Gait Analysis

Hello everyone, welcome to module 6. In this section, we will look at the gate analysis. So, in this module, we will look at the definition and importance of gate sign analysis followed by walking gate analysis or walking gate cycle. And then, we will further look at the way terminology used in the gate analysis, further breaking it down into spatial parameters and temporal parameters followed by few examples in gate analysis. So, what is gate analysis? So, we normally see all of us walk in a particular fashion, like what happens is we contact the floor with one foot and then move our body from one point to another point. So, gate analysis is nothing but a systematic study of human locomotion.

So, in this, what we look at, we look at the way how our body moves, particularly we are more interested into basic modes of transportation such as walking or running, which will help us to move from one place to another place. So, gate is a very complex function which involves the use of visual somatosensory and vestibular systems. So, human walking and running is defined as a method of locomotion involving the use of two legs alternatively to provide both support and propulsion. So, what is the basic difference between walking and running? So, in running our, in running analysis, what we look at is at least one foot is being in contact with the ground at all the times.

So, this is one of the prominent feature which distinguish walking and running. However, there are other ways where we can move our body from one place to another place. For example, hopping with two legs itself, which is known as three point step through gate. So, visually if we look, we stand both the feet on the ground, and then, for example, this blue line, we jump across the line. That is also another way of moving our body from one place to another place.

So, that is known as three point step through gate. But we are more concerned in this section about the walking and then try to see the difference between running also. So, in human motion analysis, we use gate and walking very interchangeably. However, they are not exactly the same thing. So, gate, if we look at gate, gate is nothing but the manner of style of walking rather than the walking process itself.

Why? Because if we say gate is just walking, then when we analyse other movements, for example, jumping or running, then we cannot use the term gate analysis of running or running gate or jumping gate. So, to avoid that confusion, what we will use in this particular section, gate will define as the style of walking or the pattern of movement rather than the process itself. So, why we say it in this way? Because it makes more sense like when we say two people are walking with different gate or walking in two different ways. So, gate is looking at the pattern of movement rather than the movement itself. So, now let us try to understand the different aspects of gate cycle.

Since we know walking is a repetitive sequence of limb motion to move our body forward position, forward or backward depending upon in which direction we are walking. What does it do? It involves a series of interaction between two multi-segmented lower limbs. For example, our thigh segment, our lower leg, which is also known as shank segment, and then foot segment. There are number of events that occur during gate, which can be viewed from several aspects. So, these series of events when repeated by each limb with reciprocal timing, like one limb performed it and then the other limb performed the same events repeatedly until the person reaches to its destination.

So, this single sequence of events or functions by one limb is known as gate cycle. Since we know we are moving from one leg or one event to the other event very smoothly, there is no specific starting or ending point. So, gate can be started, or we can say the onset of a gate cycle could be any event during that process. However, what happens is since some of these events occur very fast, so it would become very difficult to pinpoint the particular instance when that particular event happened. So, we usually refer heel strike either left side or right side as the starting of the gate cycle because visually you can distinguish the foot contact with the ground quickly as compared to the other aspects of the gate.

So, normally in normal human beings when we walk, so usually we contact the floor with our heel, but there are certain cases or certain special population where they do not contact the ground with heel as the first instance rather than sometimes they contact the ground with midfoot or the toes also. So, that is why to generalize this thing we term the heel strike in a very generic way as initial contact as the onset of gate cycle. So, gate cycle is nothing but reciprocal floor contact patterns of our lower limbs. So, in this one limb serve as a support and the other limb advances itself to the new support site or point. These limbs for example, if we contact the floor or the ground with our left side, then next we will move over right side and then contact the floor with the right side.

In this way we are doing the reciprocal motion between left and right sides, so that limbs can reverse their roles in supporting as well as advancing the body. And in both of these like there is a specific point when the weight transfer occurs. So, this is the event when both the feet are in contact with the ground. For example, here and here. Another way of looking at the gate cycle is if we look at the stride and step.

So, let us define what is stride? Stride sometimes is also known as gate cycle. It is based upon the actions of one limb, and the duration of stride is the interval between two sequential initial floor contacts by the same limb. So, stride is defined by over here in this figure from this to this like the same foot like left foot over here I marked like left foot to left foot that is known as one stride or one gate cycle. Similarly, how we define step?

Occasionally what we do is we confuse step with the stride. However, step refers to the timing between two limbs like step is from left to right.

So, this is one step and from here to here is one stride or gate cycle. So, initial contact by each foot is a step. For example, left and then right, like sequential contact by each foot defines our step. And usually, it is the midpoint between of one stride and the other foot contacts the ground before the next stance period starts. We can divide the gate cycle into stance period and swing period.

So, previously we looked at stand stride and step. Now, we can divide the gate into stance and swing also. So, stance period is when the foot is in contact with the ground starting with the initial contact till the point the foot leaves the ground. It can be further divided into subcategories. For example, initial double stance when both the feet are in contact with the ground or single support limb where the opposite foot is lifted for swing.

For example, initially your left foot is on the ground and then you strike the floor or ground with your right foot that is your initial double stance. Once we transfer the whole weight on our right side and our left foot is in the air that is known as single limbs sport. And finally, once our left foot again hits the ground for the next try then that results in the terminal double stance phase. Similarly, in swing phase is nothing but when the foot is in the air for the next initial contact. Now, let us look at the division of gate cycle.

So, as we know from our previous discussion gate cycle is also known as stride. This stride can be further divided into two periods one is stance period and another one is the swing period. These two periods can be further divided into subtasks like the task which are being performed during this cycle. So, for stance it will start with the weight acceptance where the body will transfer the weight from one limb to the another limb followed by a single limb support where the whole weight of the body is being supported by one limb only. Whereas in swing we will perform the task of limb advancement.

For example, if we start our gate cycle looking at like we started with the right side. So, right heel strike or initial contact then transferring the weight towards the right leg and our left foot or left leg will be in swing or in air which will move in front of our right leg that will perform the function of limb advancement. Then these tasks are further subdivided into eight sub phases. So, these phases are in weight acceptance can be further subdivided into two phases. First one is the initial contact when the foot contacts the floor or ground followed by loading response where the weight transfer will happen from one limb to the another limb.

This is being followed by single limb support phase where the contralateral or the opposite limb is in air, and the whole body weight is being supported by one limb only. So, this is further divided into three phases which are mid stance, terminal stance and pre swing. And the limb advancement has an overlap between single support phase which

this limb advancement task can be further subdivided into four sub-phases. This single limb support is three, and then weight acceptance is two. So, there is an overlap between single limb support and limb advancement in the pre-swing phase.

So, this is common. So, if we add up they will add to eight phases. So, limb advancement will start with the pre-swing, like the preparation for the swing phase followed by the initial swing, then the mid-swing, and finally, the terminal swing. So, the terminal swing will end the gait cycle. So, now let us look in detail into all these phases and then try to understand how these sub-phases play an important role in the support as well as advancement of the whole body during the process. Now, let us look at the different phases of gait cycle.

So, the first phase is known as initial contact. So, it starts with the stance period and it determines the loading response pattern of the body. It happens during the interval of 0 to 2 percent of the total gait cycle. If we normalize heel strike to the heel strike as a 100 percent, the first 0 to 2 percent represents the initial contact. It is being followed by the phase two which is known as loading response.

In this what happens is initial double stance period starts. So, in this what happens it starts with the initial contact and continues until the other foot is lifted from the ground over here. As we can see this foot is at the verge of lifting from the ground or floor. It performs various important functions such as shock absorption, weight varying, stability and preservation of progression and it happens during the interval of 0 to 10 percent of the total gait cycle. These two phases of gait cycle are subcomponents of weight acceptance.

And this is the most important and demanding task in the gait cycle as the challenges abrupt transfer of body weight from one limb into another limb which just finished the swinging phase or swinging forward and has unstable alignment. So, it is being followed by the third phase which is the mid stance. This is the first half of the single support interval and it starts with the lifting of the opposite foot and it continues until the weight is aligned over the forefoot over here. It helps in the progression of the body over the stationary foot or the stance leg and also help in limb and trunk stability. It happens during the interval of 10 to 30 percent of the gait cycle.

This phase is followed by the terminal stance phase. So, as the name indicates, it completes the single limb support, what happens, in terminal stance your swinging leg moves in front of your supporting leg. So, what happens it begins with the heel rise. So, you are in your mid stance your foot is flat and it begins with rise of your heel and continues until the other foot strikes the ground. It helps in the progression of the body beyond supporting foot like in front over here like if this leg is moving forward over here apologies for the bad drawing but this is how you can imagine like how it helps in the

progression of the body beyond the supporting foot and it happens during the interval of 30 to 50 percent of the total gait cycle.

This is then followed by the phase 5 of the gait cycle which is pre-swing. So, in pre-swing what happens our second double stance interval starts because what happens in the previous phase we see the contact or stance leg starts with the lifting of the heel and then the contact of the contralateral foot. It starts with the initial contact of the opposite foot and ends with the toe off. So, once this foot moves into air and then this foot contacts the ground or floor this is the pre-swing phase of the gait cycle. It performs the following function which is weight release, weight release from the one limb to the other limb and also transfers the weight from your right limb to the left limb, and it happens during the 50 to 60 percent of the gait cycle.

It is then followed by the initial swing phase where your right limb is in the air, and left limb is supporting or accepting the weight. So, it is approximately one third of the total swing phase. It begins with the foot off and ends when the swinging foot in this case the right foot is opposite to the stance foot. It helps in foot clearance and advancement of the trailing limb or the limb which is behind previously and it happens during the interval of 60 to 73 percent of the gait cycle. This is then followed by the phase 7 which is known as mid-swing.

So, over here what happens it is the second phase of the swing period as we know it started with the initial swing now the mid-swing. It started with swinging limb opposite to the stance limb and ends when the swinging limb is forward, and tibia is vertical. So, over here you can see the tibia of the right leg is approximately at 90 degrees. It helps in limb advancement and foot clearance and usually happens in normal individuals between 73 to 87 percent of the gait cycle. And finally, the last phase of the gait cycle is terminal swing.

So, it is the final phase of the swing begins with the tibia vertical and ends with the foot strike over here with the same limb. Since in the initial contact we started with the this is this particular phase is identical with the initial contact, like where the tibia we started with the tibia vertical from our mid swing phase and then moved with the and it with the foot strike. It helps the limb advancement like our right limb is moving forward and prepares it for the next stance period and it happens in the 87 to 100 percent of the gait cycle. So, now let us sum up the human walking gait, particularly here we will talk about the normal walking only. So, this first phase where our both feet are in contact with the floor is known as our first double support phase.

And during this interval, whatever body does is it accepts the weight from one limb to the another limb. Next, what happens is from here till this point we have single limb support. And then, from this point onwards till this point, we have the second double

support, which again is being followed by our single limb support phase. So, during this whole process like from the second double support to the second single limb support, this is where our limb advancement happens. So, what we did is we divided the whole gait cycle into stance phase and followed by our swing phase.

And then can be further divided into first double support, then single limb support, second double support, and single limb support for the contralateral or the opposite foot or this is also known as you know the swing phase for the same foot which was previously was in stance phase. So, this is how the whole gait cycle is being divided, and with this understanding we will be able to understand the human motion particularly during walking in a more systematic way. So, another thing which is important while discussing gait analysis is spatial parameters. So, the spatial parameters such as stride length, spatial means related to space, and it is usually measured in meters, centimetres or other units, but the standard unit is in meters. So, what happens, or how we define stride length? We start with one foot, for example, in this case this is right foot, left foot, and right foot looking from the top or in the transverse plane.

So, stride length is nothing, but the distance travelled by a person during one complete gait cycle. So, for right gait cycle this is your stride length. So, the distance between heel strike to the next heel strike of the same foot. So, it is nothing, but length between heel strike from one heel to the next heel strike on the same side. It consists of two steps like left and right for example, you are moving from here to here and then from here to here and in normal population these two step lengths are approximately equal, but in case of certain pathological conditions, there might be difference in the two step lengths.

So, the next parameter we look into is the step length itself. So, step length is nothing, but distance between contact of one foot and the subsequent contact of the opposite foot. For example, right to left the distance between these two is your left step length and then followed by your right step length. Another important special parameter which is important to analyze human movement particularly walking is stride width or base of support. So, it is nothing, but if you it is nothing, but the medial lateral distance between the feet calculated from the same point.

For example, if I see like a horizontal line passing from the heel of right foot and the heel of the left foot the medial lateral distance between both left and right is known as base of support or stride width. Another important factor from special parameters is your foot progression angle. So, it is nothing, but angle between the long axis so over here like we draw the long axis of the foot and the line of forward progression. So, if this is the line of forward progression, the angle between these two is known as your foot progression angle.

Now, let us look at the temporal parameters. So, temporal parameters are parameters which are related to time. So, first is stride time as the name indicates it is the time elapsed between the ground contact of one foot and contact of the same foot with the ground. So, from here to here the time elapsed between this is known as stride time. Similarly, stance time is nothing, but the time in seconds during the foot is in contact with the ground. For example, from here till this point over here after this there will be toe off.

Swing time starting from when the foot leaves the ground till it hits the ground again that is your swing time. Another important aspects is your swing stance ratio this shows the distribution of stance and swing phases of the gait in a particular individual. Another temporal parameters which are of importance are double support time it is nothing, but time in seconds during two feet are in contact with the ground. For example, over here till this point like after this it will be in here and similarly in the second phase also over here. Then single support time when only one foot is in contact with the ground.

Cadence is nothing, but steps per minutes how many steps you will take in a minute and cycle time since we already know the cadence is steps per minute. So, in a single stride we take two steps and in one minute there are 60 seconds. So, cycle time will be like left cycle or right cycle. So, we can calculate from it cadence. Another thing which is of importance is to know the speed of walking.

It is a function of both cadence and step length, and mathematically, it is being calculated as

$$Speed\ (m/s) = \frac{Stride\ Length\ (m) * Cadence\ (steps/min)}{120}$$

or in other words,

$$Speed\ \left(\frac{m}{s}\right) = \frac{Stride\ Length\ (m)}{Cycle\ Time\ (s)}$$

also gives us the speed of walking. So, with this we now have a better understanding of the various phases, tasks being performed in a gait particularly walking gait. And now we will move our discussion towards the various application of gait analysis. So, gait analysis help us to assess and improve mobility also help in diagnosis and treatment of movement disorders and eventually help us in enhancing the athletic performance. There are various applications of gait analysis for example few of them are shown on the slide, like orthopedics and rehabilitation, pediatrics, neurology, sports science and performance, geriatric and aging, rehabilitation engineering, biomechanics research, as well as more recently in forensic science also.

So, now let us look at these examples one by one and then see how the knowledge from gait analysis can be applied in these particular applications. We start with the orthopedics

and rehabilitation. In orthopedics and rehabilitation gait analysis helps in pre and post-surgical assessments. So, what we will do in pre and post-surgical assessments is like when in orthopedic settings, a patient is required to undergo a surgical intervention. So, the gait analysis will help the surgeons to evaluate the various gait parameters like for example, for knee surgery.

So, they will look at the various joint angles, forces being produced or the timings the various gait parameters like spatio-temporal parameters which we discussed in the previous slides. They will look at all those parameters to decide the surgery or that is known as pre-surgical assessment which and then after the surgery also after basic rehabilitation they will again perform the gait analysis to look at the recovery and then ensure proper functioning of the limbs or the patient itself. In orthopedics and rehab gait analysis is also being utilized in prosthetics and orthopedic design. So, with the knowledge of gait for a particular patient it will be very helpful in designing customized prosthetic limbs or orthopedic devices which will perform optimally in terms of function and are more comfortable compared to the on the shelf orthotics and prosthetics. In stroke rehabilitation also, gait analysis helps in assessing the patterns which gait or sorry the which stroke survivors develop and help in designing personalized rehabilitation plans.

And also the gait analysis being performed at different time intervals during the rehabilitation process helps in tracking the progress. In pediatrics gait analysis helps in addressing the developmental disorders by detecting and addressing several developmental issues, such as flat feet, in-towing or toe walking. So, how you will define in-towing and out-towing we discussed about foot progression angle. So, whether the feet are rotated inside or outside so gait analysis will provide information on the mechanism or look into the mechanics which effect or which results in these developmental issues and help clinicians to address those issues. A very specific example of gait analysis in pediatrics is its uses in the management of cerebral palsy.

So, cerebral palsy or CP in short is a group of disorders that affect a person's ability to move and maintain balance and posture. It can affect one side of the limbs or all four depending upon the severity of the disease. And in this gait analysis help in evaluating the gait pattern and help clinician to guide the treatment and intervention strategies. For example, in literature, it has been found that with the help of gait analysis now the success rate of surgeries in CP has been increased compared to observational gait analysis only. In neurology, it will help in identifying and characterizing gait abnormalities such as in case of Parkinson s disease or multiple sclerosis.

So, this also helps in differentiating the effect of different neurological disorders on the movement. This also helps to understand the impact of stroke or traumatic brain injury which affects your mobility and balance. In terms of sports science and performance,

gait analysis plays an important role in performance enhancement where it is being utilized to identify the biomechanical factors which affects the performance and help coaches and trainers in developing the programs or to optimize their running or walking techniques or in general, any specific sporting movement. Gait analysis also play an important role in injury prevention, specifically in sports science and performance. What it does is it helps in identifying the movement pattern that may contribute to overuse injuries or help in identifying the interventions, which will help athletes to reduce the risk of injury.

In terms of the pediatric and aging population, the gait analysis help to identify the risk factors for falls and develop interventions to improve the balance and stability. If gait analysis is being performed over the time on this population, it will help us to understand the normal aging process and help clinician as well as rehabilitation professionals to develop strategies to maintain mobility in older adults. Recently, gait analysis find its application in forensic science also, where the gait patterns are being analyzed from the surveillance footages or crime scenes to assist in the criminal investigations. While looking at the suspect specific gait patterns, it will help the criminal investigators to narrow down their search for their suspects. In rehabilitation, engineering as we know it helps in design and optimization of assistive devices for example, exoskeletons, walking aids, robotic systems which will help the patients with mobility impairments.

And finally, in biomechanics research, the investigators use gait analysis to analyze the mechanics of musculoskeletal system during walking or any specific activity which they are interested in to understand the normal function and dysfunction, and this will help in designing therapeutic interventions or development of new equipment for better quality of life. With this, I would like to summarize in this section we looked at the gait analysis, specifically its definition, various parameters involved in the gait analysis. We also looked at the terminology associated with gait analysis. For example, stance and swing phases, the temporal parameters, stride, step and then looked at the subdivision of gait analysis into eight different phases. Followed by the applications of gait analysis in various fields from clinical perspective as well as from sports and equipment design also. With this, I would like to thank you.