Gait analysis is a highly complex study of the biomechanics of locomotion. It is important to recognize important phases of the gait cycle when fitting and examining shoes. Understanding the customer’s gait will provide a foundation for a proper fitting of shoes and orthotics. When an individual walks, the foot acts as a lever. The muscles in the back of the leg pull up against gravity. Weight is transferred in rapid order from the anklebone to the heel bone, down the outer longitudinal arch, across the metatarsal heads, and off the big toe. Thus the body weight is propelled forward toward the ball of the foot. The center of gravity of the body is shifted to a few inches in front of the toes at a point not yet occupied by the person.

At the same time, the other foot is moved forward by the thigh and hip. The muscles in the front of the leg contract the inner longitudinal arch and prepare it to accept the weight of the body as the heel comes down in a forward motion. The muscles in the feet themselves raise the arch and act as a spring that helps support the inner longitudinal arch and increase the stability of the foot. Movement of the human foot is a coordinated action and effort by each part of its structure.

The gait cycle is divided into different phases. The following information applies to walking gait phases. However, running gait is similar to walking gait in that the same phases exist, though the percentages of time spent in each phase and stage of the phase differ between the two. Running also has an additional “float phase.”

**Phases of the Gait Cycle**

**Weight Acceptance**

- **Initial Contact:** The movement when the foot strikes the ground
  - Muscle Involvement: Anterior Tibialis (AT)
  - Muscle Function: Anterior Tibialis (AT) is a dorsiflexor and serves to decelerate plantarflexion following heel strike

- **Loading Response:** Shock is absorbed as forward momentum is preserved. A foot-flat position is achieved. AT is dorsiflexor and serves to decelerate plantarflexion following heel strike
  - Muscle and function: Posterior Tibialis works to decelerate pronation and leg rotation
Single Limb Support

- Mid-Stance: The body progresses over the foot in a controlled manner. The contralateral swing limb provides the momentum
  - Muscles and functions:
    - Peroneus Longus (PL): Stabilizes and plantarflexes the first ray when foot supinates in late mid-stance and during heel lift at terminal stance
    - Peroneus Brevis (PB): Assists PL to transfer weight from lateral to medial side

- Terminal Stance: The body progresses past the forefoot
  - Muscle and function: Posterior Tibialis accelerates subtalar joint supination and external leg rotation

Swing Limb Advancement

- Pre-Swing: The foot remains on the floor. The knee rapidly flexes while weight is shifted to the other limb
  - Muscle and function: Gastrocnemius works to provide heel lift

- Initial Swing: The thigh begins to advance; the knee continues to flex and the foot clears the ground
  - Muscles and functions:
    - Anterior Tibialis, extensor hallucis, and digitorum longus; work to dorsiflex the foot so it can clear the ground.
    - The hamstrings work to flex the knee and lift the foot off of the ground

- Mid-Swing: The thigh continues to advance as the knee begins to extend. Foot clearance is maintained
  - Muscle and action: Quadriceps muscles work to swing leg forward

- Terminal Swing: The leg reaches out to achieve step length
  - Muscles and actions:
    - Hamstrings: Deceleration of leg and foot
    - Quadriceps: Lift and swing leg forward. Stabilize knee at heel contact

Examples of common problems in gait and the gait cycle:

- Contact occurs directly on forefoot or flatfoot during weight acceptance. Weak tibialis posterior and quadriceps muscles can cause excessive forefoot contact and lead to excessive pressure on metatarsal heads
  - Corrective action: Accommodative orthotic and rocker sole
- Foot slap: usually there is some nerve involvement; muscles involved include tibialis anterior, calf and quadriceps. Occurs during weight acceptance and results in high forefoot pressure
  - Corrective action: Rocker sole
• Excessive inversion/supination: due to weak peroneals, most evident in single limb acceptance and support. Causes high pressure and ulcers on base of fifth metatarsal shaft and head
  o Corrective action: Outflare sole, lateral post
• Excessive eversion/pronation: weak posterior tibialis and sometimes anterior tibialis or soleus causes this in weight acceptance and single limb support phase. Associated with first and second metatarsal head breakdown and in advanced stages may include dropped navicular and associated ulcers
  o Corrective Action: Straight last shoe, strong heel counter and medial post on foot orthotic
• No heel lift: caused by weak calf muscles during single limb support phase
  o Corrective action: Rocker sole

Terminology

• Accomodative foot orthosis: An orthotic device designed to try to control abnormal function of the foot. They are used to cushion, pad or relieve pressure from a painful or injured area on the bottom of the foot, and can be fabricated from a three-dimensional model of the foot via taking a plaster mold of the foot, having the patient step into a box of compressible foam, or using a mechanical or optical scanner to scan the foot
• Active propulsion: The point of time in the gait cycle in which there is heel off of the support limb that ends with heel contact of the swing limb
• Angle of gait: The angle the longitudinal axis of the foot makes with the line of progression. The average gait angle is 7° toe out per side or 12° to 15° total
• Antalgic gait: Walking with a limp to minimize pain on weight bearing structures
• Base of gait: The horizontal distance from one heel strike to the next heel strike. The average base of gait is 3.4 inches
• Biomechanics: The study of motion in individuals as it relates to internal and external forces that cause or influence movement, i.e. the study of movement and physics of the physical form
• Cadence: Also known as step rate, cadence refers to the steps per minute as an individual walks. The average cadence is between 101 to 122 steps per minute, and is directly related to an individual’s height
• Compression force: A force that pushes along both ends of a structure and causes compression of the object
• Contralateral: Located on the opposite side of the body
• Double support: The phase of gait that encompasses the period of time when both feet are on the ground, and occurs twice in the gait cycle. Consists of initial double support and terminal double support
• Drop foot: A condition that results in excessive ankle plantarflexion in the terminal swing as a result of insufficient dorsiflexors
• Foot flat: The moment in time during the stance phase when the foot is flat on the ground
• Functional foot orthosis: An orthotic device used to correct abnormal foot function as well as correct for abnormal lower extremity function. There are various types and some may also attempt to accommodate painful areas on the plantum of the foot. These are generally made of flexible, semi-rigid, or rigid materials fabricated from a
three-dimensional model of the foot via taking a plaster mold of the foot, having the patient step into a box of compressible foam, or using a mechanical or optical scanner to scan the foot

- **Gait cycle**: The activity that occurs between the heel strike of one limb and the succeeding heel strike of the same limb
- **Gait stride**: The distance from initial contact of one foot to the following initial contact of the same foot
- **Gait**: The rhythmic alternating movements of the limbs of the lower extremity, which lead to the forward movement of the body
- **Ground Reaction Force (GRF)**: The force generated when the foot contacts the ground, and is equal but opposite to the force the foot applies to the ground
- **Heel-off**: A point during the stance phase when the heel leaves the ground
- **Initial contact**: The stage of gait when the foot strikes the ground and represents the beginning of the stance phase
- **Initial swing**: The stage of gait in which the thigh begins to advance; the knee continues to flex and the foot clears the ground
- **Ipsilateral**: Located on the same side of the body
- **Loading response**: In gait, refers to the initial double support stance period
- **Mid-stance phase**: The stage of gait in which the body progresses over the foot in a controlled manner and the contralateral swing limb provides the motion
- **Mid-swing**: The part of the swing stage of gait in which the thigh continues to advance as the knee begins to extend and foot clearance is maintained
- **Passive propulsion**: The point of time in the gait cycle which begins with heel contact of the swing limb and ends with toe-off of the support limb
- **Pre-swing**: The stage of gait in which the foot remains on the floor while the knee rapidly flexes and weight is shifted to the other limb
- **Push-off**: In gait, this is the period of time in which there is advancement of the limb into swing phase
- **Rocker soles**: These shoe soles are used to control motion in the ankle joint, and the metatarsalphalangeal joints. They also help reduce ground-reactive forces to the metatarsal heads, the toes, and any area of the foot over which the body propels
- **Shear force**: A force that acts parallel to a plane; the planes remain parallel, but the angles change
- **Single support**: The point in the gait cycle which consists of mid-stance and terminal stance phases, and begins with toe-off of the opposite limb and ends with heel contact of the same limb
- **Stance phase**: In gait, the period of time during which the foot is in contact with the ground. This is the weight bearing phase of gait
- **Step length**: Measured from the heel contact of one limb to the heel contact of the opposite limb. Each stride length will consist of two steps, usually of equal length
- **Stride length**: The distance between two consecutive contacts of the same foot, measured from the heel contact to one limb to the next heel contact of the same limb. The average stride length is 4.5 feet, and men have a 14% longer stride length than women
- **Swing phase**: In gait, the period of time in which the foot is off the ground and swinging forward
• **Tensile force**: A stretching force or tension that pulls at both ends of a component or structure along its length

• **Terminal stance**: The stage of gait that takes place from the time the heel rises until the other limb makes contact with the floor, and the body progresses past the forefoot

• **Terminal swing**: During the swing stage of gait, the moment when the leg reaches out to achieve step length

• **Toe-off**: When terminal contact is made with the toe

• **Windlass Mechanism**: A ‘windlass’ is a tightening of a rope or cable. In this instance it is a foot mechanism in which the plantar fascia winds around the metatarsal head when the toes dorsiflex and the heel rises off the ground. This causes the winding of the plantar fascia around the metatarsal heads and leads to elevation of the arch and shortens the distance between the calcaneus and the metatarsal heads