

## Gait Analysis

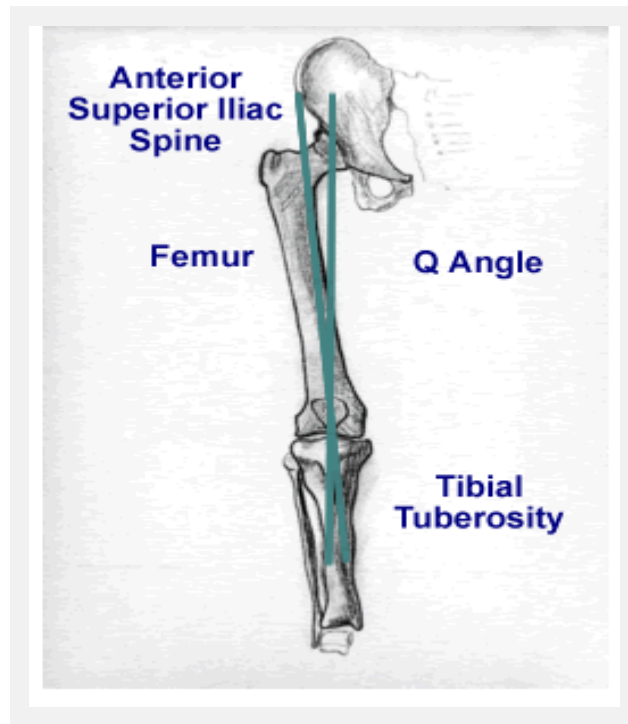
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**Abstract:** Gait is the way in which we move our whole body from one point to another. Most often, this is done by walking, although we may also run, skip, hop etc. Gait analysis is a method used to assess the way we walk or run to highlight biomechanical. The technology supporting the analysis of human motion has advanced dramatically. Past decade of locomotion research have provided us with the significant knowledge about the accuracy of the test performed, the understanding of the process of human locomotion and how clinical test can be used to evaluate medical disorder and effect their treatment. Gait analysis is now recognized as clinically usefully and financially reimbursable for medical conditions. Yet, the route clinical use of gait analysis has been very limited growth. The issue of its clinical value is related to many factors, including the applicability of existing technology to addressing clinical problems, the limited use of such test to address a wide variety of medical disorder; the manner in which gait laboratories are organized ,test are performed and reports generated ;and clinical understanding and expectation of laboratories results. Clinical use is most mast hampered by the length of time and cost required for performing a study and interpreting it. A “gait” report is lengthy, its data are not well understood, and it includes a clinical interpretation, all of which do not occur with other clinical tests. Current biotechnology research is seeking to address these problems by creating techniques to capture data rapidly, accurately and efficiently and to interpret such data by an assortment of modeling, statically, wave interpretation and artificial intelligence methodologies. The success of such efforts rests on both our technical abilities and communication between engineers and clinicians.

**Keywords:** *Gait analysis, gait cycle, motion analysis, clinical gait analysis, Stance Phase Contact Sub phase.*

### Introduction:

Before discussing the specifics of gait let's take a quick look at the bones involved. The key boney structures are the talus (2) and calcaneus (1), located at the ankle. The three part joint formed by these two bones is called the subtalar joint. Other key bones include the navicular(3) and cuboid (7), located just anterior to these bones. The two individual joints formed by the talus and navicular and the calcaneus and cuboid make up what is known as the mid-tarsal joint. The leg bones of significance include the femur which is the thigh bone and the tibia which is the larger of the two lower leg bones. The fibula is the smaller leg bone. In front of the tibia is the patella or knee cap. We will not review the anatomy in detail.



### **Phases of Gait**

The gait cycle of each leg is divided into the stance phase and the swing phase. The stance phase is the period of time during which the foot is in contact with the ground. The swing phase is the period of time in which the foot is off the ground and swinging forward. In walking, the stance phase comprises approximately 60% of the gait cycle and the swing phase about 40%. The proportion of swing to stance phase changes as the speed of walking or

running increases. As the speed is increased the percentage of time spent in the stance phase decreases. Increased time is then spent in the swing phase and there is an increase in the importance of swing phase muscles. An important point to note is that in running an added sub phase is present. Float phase. During float phase, neither foot is on the ground.

### **Ankle/Foot**

The arcs of motion at the ankle are relatively small; yet, they are essential for shock absorption and progression of the body's center of mass. The ankle plantar flexes throughout loading response. Dorsiflexion begins with single support, as the tibia rotates forward over the fixed foot. Rapid plantar flexion begins at terminal double support, with maximum plantar flexor position of 30° attained at toe-off. This action marks the initiation of swing with dorsiflexion throughout the 3 swing-phase segments.

Motor control at the ankle is understood most easily by commencing with swing phase muscle activity. Ankle dorsiflexes undergo brief eccentric contraction in pressings, followed shortly by concentric contraction at the initiation of swing. This contraction sequence increases mechanical efficiency and assures foot clearance. Continued pretibial muscle isometric contraction through swing maintains this neutral or slightly dorsiflexed posture. Subsequent loading response is notable for eccentric contraction of the pretibial muscles to control plantar flexion. A brief period of co-contraction of ankle plantar flexors and dorsiflexes occurs at the transition from initial stance double support to single support. This co-contraction interval increases limb stability and may smooth the transition from double to single support.

The orientation of the ankle and subtalar axes couples loading response dorsiflexion with eversion. Both are attenuated by eccentric contraction of the ankle inverters (ie, posterior tibialis). The plantar flexors begin force generation in single support, with peak activity late in terminal stance and pressing. The absorptive power demonstrated in single support is related to their role in restraining forward tibial rotation. The timing of the triceps surae and per malleolar muscles is similar to that of the triceps surae (gastrocnemius plus soleus) that supplies most of the ankle plantar flexor moment. The ankle then is plantar flexed vigorously during pressing.

The role of the calf muscles during pressing is controversial. Some authors describe this gait phase as push-off and suggest that muscle force by the ipsilateral calf actively propels the limb (and body center of mass) forward. An alternative model is proposed by Perry, who

states that the ipsilateral limb makes no active contribution to the push-off. A third model is that active plantar flexion occurs at the ankle (positive power) and does not serve to propel the body forward (no increase in walking velocity), but, instead, functions as part of a closed kinetic chain to initiate knee and hip flexion in preparation for swing. This phenomenon may account for the increased knee and hip power requirements in individuals who do not plantar flex actively in pressing (i.e., transtibial amputees).

### **Knee**

Most knee motion is limited to the sagittal plane. The knee travels from slight knee flexion at initial contact ( $5^{\circ}$ ) to nearly  $20^{\circ}$  of flexion by the end of loading response. The knee then extends (net flexion) through single support, with peak stance phase extension at 40% GC. At the conclusion of terminal stance and pressing, knee flexion is rapid, continuing through initial swing until peak knee flexion ( $60^{\circ}$ ) occurs. This trend then is reversed, with knee extension continuing through terminal swing. Peak knee extension occurs slightly before the end of the swing phase, with minor flexion occurring in preparation for the subsequent stance phase.

The role of knee muscles, like that of ankle muscles, is understood most easily if one begins the analysis as the limb is in swing. In early swing phase, knee flexion is passive, resulting from active plantar flexion and hip flexion. During swing, motion at the hip changes from flexion to extension, with the knee passively extended as a result of this change of hip joint direction. All 3 hamstrings (long head of the biceps femurs, semimembranosus, and semitendinosus) are active in mid-to-late swing to decelerate the extending knee. The quadriceps is also active in terminal swing. This co-contraction of knee flexors and extensors prepares the limb for weight acceptance that follows shortly. The quadriceps continues to be active in loading support. The eccentric activity of these muscles attenuates the shock of weight acceptance, while preventing excess knee flexion ( $<20^{\circ}$ ).<sup>3</sup>

Both the hamstring and quadriceps muscles are quiescent during mid stance while the knee is extended passively. The role of the remaining quadriceps muscle is different. The rectus femurs is active electrically for only a brief period corresponding with pressing and initial swing. Although this muscle crosses and extends the knee, its role in gait is to assist in flexion at the hip as swing commences.<sup>4</sup>

### **Hip**

The gluteus maximus timing and relative intensity are similar to those demonstrated by the

other hip extensors (e.g., hamstrings). During late swing, the gluteus maximus functions to reverse hip flexion to extension. The gluteus maximus, generally the body's single strongest muscle, resists external forces from loading response that would flex the hip excessively (e.g., jack-knifing). A similar EMG profile and role are demonstrated by the adductor Magnus. Unlike in the knee and ankle, there is a substantial amount of frontal plane motion at the hip. During single support, the mass of the torso tends to rotate the body about the stance limb hip joint axis (e.g., contralateral lateral tilt). Typically, this motion is limited by eccentric activity of the gluteus medius, gluteus minimus, and, to a lesser extent, the tensor fascia latae.

Hip flexion marks transition from stance to swing. This motion advances the trailing limb and assists in foot clearance, which is accomplished by concentric contractions of the iliopsoas, rectus femoris, and sartorius muscles. Swing phase activity of the hip adductors brings the feet toward the line of progression, decreasing the energy demands of walking.

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#### **Stance Phase**

The difference in time spent in the stance phase of running to walking is 60% of the complete gait cycle is spent in stance phase while walking and only 40% of the time is spent in stance phase during running. The time period during which the forces are applied is also dramatically different between running and walking. A walker moving at a comfortable speed of 120 steps per minute has a total cycle time of 1 second. A runner moving at 12 miles per hour has a cycle time of 0.6 second. However, the stance phase has decreased from .62 second to 0.2 seconds.

#### **Stance Phase: Contact Subphase**

The stance phase can further be subdivided into its three component phases. The first portion of the stance phase is contact. This phase begins with the contact of the heel to the ground.

This phase is completed when the remainder of the foot touches the ground. During this portion of the stance phase the foot is pronating at the subtalar joint. The leg is internally rotating and the foot is absorbing shock and functioning as a mobile adaptor to the ground surface. The next portion of the stance phase is called midstance.

**Stance Phase: Midstance Subphase**

Midstance Phase begins when the entire foot has contacted the ground. The body weight is passing over the foot as the tibia and the rest of the body are moving forward. The opposite leg is off the ground and the foot, in this phase, is bearing body weight alone. During this portion of the stance phase the leg is externally rotating and the foot is supinating at the subtalar joint. It is undergoing a change from being a mobile adaptor to becoming a rigid lever in order to propel the body forward during the final portion of the stance phase - Propulsion.

**Stance Phase: Propulsion Sub phase** Propulsion begins after heel off and ends with toe off. This phase constitutes the final 35% of stance phase. The body is propelled forward during this phase as weight is shifted to the opposite foot as it makes ground contact. The subtalar joint must be in a supinated position in order for this phase to be normal and efficient. If abnormal pronation is occurring, the midstance phase and this phase will probably be prolonged and weight transfer through the forefoot will not be normal. The swing phase begins immediately after toe off. The first portion of the swing phase is the forward swing which occurs as the foot is being carried forward. The knee is flexed and the foot is dorsiflexed at this time. The next segment of the swing phase is foot descent as the foot is being positioned in preparation for weight bearing and the muscles are stabilizing the body to absorb the shock of heel contact. At heel contact the swing phase ends and a new gait cycle begins.

In normal walking, the foot initially contacts at the heel. Usually, the initial contact is postero- lateral which results in postero- lateral heel wear. The major determinant of where maximum heel wear occurs is the initial point of contact as determined by the transverse plane position of the foot at the time of contact. Medial heel wear is usually an indication of intoning gait, and usually points to rotational abnormality in the limb above. In gait of much faster speeds there may be no initial heel contact. An individual may contact at the

midfoot and then rock backwards onto the heel or not touch the heel down at all. An example of this gait pattern would occur in a sprinter. Following an understanding of the basic phases of gait, one can proceed to recognizing the motions that occur in the structures of the lower extremity and understand the interrelationships of these structures.

### Swing Phase

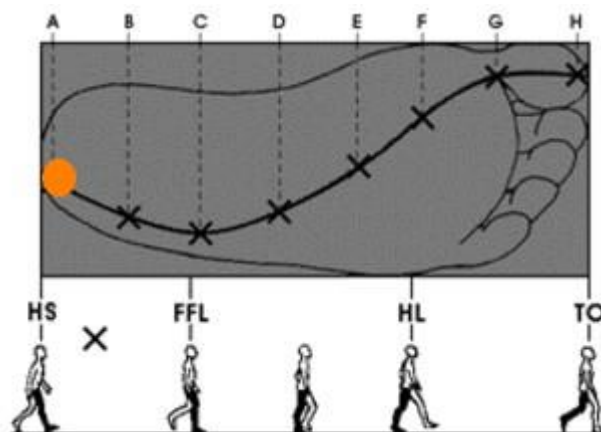
Initial swing begins at toe off and continues until maximum knee flexion (60 degrees) occurs for the foot to clear the ground.

Misdoing is the period from maximum knee flexion until the tibia is vertical or perpendicular to the ground. Leg shortened (ankle dorsiflexion) and hip elevated (abducted) to facilitate swing C. G. of directly over opposite supporting foot

Terminal swing begins where the tibia is vertical and ends at initial contact Foot supinated and positioned for foot strike.

When running, a higher proportion of the cycle is swing phase as the foot is in contact with the ground for a shorter period. Because of this there is now no double stance phase, and instead there is a point where neither foot is in contact with the ground, this is called the flight phase. As running speed increases, stance phase becomes shorter and shorter.

**Gait Stride:** The distance from initial contact of one foot to the following initial contact of the same foot.



### Shock Absorption

Shock absorption and energy conservation are important aspects of efficient gait. Altered joint motion or absent muscle forces may increase joint reaction (contact) forces and lead subsequently to additional pathology. In early stance, nearly 60% of one's body weight is

loaded abruptly (less than 20 milliseconds) onto the ipsilateral limb. This abrupt impact is attenuated at each of the lower extremity joints. Loading response plantar flexion is passive, substantially restrained by eccentric work of pretibial muscles. The absorptive work by pretibial muscles delays forefoot contact until late in the initial double support period (7-8% GC).

At initial contact, external (ground reaction) forces applied to the contact foot produce a tendency toward knee flexion. Repositioning the knee (recurvatum) increases knee mechanical stability, but at the cost of increased contact forces and shock generation. A balance between knee stability and shock absorption is achieved by eccentric quadriceps contractions during loading response. The impact of loading is minimized at the hip during single support through hip abductor muscle contraction.

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