Biomechanics of Joints and Orthopaedic Implants
Professor Sanjay Gupta
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur
Lecture 15
Gait Analysis and Abnormalities

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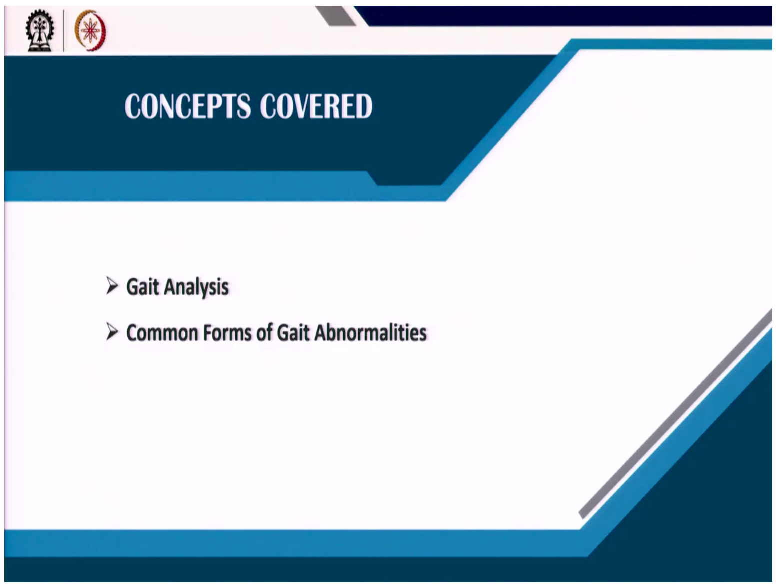

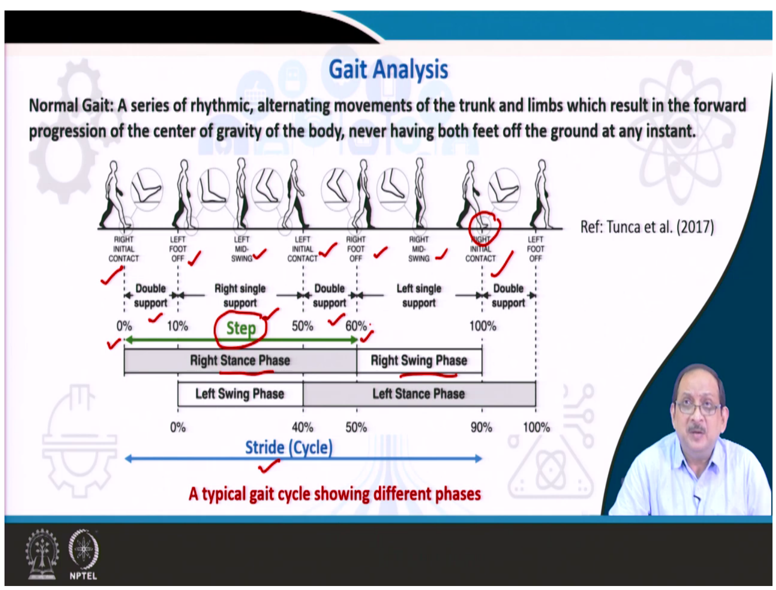

Good morning everybody. Welcome to the lecture on gait analysis and abnormalities. In this lecture, we will be discussing gait analysis and the common forms of gait abnormalities. Before we discuss gait analysis, we should first define normal gait and the gait cycle. So, normal gait is defined as a series of rhythmic, alternating movements of the trunk and limbs, which result in the forward progression of the center of gravity of the body, never having both feet off the ground at any instant. This is the basic definition of walking.

We had discussed in detail about the gait cycle, but it is important to briefly discuss about the gait cycle in this presentation as well. Now gait cycle starts from the right heel strike and ends at the same position in the next heel strike. The full gait cycle is represented by the stride as indicated in the figure consisting of the right heel contact to the next right heel contact as shown in the figure.

A gait cycle consists of two major phases, the stance phase and the swing phase. So, we will be explaining things with respect to the right foot. So, apart from these two major phases, there are a number of intermediate phases as indicated by double support, right single support, double support and for the left leg in the swing phase, left single support and double support. So, when the left leg is executing the stance phase, the right leg is going through the swing phase.

So, apart from these intermediate phases, there are also different instances as indicated in the gait cycle. Now, the step of a gait cycle is measured from the instant when the right foot strikes the ground to the instant when the right foot takes off the ground. So, you generate ground reaction forces from one foot to the other and then you move in a particular direction.

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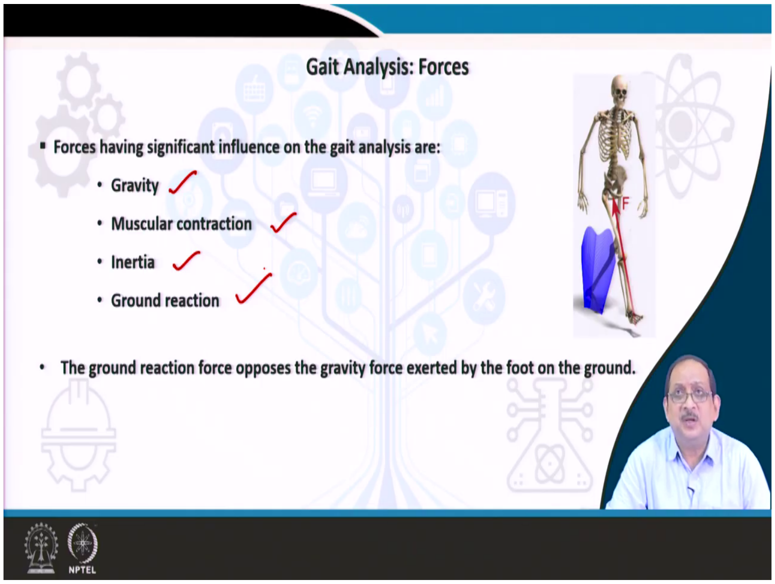

Let us now move into the details of the gait analysis. So, the forces that have significant influence on the gait analysis are the gravity force which is the weight of the body, the muscle contraction forces, the inertia forces, the mass of the body, and the ground reaction forces. The ground reaction force actually opposes the gravity force exerted by the foot on the ground.

So, it acts in the opposite direction, it is the reaction force of the ground on the body, which is exerting the gravity force on the ground. So, when a person is in a standing posture, the ground reaction force is equal to the person's weight but actually acts in the opposite direction to the gravity force.

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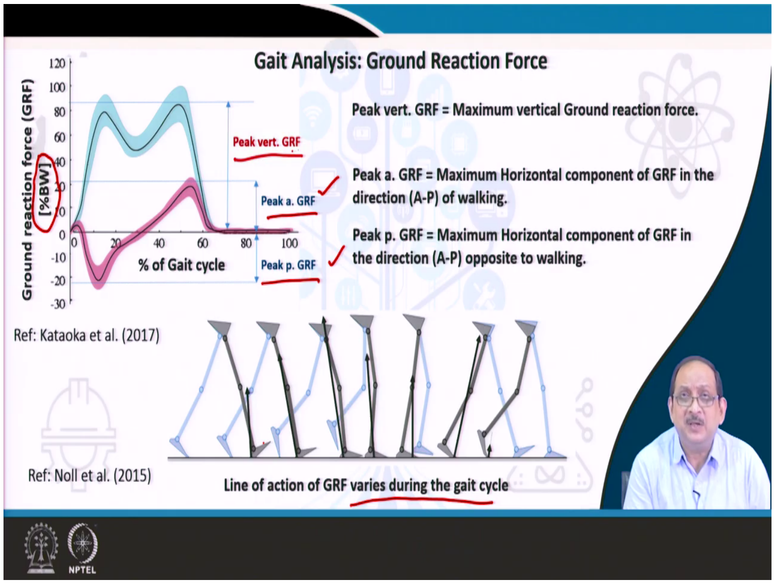

Now, let us look into the variation of the ground reaction force during the gait cycle. In the figure presented here in the slide, the vertical force component and the force component along the anterior-posterior directions are shown. The variation of these two components of the ground reaction forces during the gait cycle has been presented here.

So, in this graph, the peak magnitude of the vertical component of the ground reaction force is indicated. As you can see, the peak vertical component of the ground reaction force is predominantly high as compared to the peak values of the horizontal component of the ground reaction force along the anterior-posterior direction. So, this ground reaction force is actually expressed in terms of body weight. So, it is percent of body weight as you can see, the peak value of the vertical component of ground reaction forces reaches about 90 percent of the body weight during the gait cycle.

Now, we will be considering only these two forces, the force along anterior-posterior direction and the vertical component because we are analyzing gait in a two dimensional plane only. The mediolateral ground reaction force component is actually acting inwards-outwards to the two dimensional plane. The line of action of the ground reaction force also varies during the gait cycle, as presented in the figure.

So, the line of action of the force vector, as you can see is varying quite a lot during the different instances of the stance phase because the ground reaction force acts only during the stance phase. During the swing phase, the leg is swinging in the air and not in contact with the ground.

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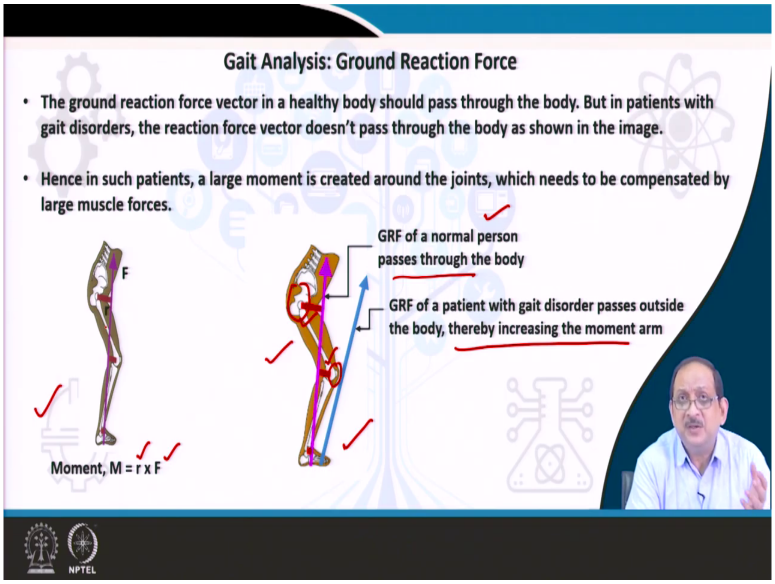

So, let us discuss more about the ground reaction force. So, the ground reaction force vector in a healthy body actually passes through the body. But in patients with gait disorders, the reaction force vector does not pass through the body, as shown in the figure. In such patients with gait disorders, a large moment is created around the joint, which is shown here. So, there is one joint here, the hip joint, another joint here, the knee joint.

So, a large moment is created, which needs to be compensated by the muscle force. So, for a normal person, as you can see, the ground reaction force passes through the body. So, when the ground reaction force is deviated due to gait disorder, it passes outside the body, increasing the moment arms. Generally, if you look in the figure towards the right, the moment is calculated as a cross product of the moment arm and the force vector.

So, the moment arm plays an important role in the magnitude of the moment created due to the ground reaction force. So, this deviation in the ground reaction force increases the moment and this moment needs to be compensated or balanced by the muscle force.

Now, since the muscles have actually small moment arm or lever arms, it acts mostly close to the body. The magnitude of the muscle force needs to be increased many times to counterbalance the increase in the moment arm of the ground reaction force. So, the muscles actually have to be very powerful to counteract the effect of deviations in ground reaction forces.

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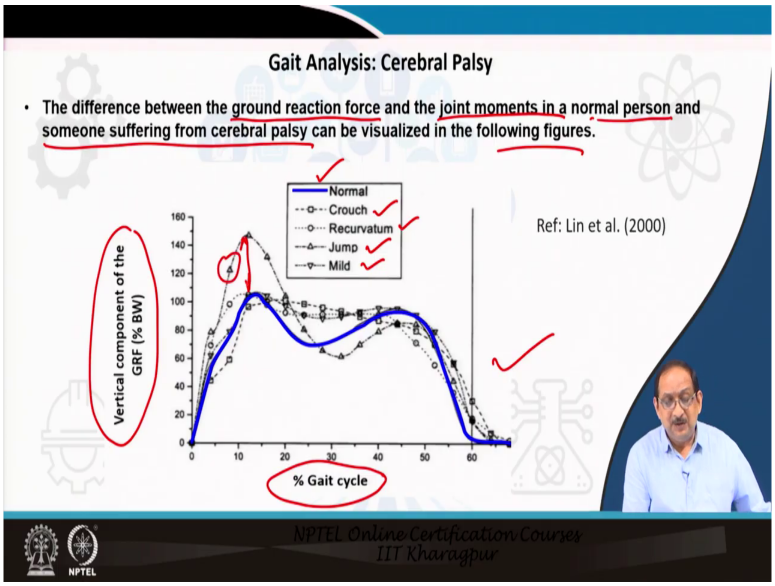

Let us focus our attention on the deviations in the ground reaction force and joint moment for cerebral palsy patients. The difference between the ground reaction force and the joint moments in a normal person and a patient suffering from cerebral palsy can be visualized in the following figures. There are two figures corresponding to the vertical component of the ground reaction force, and in the next slide, I will be presenting the figure on joint moments.

So, the excessive ground reaction force in the case of cerebral palsy patients is evident in this figure. In this figure, the vertical component of the ground reaction force is presented in terms of body weight during the gait cycle; one can see the blue line. The blue line corresponds to the normal patients and all other curves correspond to different gait patterns of cerebral palsy patients and these gait patterns of cerebral palsy patients are crouch, recurvatum, jump, and mild.

So, the deviations in the vertical component of the ground reaction force is very much evident in this figure as can be seen for one case: the jump represented by a triangle, there is a significant difference in the ground reaction force.

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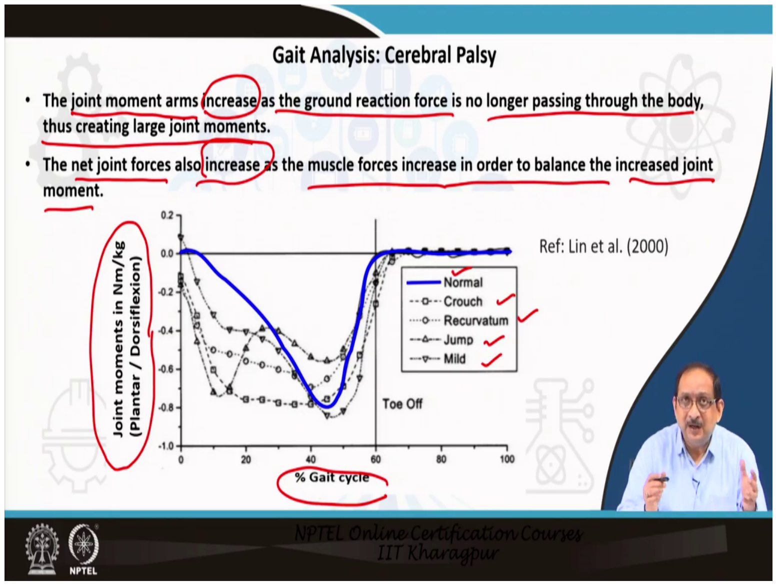

Now, in this following slide, we are actually plotting the joint moments against the gait cycle. The joint moments are the plantar dorsiflexion moments and it is evident from this figure that there are considerable deviations of the gait patterns in the case of these cerebral palsy patients: the crouch, recurvatum, jump and mild, all the four cases considerably deviate from the blue curve of the normal gait pattern.

This can be explained in the following way. The joint moment arms increase as the ground reaction force is no longer passing through the body, thereby creating large joint moments. We have discussed this earlier, the mechanics involved in the increase of joint moments. The net joint forces also increase since the muscle forces increase in order to balance the increased joint moment.

The increased joint moments actually require increased muscle forces to counterbalance the additional or excessive joint moments, otherwise, the patient would fall down. So, the muscle forces increase. So, as the muscle forces increase, it leads to an eventual increase in the net joint forces as well.

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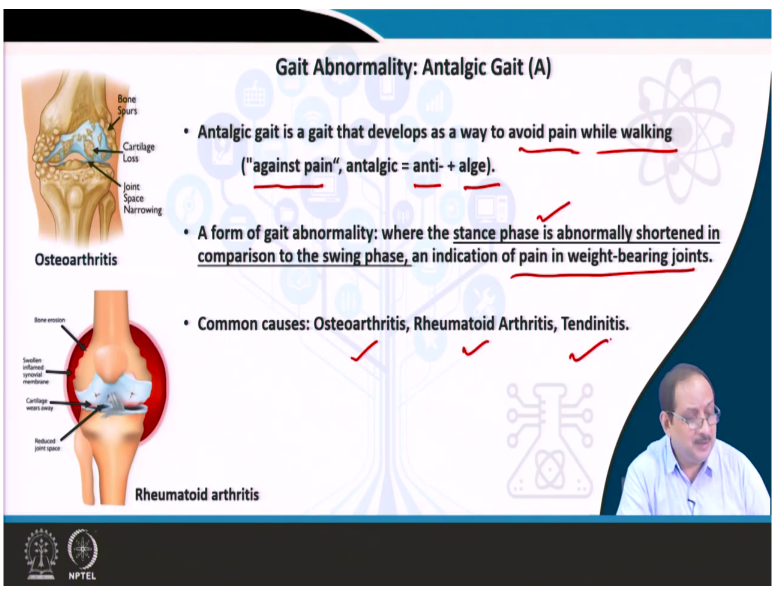

Let us come to the second topic, the common form of gait abnormalities. The common forms of gait abnormalities are antalgic gait, lateral trunk bending, functional leg length discrepancy, increased step width, inadequate dorsiflexion and plantarflexion and excessive knee extension.

Now, let us consider the gait abnormality regarding antalgic gait. Antalgic gait is a gait pattern that develops as a way to avoid pain while walking.

So, it is a gait that is developed against pain. So, as the word suggests, it is anti pain. So, a form of this great abnormality is where the stance phase is abnormally shortened in comparison to the swing phase, which indicates pain in the weight-bearing joints. So, it is important to note that the stance phase is abnormally shortened in comparison to the swing phase. The common causes are due to osteoarthritis, rheumatoid arthritis and tendinitis. On the left, the figures of osteoarthritis and rheumatoid arthritis is presented.

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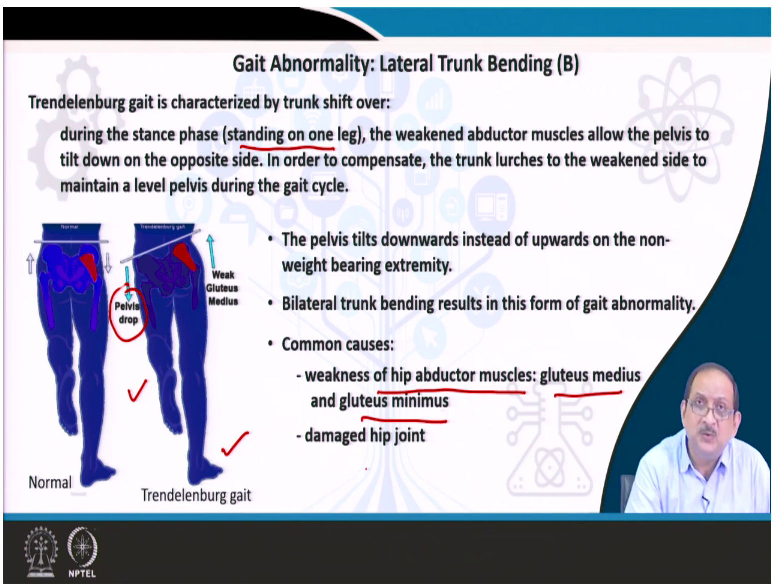

Let us come to the second gait abnormality, which is due to lateral trunk bending. This is actually called Trendelenburg gait, and it is characterized by trunk shift over. In this type of gait abnormality, we see that during the stance phase, when it is standing on the one leg as indicated here, the weakened abductor muscle allows the pelvis to tilt down on the opposite side. In order to compensate, the trunk actually rotates to the weakened side to maintain a level pelvis during the gait cycle. The trunk lurches to the weakened side to maintain a level pelvis during the gait cycle.

So, the pelvis actually tilts downwards instead of upwards on the non-weight bearing extremity, which results in bilateral trunk bending. The common causes for this type of abnormality are the weakness of the hip abductor muscles, the gluteus medius and gluteus minimus. And it may also be due to a damaged hip joint.

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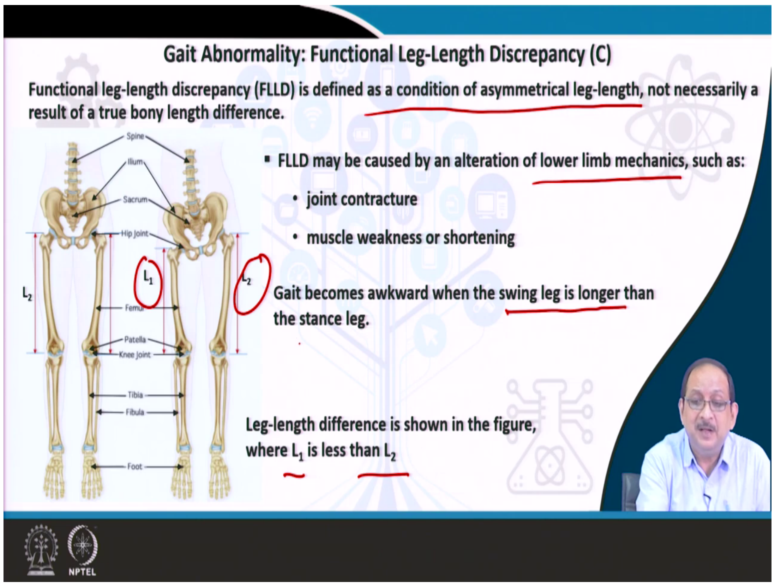

Functional leg length discrepancy is another form of gait abnormality. Now leg length discrepancy, in general, could be structural as well as functional. The structural discrepancy is associated with true bone length difference, whereas the functional leg length difference is defined as a condition of the asymmetrical leg length, not necessarily arising out of true bone length difference.

So, the figure presented in this slide actually presents the leg length difference, where L1 is less than L2. Now, the functional leg length discrepancy may be caused by an alteration of lower limb mechanics; it may be due to joint contracture and also due to muscle weakness or shortening. Now joint contracture is a condition of shortening and hardening of muscles, tendons, or other tissues, often leading to deformity and rigidity of the joint. So, the gait becomes awkward when the swing leg is longer than the stance leg.

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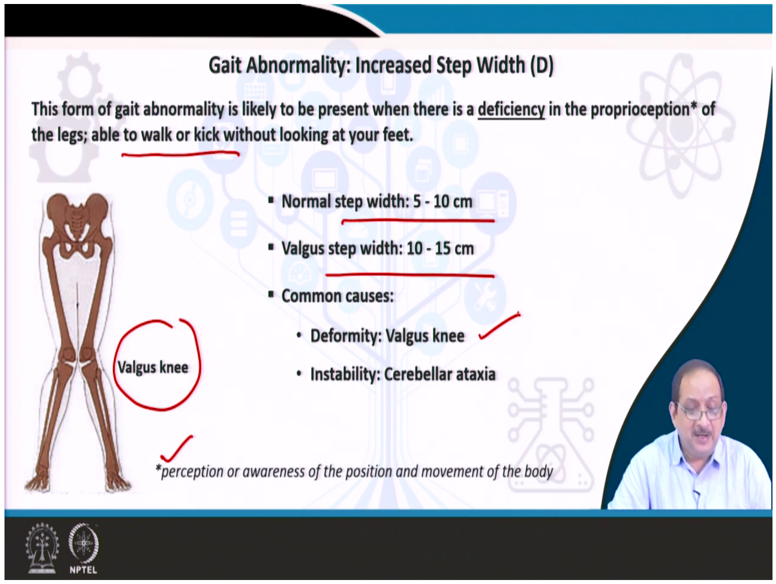

Let us come to the fourth gait abnormality, which may be caused due to increased step width. So, this form of great abnormality is likely to be present when there is a deficiency of the proprioception of the legs. Now, proprioception is defined as perception or awareness of the position and movement of the body. It is basically the ability to walk or kick a ball without looking at your feet. So, any deficiency in the proprioception of the legs would lead to this form of gait abnormality.

So, in the case of a normal person, the step width is about 5 to 10 centimeters. Valgus knee, as presented here on the left, is actually a joint deformity where the knee joint is bent inwards. So, in this case of valgus deformity, the step width is increased to 10 to 15 centimeters. So, the common causes of this form of gait abnormality are due to joint deformity valgus knee and instability caused due to cerebellar ataxia. Cerebellar ataxia results in uncoordinated movement due to the damage at the cerebellum.

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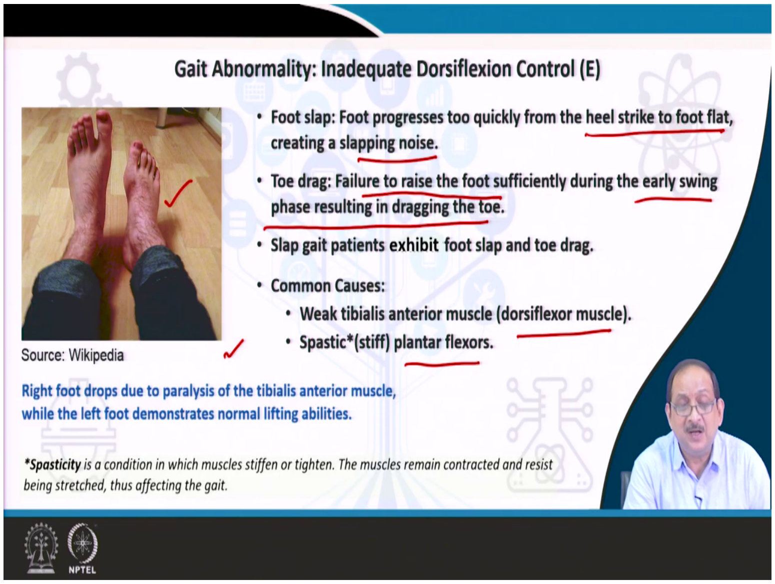

Let us discuss about another form of gait abnormality due to inadequate dorsiflexion control. On the left, you can see a figure,the right foot drops due to paralysis of the tibialis anterior muscle, while the left foot demonstrates normal lifting abilities. So, what happens is the right foot actually drops. So, the foot, it is a form of foot slap, where the foot progresses too quickly from the heel strike to the foot flat.

So, there is a quick progression of the foot, creating a slapping type of noise. Now there is another problem here about the toe drag. The failure to raise the foot sufficiently during the early swing phase can result in dragging of the toe. So, there is a foot slap, followed by the dragging of the toe in the foot.

Now, slap gait patients exhibit foot slap and toe drag. Now in a normal walking gait, the heels strike the ground first, followed by a controlled relaxation of the foot and ankle dorsiflexors, in order to allow the forefoot to come in contact with the ground. In case of slap gait, what happens is the slap gait occurs due to weakness of the foot and ankle dorsiflexion, which causes the foot to slap down on the floor with each step.

Now, the common causes are weak tibialis anterior muscle (the dorsiflexor muscle) and the spastic (stiff) plantar flexor muscles. Spasticity is a condition basically in which the muscles stiffen or tighten; the muscle remain contracted and resist being stretched, thus affecting the gait.

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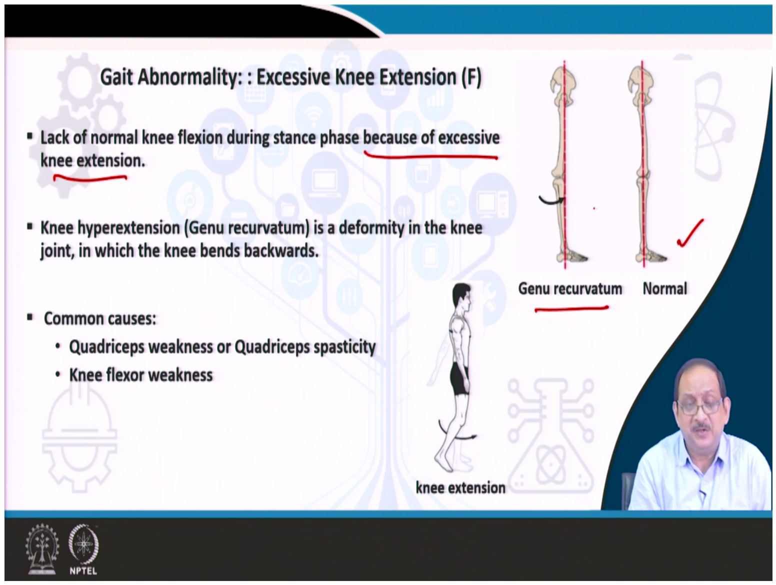

We come to the final form of gait abnormality, which is due to excessive knee extension. The lack of normal knee flexion during stance phase because of excessive knee extension is the cause of this form of gait abnormality. So, you can see on the right the normal condition. Whereas on the left, we have this case of knee hyperextension, which is a deformity of the knee joint in which the knee bends backward.

So, this line actually moves a little bit forward. The common causes of this form of gait abnormality is due to weakness in the quadriceps or spasticity in the quadriceps. It can also happen due to weakness in knee flexor muscles.

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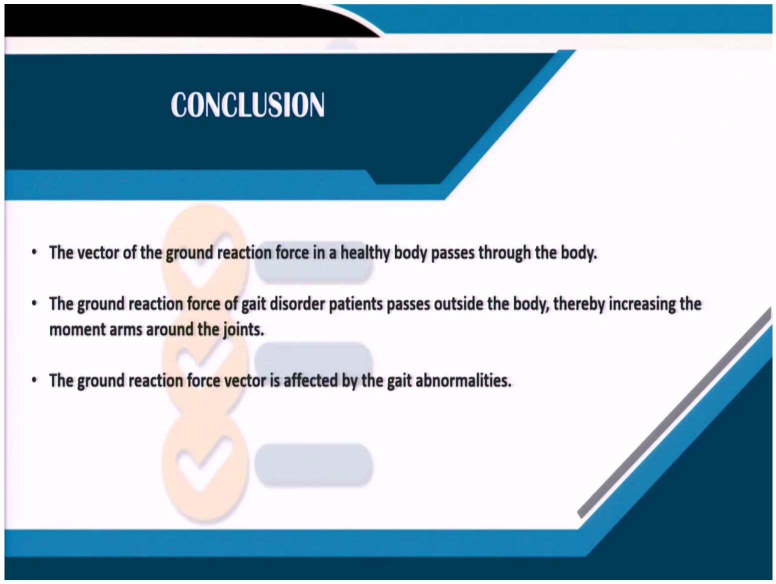

Let us come to the conclusions of this lecture. The vector of the ground reaction force in a healthy body passes through the body. The ground reaction force of gait disorder patients passes outside the body, thereby increasing the moment arms around the joints. The ground reaction force vector is affected by the gait abnormalities.

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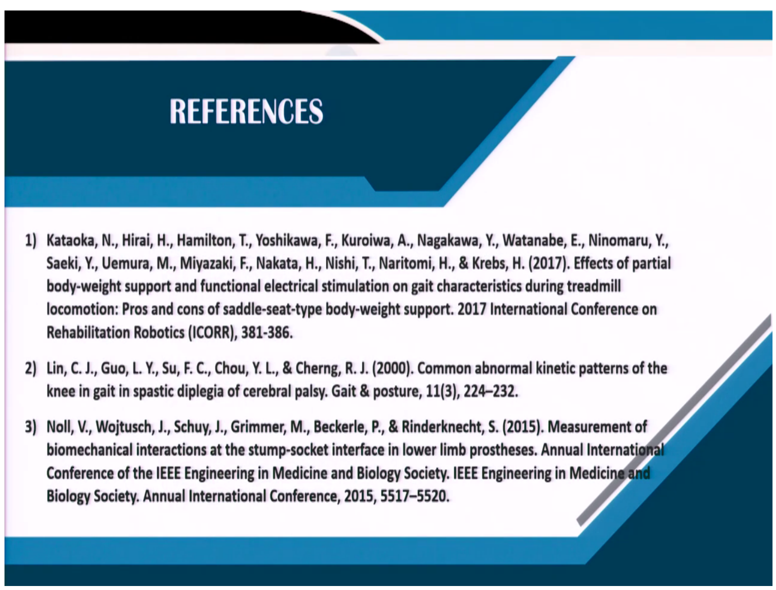

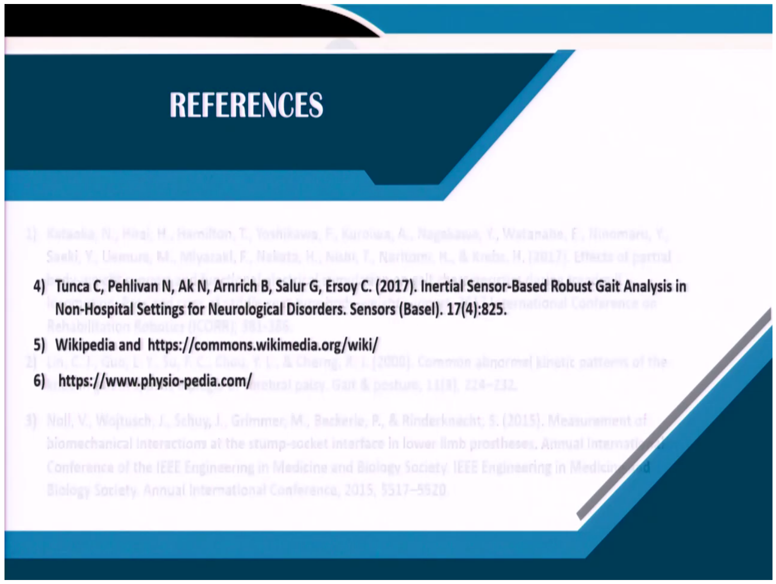

The list of reference is indicated in two slides. Thank you for listening.