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# Comparison of Foot Drop patients with Normal Person by Gait Analysis

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## ABSTRACT

*The aim of the present study is to clinical gait analysis of normal human and drop foot patients. Gait analysis is the systematic study of animal locomotion, more specifically the study of human motion, using the eye and the brain of observers, augmented by instrumentation for measuring body movements, body mechanics, and the activity of the muscles. Gait analysis is used to assess, plan, and treat individuals with conditions affecting their ability to walk. Foot drop is a deceptively simple name for a potentially complex problem. It can be defined as a significant weakness of ankle and toe dorsiflexion. The foot and ankle dorsiflexors include the tibialis anterior, the extensor hallucis longus (EHL), and the extensor digitorum longus (EDL). These muscles help the body clear the foot during swing phase and control plantarflexion of the foot on heel strike.*

## Keywords

*Drop foot, ankle foot orthosis (AFO), clinical gait analysis, human motion*

## INTRODUCTION

Gait analysis is the study of walking - a detailed examination of how the skeleton and muscles work together when we walk. In the gait analysis laboratory, we study complex walking problems in adults and children. This is used in planning patient management and in evaluating outcomes of treatment. Anyone with a movement problem which affects their walking may benefit from gait analysis. It may be used to plan therapy, surgery, checks orthotic or prosthetic prescription, for research, or as a baseline record of the walking pattern

The tenuous beginnings of gait analysis are traceable to early historic times and involve a progressive evolution that represents an amazing panorama of discovery and invention. Its evolution is important to understanding the growth of certain methods and theoretical assumptions. The Greeks and Romans presented many questions concerning human movement. During the 15th and 16th centuries, Leonardo da Vinci's interest in the accuracy of painting reinvigorated the curiosity about human movement. This inspired artists to make "graceful counterbalancing and balancing in such a way so that the figure shall not appear as a piece of wood." The work of Issac Newton followed in the 17th century, with his proclamation of the three laws of motion. During the 18th century, the Weber brothers, Eduard and Wilhelm, one a mathematician and the other an anatomist, conducted the first formal biomechanical investigations. Although they listed more than 150 hypotheses, the sophisticated equipment needed to perform such experiments had not yet evolved.

The 19th and 20th centuries were times of revolution, in which industrialization transformed the environment. Technology became more firmly based in science, and science began to depend more on new technology. Etienne Jules Marey of Paris could be considered the person who changed the study of human walking from an observational to a quantifiable science. Marey was a prolific pioneer of instrumentation and was one of the first to use photography as a photogrammetric tool. In fact, Marey was the first person to synchronize kinematic and force measurement. In 1872, Eadweard Muybridge was hired by Leland Stanford, the governor of California, to investigate the question of "unsupported transit." Using Stanford's own horse, Occident,

Muybridge developed a special high-speed multiframe still camera that took a sequence of 25 photographs. His results were astonishing, revealing that all of Occident's feet left the ground at one time. Muybridge continued his work with photographs of both humans and animals and went on to publish two classic volumes, *Animals in Motion* (1899) and *The Human Figure in Motion* (1901). In 1891, Braune and Fischer applied the principles of Newtonian classic mechanics to human gait. Their methods of gait analysis have persisted to this day, with perhaps the only major difference being time components of data recordings. Braune and Fischer's data analysis took two nights to record just three walking cycles.

In 1945, Inman et al added further value to the field of gait analysis by initiating systematic collection of normal and amputee data. Separate contributions by Saunders et al, Rose and Gamble, Sutherland, Perry, and others have increased the understanding of human performance. Modern computer technology has supplemented a unique constellation of gait parameters in both normal and pathologic gait. Because of this progressive advancement in technology, several techniques have emerged to analyze gait; these techniques fall into four distinct areas and are discussed in the following section. It is beyond the scope of this article to give a detailed historical description of gait analysis, and the reader is referred to the publications by Cavanagh and Henley and Steindler.

Development of modern computer-based systems occurred independently during the late 1970s and early 1980s in several hospital-based research labs, some through collaborations with the aerospace industry.<sup>[4]</sup> Commercial development soon followed with the emergence of commercial television and later infrared camera systems in the mid-1980s.

One way to think about the phases of walking is to think of what happens to each foot when we walk. In this situation, there are two phases: Stance phase and Swing phase (Figure 1).

1. *Stance phase* is the time when the foot is on the ground. It comprises about 60% of the walking cycle. For part of the stance phase, both feet will be on the ground for a period of time.
2. *Swing Phase* occurs when one foot is on the ground and one in the air. The foot that is in the air is said to be in the "Swing" phase of gait.

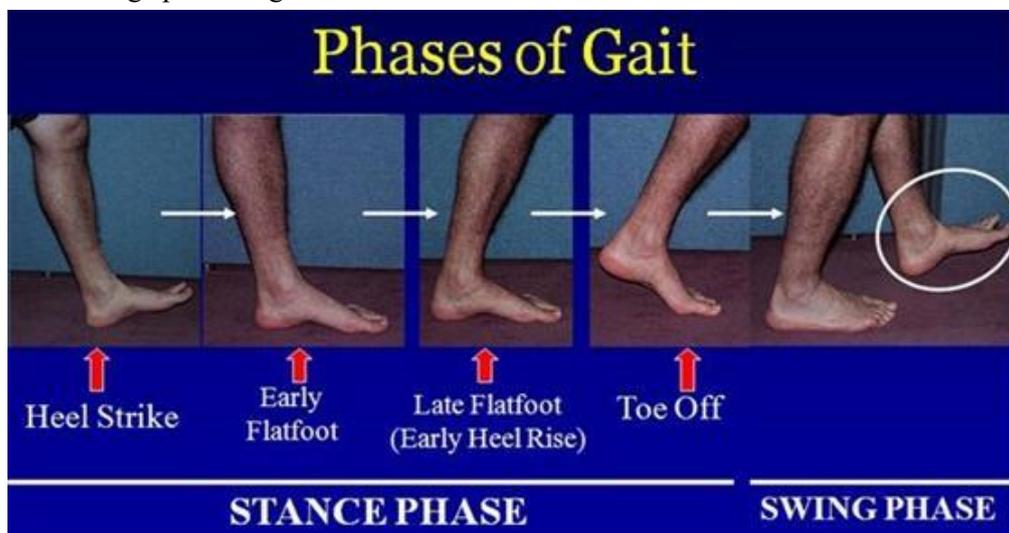


Figure 1: Phases of Gait

A more convenient and precise way to think about the stance phase (foot on the ground) of walking is to consider the five sub-stages that a single foot undergoes (Figure 1). They are as follows: Heel strike, Early flatfoot, Late flatfoot, Heel rise, and Toe-off.

### Heel Strike

The heel strike phase starts the moment when the heel first touches the ground and lasts until the whole foot is on the ground (early flatfoot stage).

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### Early flatfoot

The beginning of the “early flatfoot” • stage is defined as the moment that the whole foot is on the ground. The end of the “early flatfoot” □ stage occurs when the body’s center of gravity passes over the top of the foot. The body’s center of gravity is located approximately in the pelvic area in front of the lower spine when we stand and walk. The main purpose of the “early flatfoot” • stage is to allow the foot to serve as a shock absorber, helping to cushion the force of the body weight landing on the foot.

### Late flatfoot

Once the body’s center of gravity has passed in front of the neutral position, a person is said to be in the late flatfoot stage. The “late flatfoot” stage of gait ends when the heel lifts off the ground. During the “late flatfoot” • phase gait, the foot needs to go from being a flexible shock absorber to being a rigid lever that can serve to propel the body forward.

### Heel rise

As the name suggests, the heel rise phase begins when the heel begins to leave the ground. During this phase, the foot functions as a rigid lever to move the body forward. During this phase of walking, the forces that go through the foot are quite significant: often 2-3x a person’s body weight. This is because the foot creates a lever arm (centered on the ankle), which serves to magnify body weight forces. Given these high forces and considering that the average human takes 3000-5000 steps per day (an active person commonly takes 10,000 steps/day), it is not surprising that the foot can easily develop chronic repetitive stress-related problems, such as metatarsalgia, bunions, posterior tibial tendon dysfunction, peroneal tendonitis, and seasmoditis.

### Toe off

The toe-off stage of gait begins as the toes leave the ground. This represents the start of the swing phase. The defining difference between walking and running is that during running, there is a period of time when both feet are off the ground (the “float” • phase). Also because running is associated with greater speeds, the forces that go through the foot when it lands can be substantially greater than during walking (often 4-5x body weight during running and even up to 6-7x body weight during sprinting).

### Title and Authors

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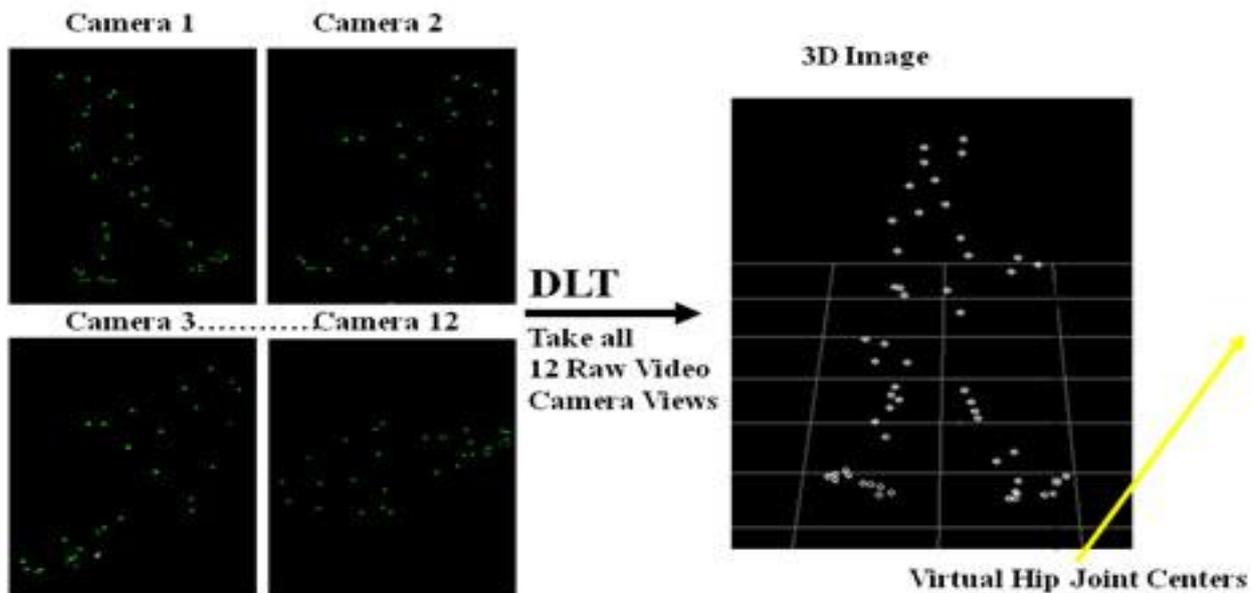
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### METHOD

A typical gait analysis laboratory has several cameras (video and / or infrared) placed around a walkway or a treadmill, which are linked to a computer. The patient has markers located at various points of reference of the body (e.g., iliac spines of the pelvis, ankle malleolus, and the condyles of the knee), or groups of markers applied to half of the body segments. The patient walks down the catwalk or the treadmill and the computer calculates the trajectory of each marker in three dimensions. A model is applied to calculate the movement of the underlying bones. This gives a complete breakdown of the movement of each joint. One common method is to use Helen Hayes Hospital marker set, in which a total of 15 markers are attached on the lower-body. The 15 marker motions are analyzed analytically, and it provides angular motion of each joint.

To calculate the kinetics of gait patterns, most labs have floor-mounted load transducers, also known as force platforms, which measure the ground reaction forces and moments, including the magnitude, direction, and location (called the center of pressure). The spatial distribution of forces can be measured with pedobarography equipment. Adding this to the known dynamics of each body segment enables the solution of equations based on the Newton–Euler equations of motion permitting computations of the net forces and the net moments of force about each joint at every stage of the gait cycle. The computational method for this is known as inverse dynamics.

This use of kinetics, however, does not result in information for individual muscles but muscle groups, such as the extensor or flexors of the limb. To detect the activity and contribution of individual muscles to movement, it is necessary to investigate the electrical activity of muscles. Many labs also use surface electrodes attached to the skin to detect the electrical activity or electromyogram (EMG) of, for example, muscles of the leg. In this way it is possible to investigate the activation times of muscles and, to some degree, the magnitude of their activation—thereby assessing their contribution to gait. Deviations from normal kinematic, kinetic, or EMG patterns are used to diagnose specific pathologies, predict the outcome of treatments, or determine the effectiveness of training programs



**Figure 2 :-** Acquisition of information on the position of the markers in 2D through the chambers of the left and right, this combination of information gives rise to a 3D image on the position of the markers

### Foot drop:

Foot drop, sometimes called drop foot, is a general term for difficulty lifting the front part of the foot. If you have foot drop, you may drag the front of your foot on the ground when you walk. Foot drop isn't a disease. Rather, foot drop is a sign of an underlying neurological, muscular or anatomical problem. Sometimes foot drop is temporary. In other cases, foot drop is permanent. If you have foot drop, you may need to wear a brace on your ankle and foot to hold your foot in a normal position.

### Symptoms:

Foot drop makes it difficult to lift the front part of your foot, so it might drag on the floor when you walk. To counter this, you might raise your thigh when you walk as if you were climbing stairs (steppage gait), to help your foot clear the floor. This odd gait might cause you to slap your foot down onto the floor with each step you take. In some cases, the skin on the top of your foot and toes may feel numb. Foot drop typically affects only one foot. Depending on the underlying cause, however, it's possible for both feet to be affected.

### Causes :-

Foot drop is caused by weakness or paralysis of the muscles involved in lifting the front part of the foot. The underlying causes of foot drop are varied and may include:

- Nerve injury. The most common cause of foot drop is compression of a nerve in your leg that controls the muscles involved in lifting the foot. This nerve can also be injured during hip or knee replacement surgery, which may cause foot drop. A nerve root injury ("pinched nerve") in the spine can also cause foot drop. People who have diabetes are more susceptible to nerve disorders, which are associated with foot drop.

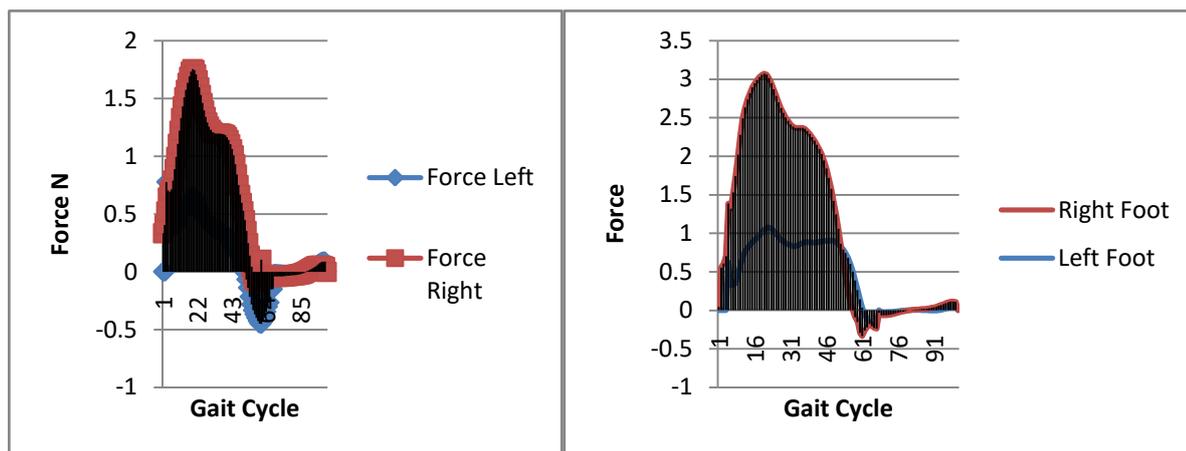
- Muscle or nerve disorders. Various forms of muscular dystrophy, an inherited disease that causes progressive muscle weakness, may contribute to foot drop. Other disorders, such as polio or Charcot-Marie-Tooth disease, also can cause foot drop.
- Brain and spinal cord disorders. Disorders that affect the spinal cord or brain — such as amyotrophic lateral sclerosis (ALS), multiple sclerosis or stroke — may cause foot drop.

**Ankle Foot Orthosis (AFO):**

The AFO is used to treat various neuromuscular (nerve and muscle) diseases and disorders and to also provide functionality after an injury or a surgery. AFOs aim is to eliminate the problems related to foot-to-ground placement that affect foot clearance and heel contact. It is also prescribed to restore stability to the foot during the swing and stance phases of walking, and to compensate for thigh muscle weakness so that the knee does not buckle due to weakness. Our CPO orthotists evaluate your condition and then fit you with the appropriate ankle foot orthosis. Depending on your condition, you could be fitted with a Static AFO, Dynamic AFO, Foot Drop Splint, Hinged Ankle AFO, Flexible AFO, Tubular AFO, Gauntlet AFO or Fixed AFO. CPO provides you with customised and fabricated AFOs that suit your particular and specific needs.

**Results & Discussion**

Sr .No	Human Gait Parameters	Normal Person	Drop Foot Patients
1.	Stride Time	1.1	1.31
2.	Stance Time	0.65	0.8
3.	Swing time	0.44	0.51
4.	Stride Length	1.36	1.1
5.	Step Length	0.62	0.58
6.	Mean Velocity	1.2	0.8
7.	Gait Deviation Index	≥100	70.84



**Figure 3** (a)Force of Drop Foot Patients (b) With Ankle Foot Orthosis

**Conclusion :**

The ability to walk upright is a key functional activity which, when performed abnormally, impacts adversely on activities of daily living. The clinical evaluation of gait abnormalities, performed in conjunction with a thorough history and physical examination, is an important undertaking. These gait abnormalities result from various neuromusculoskeletal disorders and can often be detected during the screening evaluation. Making the

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proper diagnosis is important in allowing for appropriate rehabilitation and orthotic strategies. Occasionally, for managing complicated spasticity or for determining surgical correction, a formal gait laboratory evaluation may be necessary.

## REFERENCES

- [1] ANDRIACCHI TP, ALEXANDER EJ, 2000: Studies of human locomotion: past, present and future. *J Biomech* 33: 1217.
- [2] ABOUND RJ, 2002: Mini-symposium: the elective foot: relevant foot biomechanics. *Curr Orthop* 16: 165.
- [3] BECKETT ME, MASSIE DL, BOWERS KD, ET AL, 1992: Incidence of hyperpronation in the ACL injured knee: a clinical perspective. *J Athl Train* 27: 58.
- [4] BONCI C, 1999: Assessment and evaluation of predisposing factors to anterior cruciate ligament injury. *J Athl Train* 34: 155.
- [5] CAVANAGH PR, HENLEY JD, 1993: The computer era in gait analysis. *Clin Podiatr Med Surg* 10: 471.
- [6] DAVIS R, OUNPUU S, TYBURSKI D, ET AL, 1991: "A Comparison of Two Dimensional and Three Dimensional Techniques for the Determination of Joint Angles," in Proceedings of the First International Symposium on 3-D Analysis of Human Movement, International Society of Biomechanics.
- [7] DELUCA PA, 1989: The use of gait analysis and dynamic electromyogram in the assessment of the child with cerebral palsy. *Semin Orthop* 4: 256.
- [8] DORLAND NW, NOVAK PD, 1995: *Dorland's Pocket Medical Dictionary*, 25th Ed, WB Saunders, Philadelphia.
- [9] HOLZREITER SH, KÖHLE ME, 1993: Assessment of gait patterns using neural networks. *J Biomech* 26: 645.
- [10] NHS EXECUTIVE, 1998: *A First Class Service: Quality in the New NHS*, Department of Health, Leeds, England.
- [11] PERRY JE, 1992: *Gait Analysis: Normal and Abnormal Pathological Function*, Slack, Thorofare, NJ.
- [12] SUTHERLAND DH, OLSHEN R, BIDEN E, ET AL, 1988: *The Development of Mature Walking*, Cambridge University Press, London.
- [13] SALEH M, MURDOCH G, 1985: Defence of gait analysis. *J Bone Joint Surg Br* 67: 237.
- [14] TOMARO J, BURDETT RG, 1993: The effects of foot orthotics on the EMG activity of selected leg muscles during gait. *J Orthop Sports Phys Ther* 18: 532.
- [15] TRIMBLE MH, BISHOP MD, BUCKLEY BD, ET AL, 2002: The relationship between clinical measurements of lower extremity posture and tibial translation. *Clin Biomech* 17: 286.
- [16] VAUGHAN CL, 2003: Theories of bipedal walking: an odyssey. *J Biomech* 36: 513.
- [17] WATERS R, MULROY A, 1999: The energy expenditure of normal and pathologic gait. *Gait Posture* 9: 207.
- [18] WHITTLE MW, 1996: Clinical gait analysis: a review. *Hum Movement Sci* 15: 369.