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SOME THEORETICAL ASPECTS ABOUT NORMAL CYCLE GAIT

Ciprian Radu
Department of Fine Mechanics and Mechatronics
Transilvania University of Braşov
Vlad Țepeş 16 Street, 500036 Brasov 1
Romania

ABSTRACT
This article briefly outlines the conceptual basis of biomechanics analysis and discusses a number of the key technical considerations involved, specifically from the standpoint of effective modeling of biomechanical systems. The purpose of this paper is to perform a biomechanical theoretically analysis of a human cycle gait. This analysis will be the material base for next future research, where it will be analyzed the human cycle gait by using a Kistler force plate.
Keywords: force plate, normal gait, stance phase, swing phase

1. INTRODUCTION
The science of human motion analysis is fascinating because of its highly interdisciplinary nature and wide range of applications. Histories of science usually begin with the ancient Greeks, who first left a record of human inquiry concerning the nature of the world in relationship to our powers of perception. Aristotle (384-322 B.C.) might be considered the first biomechanician. He wrote the book called «De Motu Animalium - On the Movement of Animals». He not only saw animals' bodies as mechanical systems, but pursued such questions as the physiological difference between imagining performing an action and actually doing it.
Many different disciplines use motion analysis systems to capture movement and posture of the human body. Basic scientists seek a better understanding of the mechanisms that are used to translate muscular contractions about articulating joints into functional accomplishment, e.g. walking. Increasingly, researchers endeavor to better appreciate the relationship between the human motor control system and gait dynamics.
In the realm of clinical gait analysis, medical professionals apply an evolving knowledge base in the interpretation of the walking patterns of impaired ambulators for the planning of treatment protocols, e.g. orthotic prescription and surgical intervention and allow the clinician to determine the extent to which an individual's gait pattern has been affected by an already diagnosed disorder [1].

2. BIOMECHANICS OF THE GAIT (WALKING) CYCLE
There are two major abilities essential to walking.
The first, **equilibrium**, is the ability to assume an upright posture and maintain balance.
Locomotion, the ability to initiate and maintain rhythmic stepping, is the second. However, although these two abilities are essential, there are many additional contributing factors involved. The musculoskeletal system must provide intact bones and well functioning joints as well as adequate muscle strength. Normal muscle tone is very important and is controlled at the subcortical level. Muscle tone must be high enough to resist gravity, but low enough to allow movement. Reciprocal innervation of muscles allows for graded action between agonist and antagonist necessary for skilled movements.
Vision is also vital to normal walking. It is particularly important when other sensory input is reduced. Vision gives information about the movement of the head and body relative to the

surroundings and is important for the automatic balance responses to changes in surface conditions. Other sensory systems that are important are the vestibular, auditory and sensorimotor systems [5][7].
The gait cycle is the period of time between any two identical events in the walking cycle. Any event could be selected as the onset of the gait cycle because the various events follow each other continuously and smoothly. Initial contact, however, generally has been selected as the starting and completing event.
By contrast, the gait stride is the distance from initial contact of one foot to the following initial contact of the same foot.
Each gait cycle is divided into two periods, **stance** and **swing** (figure 1). A full gait cycle is described as the undertaking of both stance and swing phases by one limb.

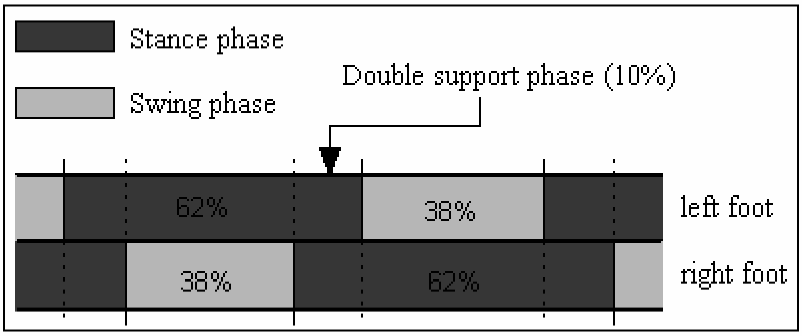

Figure 1. Gait cycle divided into two periods, stance and swing [4].

Stance is the time when the foot is in contact with the ground, constituting 62 percent of the gait cycle (figure 1). This phase is broken down into three distinct phases [1][2][3][8]:

- *Contact* - is the cushioning phase of the gait cycle. At this time the knee flexes immediately prior to the foot hitting the ground and the foot pronates or rolls in. The beginning of the contact phase of gait is signaled by the instance of heel strike. The end of the contact period is signaled by the instant the forefoot makes contact. This event is called foot flat and it marks the beginning of the mid stance phase of stance. The contact period lasts for about 25% of the total time the foot is in contact with the ground (figure 2. a);
- *Mid stance* - is the time when the foot and leg provide a stable platform for the body weight to pass over. If the foot is still pronating at this time there is too much movement and instability. During mid stance the other foot is in swing phase and so all the body weight is born on the stance limb alone. This means that mid stance is a time when lower limb is particularly susceptible to injury. Mid stance is also the longest phase of the stance period and it lasts approximately 50% of the total stance period (figure 2. b).
- *Propulsion* - is the final stage of the stance phase of gait. Propulsion begins immediately as the heel lifts. As the big toe dorsi flexes the windlass mechanism comes into play, tightening the plantarfascia and helping to raise the arch of the foot. The foot should be supinated during propulsion allowing the bones of the mid foot to brace against each other and producing a rigid structure capable of propelling the body weight forwards (figure 2. c).

a) b) c)

Figure 2. Distinct phases of the stance: a) contact phase; b) mid stance phase; c) propulsion phase.

Swing denotes the time when the foot is in the air, constituting the remaining 38 percent of the gait cycle (figure 1). The swing phase begins when the foot is lifted from the floor until the heel is placed down. While walking the thorax rotates in clockwise and counterclockwise directions opposite the pelvic rotations. Some people display more rotation of the thorax, while others display more rotation of the pelvis. With each step the pelvis drops a few degrees on the side of the non-weightbearing, or swinging, leg. While the leg is swinging, the hip abductors of the weightbearing leg contract in order to prevent the pelvis from falling excessively on the unsupported side.

This phase is broken down into four distinct phases [2][3][4][5][8]:

- *Preswing* (figure 3. a) – begins with the initial contact of the blue foot and ends with red toe-off. During preswing, the ankle moves rapidly from its dorsiflexion position at terminal stance to 20 degrees of plantarflexion. Although the ankle reaches its angular peak of plantarflexion during this period, actual plantarflexor activity is decreased in intensity, as the limb is unloaded. In late preswing, the vertical force is diminished, and the plantarflexors are quiescent.
- *Initial swing* (figure 3. b) - begins when the foot is lifted from the floor and ends when the swinging foot is opposite the stance foot. The initial one-third of the swing period, from the 62- to 75-percent periods of the gait cycle, is spent in initial swing. It begins the moment the foot leaves the ground and continues until maximum knee flexion occurs, when the swinging extremity is directly under the body and directly opposite the stance limb.
- *Midswing* (figure 3. c) - continues from the end point of the initial swing and continues until the swinging limb is in front of the body and the tibia is vertical. The knee is allowed to extend in response to gravity while the ankle continues dorsiflexion to neutral. The blue leg is in late mid-stance.
- *Terminal swing* (figure 3. d) - begins when the tibia is vertical and ends when the foot touches the floor. Limb advancement is completed by knee extension.

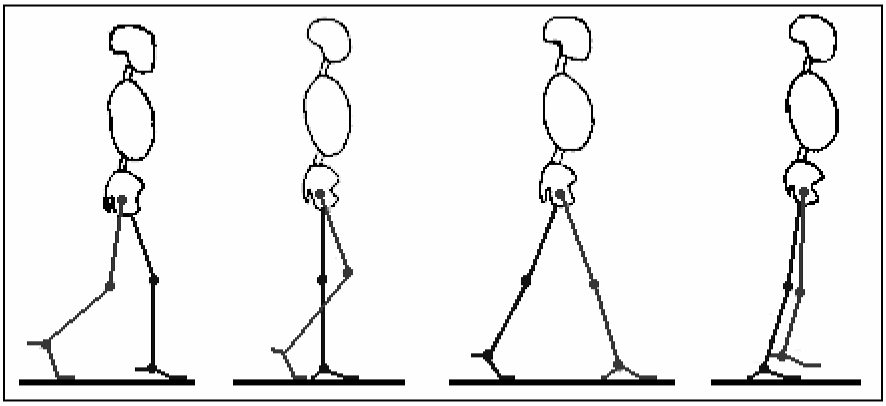

Figure 3. Distinct phases of the swing: a) preswing; b) initial swing; c) midswing; d) terminal swing.

There are times when both feet are on the ground. This phase is called ***double limb support*** occurs when both feet are on the ground. Double limb support occurs for two periods of 10% of the gait cycle in a normal walk (figure 1). Double limb support occurs between heel strike of the limb and toe off of the contralateral limb.

During the stance phase of gait, weight passes through the ankle and then through the stable bones of the foot to the ground. The average direction of forces passing through the foot to the ground can be plotted at each instant of time during stance phase. A line connecting each point in time is called a force curve (gait line). The force curve represents the direction in which weight is transmitted through the foot during the stance phase (figure 4).

In the normal functioning foot, the force curve has three components. They are the pronatory curve (from A-E above), the supinatory curve (from E-F above), and the straight propulsive line (from G-H above). From point F-G above, heel lift everts the forefoot to bring force from the fifth met head to the first. So the motion for F to G is the rear foot supinating and the forefoot pronating [5].

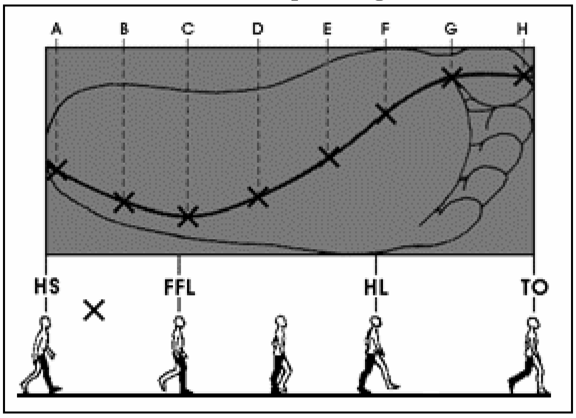

Figure 4. The force curve of the weight transmitted through the foot during stance phase.

Weight is first received by the lateral side of the heel because the foot is slightly supinated as it contacts the ground. The foot immediately begins to pronate and in normal gait, pronates until about 22% of the stance phase. Weight is then received by the medial side of the heel, then the 5th metatarsal head, and then the forefoot loads from a lateral to medial direction. As the foot unloads, the heel unloads first, then the metatarsals and toes begin to unload from lateral to medial, and the hallux is the last to unload at toe-off.

Pronation shifts weight to the medial side of the foot, and supination shifts weight toward the lateral side. Line A-B represents the lateral thrust of weight caused by the supinated position of the foot at heel strike. Pronation then shifts weight medially in a curve (curved line B-E). Supination of the foot during propulsion then reverses the weight thrust (curve E-G), and weight is finally directed down the long axis of the hallux at toe-off [5].

3. CONCLUSIONS

Normal bipedal gait is achieved with a complex combination of automatic and volitional postural components. Normal walking requires stability to provide antigravity support of body weight, mobility of body segments and motor control to sequence multiple segments while transferring body weight from one limb to another. The result is energy-efficient forward progression.

4. REFERENCES

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