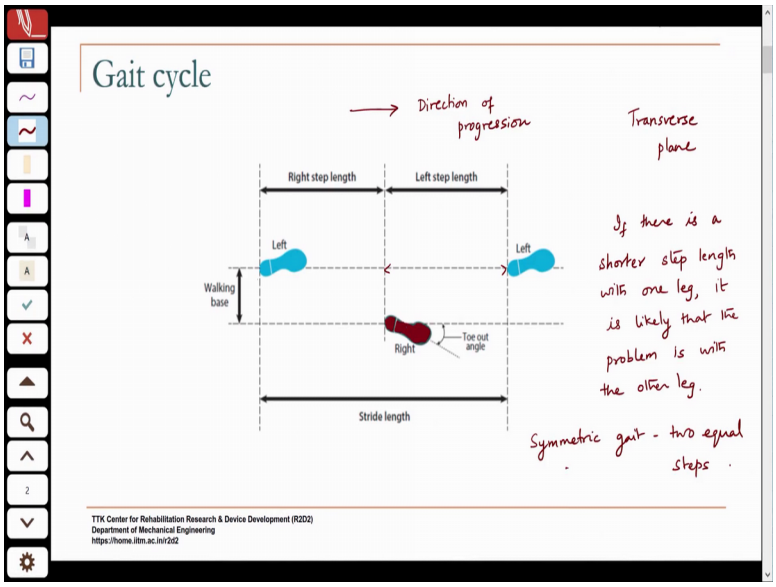

So, if you look at the view from the, what plane is this? View from.

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Transverse plane; so, if you look at that view from the transverse plane, you will see that when we walk we actually have a slight toe out angle of the foot is called the toe out angle. So, you have this direction of progression and your feet are structured in such a way that there is a slight toe out angle. And, then if you look at the walking base, you know we do not walk one foot in front of the other that is what somebody would do where walking on a tightrope right. They would place one foot directly in front of the other.

But in general we have a finite walking base we and this base can again vary with the way people you know people walk with different between men and women you can say differences in the walking base. You can see differences as you age you can see differences between children and adults etcetera. So, the walking base is this distance that you see here. So, the right step length is the distance that the right leg swings

through in front of the left foot. So, from here to here it will touches right swings through and touches the ground that distance is the right step length ok. So, this leg is in swings forward and plants on the ground here and this distance then is the right step length.

Similarly, the left step length so, you have that this is one gait cycle right left heel contact to left heel contact; so, that is once stride. So, that length is one stride length and then you have the left step length is the distance between where the right leg the heel of the right leg touches the ground to where the heel of the left leg now touches the ground; swings forward how much the left legs swings forward. So, in normal gait these two step lengths are equal. So, we call normal gait as symmetric. In other kinds of gait we will see that this may not normally be the case ok. So, you may have left step length that is shorter than the right step length or vice versa.

An example would be say you are wearing an artificial leg ok, you have a prosthesis. So, you want to spend less time on the prosthesis; so, you would swing forward quickly with your good leg. And so, the step length of the good leg would actually be shorter because you are you are trying to quickly get back on to your good leg, you do not want to let it swing for too long because you do not want to you are not as sure about spending time on your prosthetic leg ok.

So, that is so, if there is a shorter step length it is likely that the problem is with the other leg. So, if the right step length is shorter it is likely that the problem is with the left leg. We will see that when we come to the pathological gait, but something to remember. So, if there is with one leg, it is likely that the problem is with the other leg ok. Symmetric or normal gait has two equal steps.

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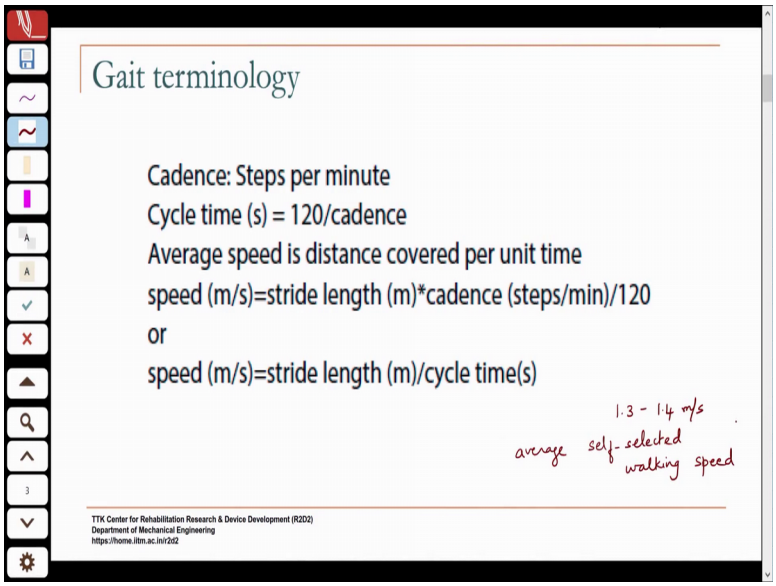

Now, some more terminology with respect to gait; we typically talk about cadence. Cadence is the number of steps per minute that you take. So, steps per minute is cadence. The cycle time is the time for one gait cycle right so, that is why you have a 120 here, 60 into 2. This is cycle time is measured in seconds cadence is per minute. So, for 60 seconds since you are talking about the cycle you are talking about two steps ok. So, that is why the 120 comes there; 120 divided by cadence is your cycle time and the average speed is the distance covered per unit time as we all know. So, the three are related.

You can relate the speed to the stride length and the cycle time. It is basically just a stride length divided by in meter per second is stride length divided by cycle time. And the we all tend to walk at a self selected walking speed and that average of that speed is about 1.3to 1.4 meter per second. That is considered most people's self selected walking speed; this is the average self selected.

So, most gait studies would ask the person to walk at their self selected walking speed and it is been found that around the speed is when you at minimizing your energy cost of walking. So, based on that we walk we normally walk self at higher and lower speeds, you actually tend to consume more energy. So, this is the self selected walking speed that we usually adopt.

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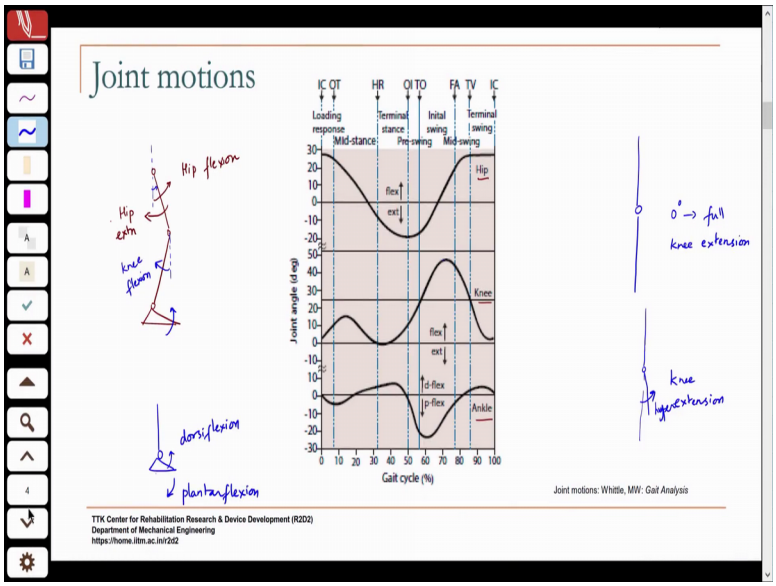

So, we will now look at the motions about the various joints that happened during this gait cycle. So, the major joints that we are looking at are the hip, the knee and the ankle joints of the lower limb; the hip, the knee and the ankle. And most of this data is usually expressed in terms of percentage of gait cycle. So, you say the gait cycle; one gait cycle is a 100 percent, then you divide that up and you look at so. So these are the various events you have IC initial contact opposite toe off, heel rise, opposite initial contact, toe off, feet adjacent, tibia vertical and initial contact corresponding to the other figure that we have and then flexion extension.

So, if you have the hip right, you are talking about hip flexion in this direction extension in this direction. And most cases; so here for example, we are talking about angles from say the vertical. So, if you have that would be your hip flexion angle. So, you can see that the hip the range of motion at the hip required for walking is about 30 degrees of flexion to about 30 degrees of extension. So, 30 degrees in this direction, 20 degrees from the vertical in that direction is the range of motion at the hip.

At the knee, you have knee flexion in this direction ok. So, from the vertical you have; so, if you are standing straight, your knee angle is considered to be 0 degrees [noise.] 0 degrees is full knee extension and if it goes beyond; so, if it goes the other way, it is slightly then that is your knee extension or hyperextension. Actually because that is not 0 is considered the normal state of the extended weight. And then for the ankle you have if

this is the 0 the neutral position; so, if you have the neutral position of the ankle like this, then this is your dorsiflexion.

So, this is measured from the horizontal base angle and this is your plantar flexion. The neutral position is with the tibia vertical and the foot flat that is your 0 angle ok. So, the knee you see that you have a maximum of sometimes 50 or 60 degrees of flexion your, you have a large range of motion at the knee and that happens during swing that happens during swing. So, we will look at each of the different stages of gait and look at the motions.

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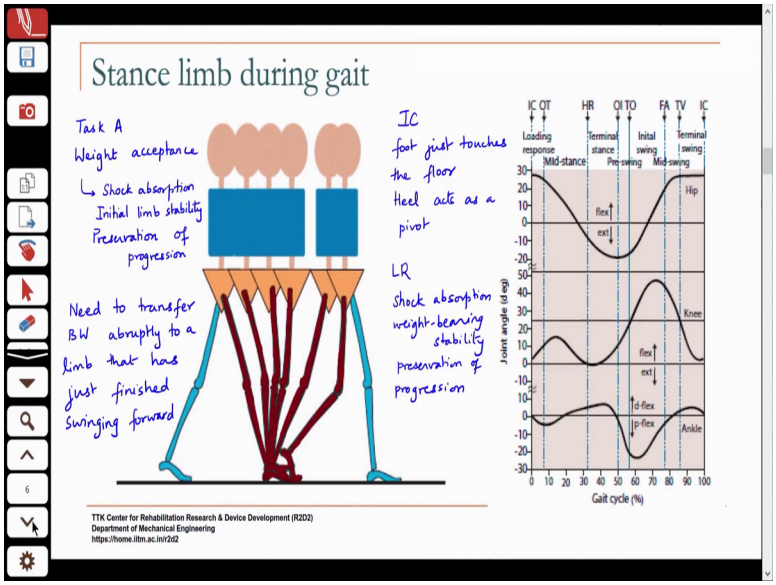

So, if you look at this stance limb. So, this is how stands happens. So, you have heeled contact, you saw them separately initially right. So, during stance, what happens? The foot contacts the ground, goes down flat and then you know it stays there till it in space it stays at that point. You know in the previous slide when we saw the different ones, it look like it is, but in stance actually the foot stays in one location in the stance. You look at the stance limb the foot stays in one location and so, the entire stance phase happens with the foot in that particular location.

And really the forward progression that is happening is of the limbs above the foot limbs above the foot and the rest of the body is moving forward. Basically pivoting about this fixed foot and of course, then towards end of stance the foot also starts lifting off the ground. So, if you look at the stance phase, then you have the task is; what was the first

task of stance? If you remember when it first contacts the ground, it has to accept the weight. The first task is weight acceptance and this weight acceptance implies that you have to have some kind of shock absorption.

Because, you have a moving limb that is being suddenly stopped by the ground contacting the ground; so, there is an impact at the point of contact. So, the limb has to have some mechanism for shock absorption; so, that all those loads do not done. So, you know if you are walking with hard shoes or a hard floor you can feel, you can feel the shock, you can feel the shock even or if you are walking fast because now you have a fast moving swinging limb suddenly stopped by the ground.

So, you feel the shock when you. So, shock absorption is an important function that is needed during this weight acceptance. Then of course, you need to have stability. You have an articulated set of limbs that are making contact with the ground. If so now, you are applying a load to two bars that are connected by say a joint right, for them to not buckle. When I say buckle here I mean for them to not collapse.

So, buckling in is not the same as the buckling that we use when we talk about columns is a difference in the; when we talk about knee buckling in biomechanics, we are talking about the knee allowing the body to collapse. So, maintaining when you when you applying load on that limb ok, it is necessary to maintain that stability of the limb. So, that the knee does not buckle and you do not fall down and of course, because the function of walking is to progress forward you have to preserve that progression even when the foot is on the ground. You cannot just stop there ok; you have to preserve the progressions.

So, these are the functional requirements when you are talking about weight acceptance. You are talking about some shock absorption that needs to be there some initial this limb has to be stable enough to accept the weight and it also has to continue moving forward. So, the body has to continue moving forward while it is in the stance phase as well because the whole purpose of this weight acceptance is you are trying to the need is to transfer the body weight abruptly to a limb that has just finished swinging forward.

And also it has an unstable alignment ok. You have it is a jointed limb and you also you will also find that the way the ground reaction force acts will be to actually bend the limb ok; to bend the shank with the so, to make the knee buckle. So, maintaining the stability

becomes a very key. So, of course, the phase the in initial contact what happens is the foot just touches the floor and you have what is known as will we will look at that the body now say it (Refer Time: 26:12) about the heel.

The foot touches the floor and now that is the pivot about which you are going to have motion. So, heel acts as a pivot. And in the loading response phase you basically have, again you need to have some shock absorption because more of the body weight is being transferred to the limb and weight bearing stability because it is going to start assuming full responsibility for the weight bearing. At the end of loading response the other limb is going to lift off the ground. You have opposite toe off which this has to and of course, again preservation of progression. So, functionally this is what the limb has to accomplish in the initial part of stance.

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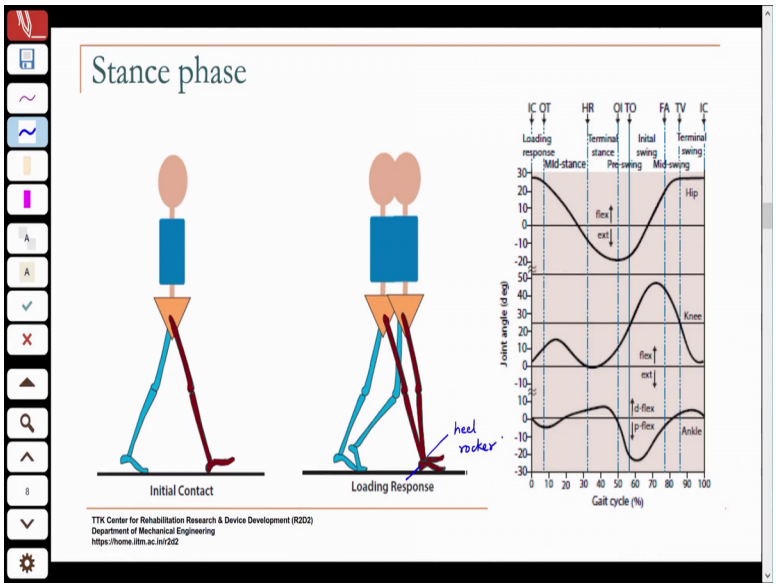

So, this is initial contact, you can see from initial contact. You can see that the limb pivots about an axis passing through the heel ok. So, this is called a heel rocker. Initially during loading response the foot pivots about the heel and then comes down flat on the ground. So, from heel contact foot flat; this is your pivot the heel you have the foot pivoting about the heel.

So, the reason from a single point of contact or a small area, now you have the entire foot making contact with the ground which is necessary for the weight acceptance because

you are trying to get that base of support to start loading the limb further. So, this is the initial stance phase.

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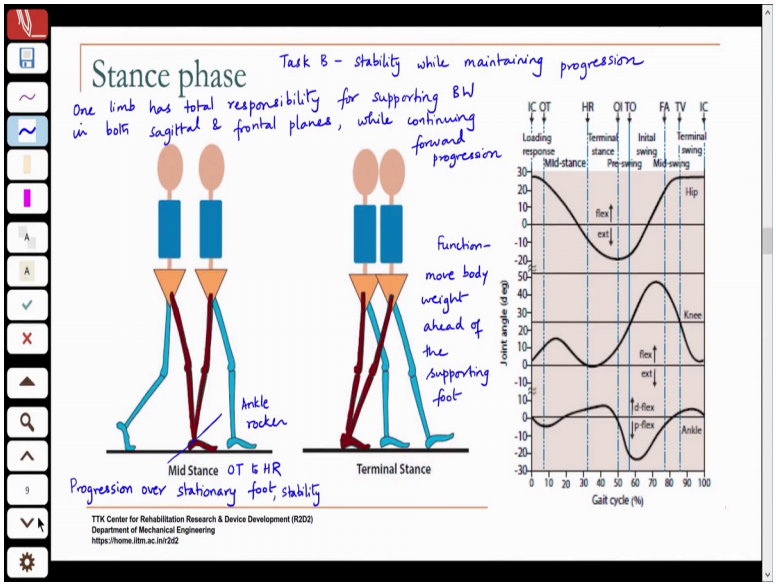

Then if you look at mid stance what happens is here, now the foot is flat on the ground and the ankle starts functioning as the pivot. Initially you had the heel the foot pivoted about the heel and landed flat on the ground. Now in mid stance, the upper portion of the limb limbs start pivoting about the ankle.

The tibia starts pivoting about the ankle to move forward because the entire foot is now flat on the ground. And the function is so, in this essentially one limb has the entire responsibility for supporting the body weight in both place in both the sagittal and the frontal planes because the other limb is now of the ground and frontal planes. So, stability is a very important aspect of this phase and you have to continue the progression; while continuing forward progression because all these events all. These phases are happening with continued forward progression.

There is no going back and forth let me do this compare then there is a continuous forward progression happening as you walk. So, in mid stance when is mid stance opposite toe off to heel rise ok; opposite toe off to heel rise. When you have that, you have progression over the stationary foot and of course, you have to maintain stability of the entire system. So, that and stability are the functions in mid stance. In terminal stance, now the body has moved over. So, if you see here after mid stance in terminal

stance, the body weight has actually moved ahead of the supporting foot. You see the last two here the bodyweight has now moved the body weight is now ahead of the supporting foot. Initially it was behind the supporting foot goes over the supporting foot in mid stance and now it is ahead of the supporting foot in terminal stance and you have. So, you are basically maintaining the forward progression.

So, the function of this terminal stance is move the body weight ahead of the supporting foot that is the function in. So, this in the single support phase stability while maintaining progression is the key task this is the key task progression.

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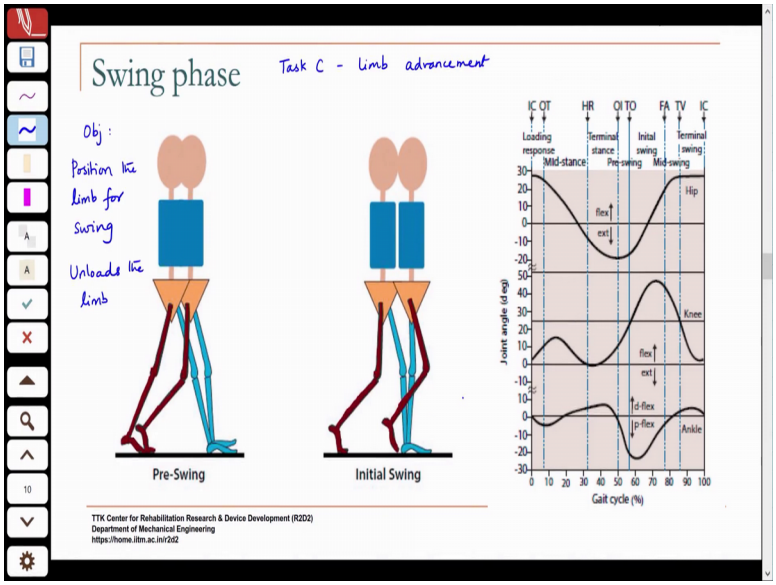

Pre swing gets you into the swing phase ok. Now by this time when we are in the pre swing period we are again in the other double support period. So, stability wise you are ok. What you are doing now is transferring to the other foot. The other foot has made contact with the ground and here that is basically entering stance phase. So, it is going through what this leg went through just before this, ok. So, in this essentially the task in swing is to advance the limb in preparation for the next support phase.

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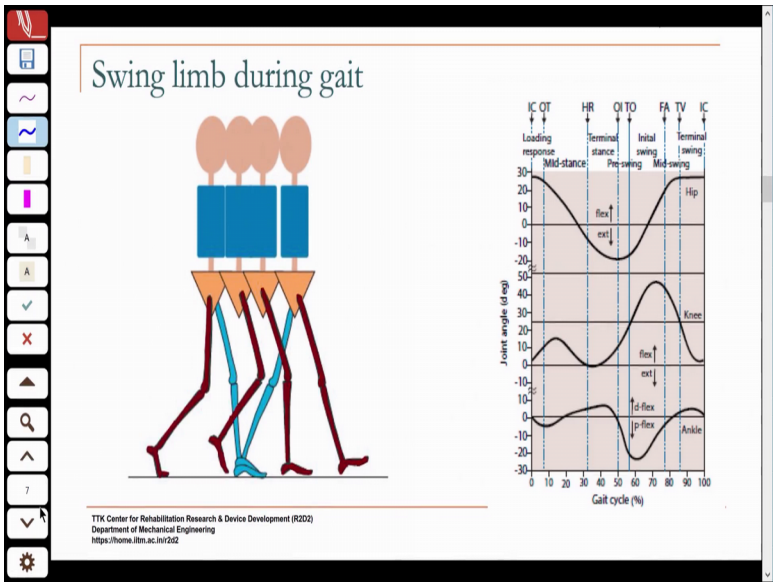

So, if you see here this has to; if you look at this one which shows the entire swing limb you see that once the foot lifts off the ground, it is swings up and then swings forward in preparation for the next stance phase. So, our once it comes here, then it is going to again make contact with the ground and the cycle repeats; so, each leg goes through this alternating task. It supports then moves forward; supports moves forward and the two legs take turns right the right leg support, then the left leg assumes the support they starts moving forward. Again that that leg then starts moving forward. So, you have this alternating pattern between the two legs.

So, in the pre swing phase the objective is to position the limb for swing. So, get ready for swinging forward and this is also called weight release because right now you in order to be able to lift that leg, you have to unload this limb. So, this is it basically unloads the limb in this phase because the other limb is now accepting the weight. So, you have to unload this limb, then it swings forward gravity asses it in the swing phase.

So, initially it lifts off, then comes to rest and starts swinging forward like a pendulum ok. But there is one when you are in the swing phase there are some important objectives. So, this is unloading it starts moving forward such that the two feet are adjacent.

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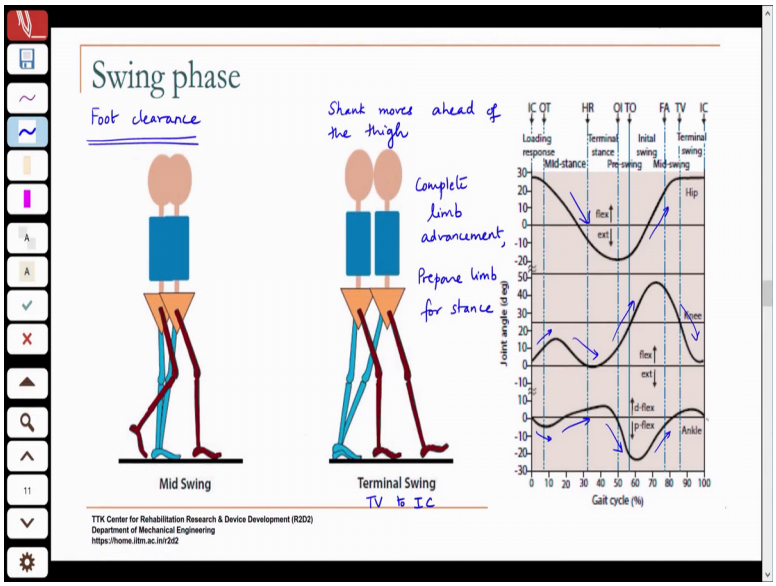

Then here it is very important in swing that there is foot clearance. If the swing does not happen properly, what is going to happen? You are going to stumble. The swing has to happen in a clean manner such that the foot clears the ground. No part of the foot touches the ground while it is swinging that is why if there is a sudden obstacle sometimes. You know you are in rhythm of walking and if you do not notice the obstacle what happens? Your and it tries to do it in a very efficient manner. So, that is why we do not lift it very high and then swing it forward because that is going to take energy.

So, you lift it just enough to swing it forward to clear the ground. So, if you encounter an unexpected obstacle, then what happens? The swinging leg hits that and you stumble because your body is tuned. So, if you are walking on level ground, you have a certain rhythm your body you know adapts to that. If not, if you are walking on uneven ground; you have to make it is it is a little bit more effort because you have to consciously clear obstacles when you are swinging.

So foot clearance is an important aspect functional aspect of the swing phase. So, this is an important aspect of the swing phase. And in the terminal swing which is from the tibia vertical to the next initial contact; so, you see here tibia vertical to next initial contact. This is from toe of no, from feet adjacent tibia vertical. So, you have the terminal swing your limb advancement is completed and you want the limb to prepare for weight acceptance. So, the leg the shank moves ahead of the thigh in terminal swing. So, you are

essentially completing the limb advancement and you have to prepare them limb for stance for the next stance.

So, if you look at the hip motion, if you start off with a flexed hip say; this is initial contact you are starting of the flex step. It moves in the direction of extension and then flexion ok. So, in the gait cycle it extents and then flexes again. If you look at the knee, the knee flexes. You have knee flexion initially we will talk about individual stages; then it extends flexes again, then it extends. So, two cycles of flexion and extension; hip one cycle of flexion, then one of extension. And then with the ankle you have a plantar flexes, then dorsiflexes and then again plantar flexes dorsi flexes and comes to neutral. .

Student: Ma'am

Yes.

Student: Initial (Refer Time: 42:50) initially.

Initial contact.

Student: There will some amount of dorsiflexion.

So, towards when it is prepares for initial contact it actually back to neutral. So, like I said there will be individual variations, but see because you want to go from neutral to a plantar flex state; when you have foot flat when it perplex about the heel, you are going to a plantar flex state. So, your direction of motion is from dorsiflexion to plantar flexion. So, to be properly position for stance, the ankle actually comes to the neutral position at heel contact initial contact.

Student: Ok.

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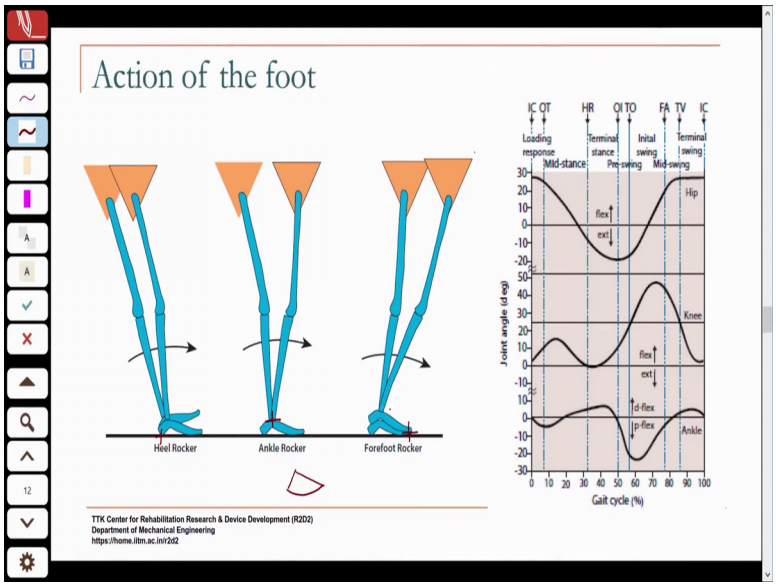

So we will look; so if you look at the action of the foot so, you have initially this is your pivot. The heel is your pivot; you are rocking about the heel. When you make contact first, you have the heel rocker, then as the body progresses over mid stance; you have the ankle rocker. So, the point the pivot point and the foot moves from the heel to the ankle ok. The whole body is now pivoting about the ankle. This is the motion that is happening. Initially you just have the foot pivoting about the heel to plant on the ground, then you have the tibia pivoting about the tibia and the rest of body about pivoting about the ankle.

And then in the final stages substance once your heel is off the ground, you are actually pivoting about the forefoot ok. So, the action of the foot the pivot point in the foot keeps changing. So, the foot is on the ground you know. So, when it starts off in stance, it pivots about the heel. Then once it is planted on the ground, once it attains foot flat by pivoting about the heel.

Then it now start the foot flat on the ground, it cannot move; then everything starts pivoting about the ankle joint that becomes the pivot for the body to progress forward. And then as the heel as the body weights moves ahead of this foot, the heel starts lifting from the ground and then the pivot point at the foot becomes the forefoot. So, these are called the three rockers of the foot. You have the heel rocker, the ankle rocker and the forefoot rocker ok.

And there is a research that shows that these three actions can actually be captured by like a rolling motion. So, if you had a rolling foot so, if you had a foot that was shaped like this ok, these three motions kind of combine are similar to a circular arc rolling on the ground ok; the kind of equivalent to that kind of a motion ok. And in fact, your project for this course one of the project has to do with finding this rocker experimentally. You can find what is the equivalent rocker that will create this kind of a motion geometrically reproduce the same motion ok.

So, we will continue in the next class.