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# A REVIEW OF GAIT CYCLE AND ITS PARAMETERS

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**Abstract**

Biometrics refers to as scientific and technological measurements of either physiological or behavioral human characteristics. e.g. fingerprints, face, iris, hand geometry, voice and gait etc. Gait is a behavioral biometric and is defined as the manner of walking. It includes both the body appearance and dynamics of human walking motion. When it is not feasible to take facial snapshots, finger prints, to record voice or to read hand geometry then gait may be proved as an effective tool to recognize a person. This paper describes a brief of gait, gait cycle and its phases.

***Keywords:*** *gait, stance, swing, gait cycle, stride, cycle time, step length.*

## 1. INTRODUCTION

Walking [1-2] can be defined as 'a method of locomotion involving the use of the two legs, alternately, to provide both support and propulsion'.

Formally walking uses a repetitious sequence of limb motion to move the body forward while simultaneously maintaining stance stability. There are three ways to divide the gait into sub phases:

1. According to the variations in reciprocal floor.
2. The time and distance qualities of the stride.
3. Identify the functional significance of the events within the gait cycle.

Gait represents the manner of walking.

## 2. GAIT CYCLE AND ITS PHASES

As the [7]body moves forward, one limb act as source of support while the other limb advances itself to a new support site. Then the limbs reverse their roles. This series of events is repeated by each limb with reciprocal timing until the person's destination is reached. A single sequence of these functions by one limb is called a *gait cycle* (GC). Normal persons initiate floor contact with their heel (i.e., heel strike).

Each gait cycle is divided into two periods, stance and swing also known as gait phases (fig. 1). *Stance* is the term used to designate the entire period during which the foot is on the ground. Stance begins with initial contact. The word *swing* applies to the time the foot is in the air for limb advancement. Swing begins as the foot is lifted from the floor (toe-off).

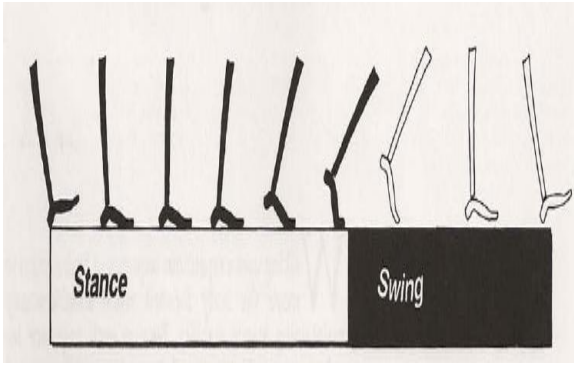


Figure 1: Gait Phases

Hence *gait cycle* can be defined as the time interval between two successive occurrences of one of the repetitive events of walking. The following terms are used to identify major events during the gait cycle (fig. 2):

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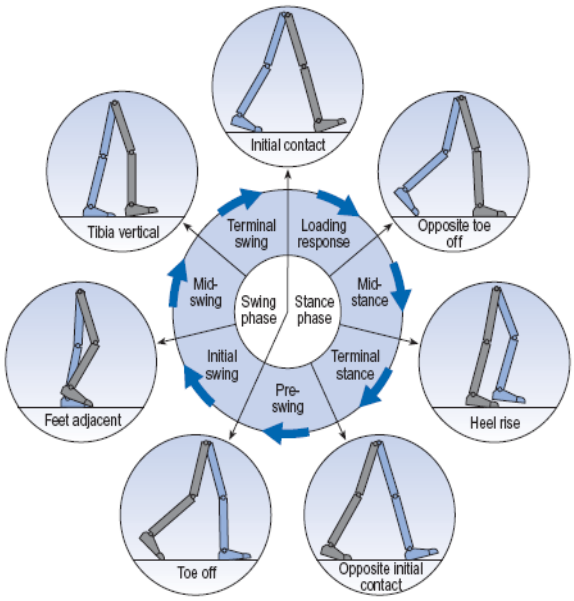


Figure 2: Events in a Gait Cycle[8]

1. Initial contact
2. opposite toe off
3. Heel rise
4. opposite initial contact
5. Toe off
6. Feet adjacent
7. Tibia vertical

These seven events subdivide the gait cycle into seven periods, four of which occur in the stance phase, when the foot is on the ground, and three in the swing phase, when the foot is moving forward through the air.

The stance phase also known as 'support phase' or 'contact phase', lasts from initial contact to toe off. It is subdivided into:

1. Loading response
2. Mid-stance
3. Terminal stance
4. Pre-swing.

The swing phase lasts from toe off to the next initial contact. It is subdivided into:

1. Initial swing
2. Mid-swing
3. Terminal swing.

The duration of a complete gait cycle is known as the *cycle time*, which is divided into *stance time* and *swing time*.

## 3. GAIT CYCLE TIME

Right initial contact occurs while the left foot is still on the ground and there is a period of *double support* (also known as 'double limb stance') between initial contact on the right and toe off on the left. During the swing phase on the left side, only the right foot is on the ground, giving a period of *right single support* (or 'single limb stance'), which ends with initial contact by the left foot. There is then another period of double support, until toe off on the right side. *Left single support* corresponds to the right swing phase and the cycle ends with the next initial contact on the right.

In each double support phase, one foot is forward, having just landed on the ground, and the other one is backward, being just about to leave the ground. The leading leg is in 'loading response', sometimes referred to as 'braking double support', 'initial double support' or 'weight acceptance'. The trailing leg is in 'pre-swing', also known as 'second', 'terminal' or 'thrusting' double support or 'weight release'.

In each gait cycle, there are thus two periods of double support and two periods of single support. The stance phase usually lasts about 60% of the cycle, the swing phase about 40% and each period of double support about 10%. However, this varies with the speed of walking, the swing phase becoming proportionately longer and the stance phase and double support phases shorter, as the speed increases [4]. The final disappearance of the double support phase marks the transition from walking to running. Between successive steps in running there is a *flight phase*, also known as the 'float', 'double-float' or 'non-support' phase, when neither foot is on the ground.

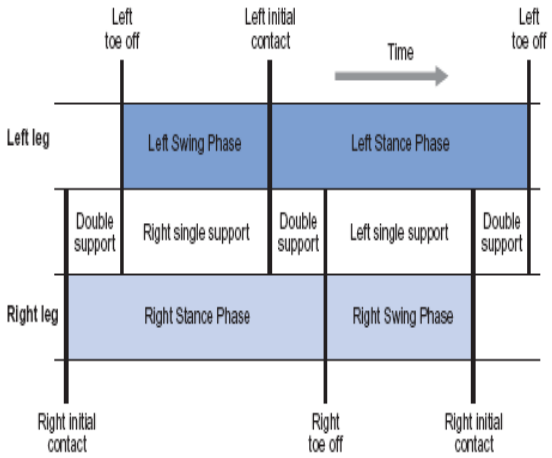


Figure 3: Sub phase Of Stance and Swing[8]

The terms used to describe the placement of the feet on the ground are:

- The *stride length* is the distance between two successive placements of the same foot. It consists of two *step lengths*, left and right, each of which is the distance by which the named foot moves forward in front of the other one. If the left foot is moved forward to take a step and the right

one is brought up beside it, rather than in front of it, the right step length will be zero. It is even possible for the step length on one side to be negative, if that foot never catches up with the other one. This definition of a 'stride', consisting of one 'step' by each foot, breaks down in some pathological gaits, in which one foot makes a series of 'hopping' movements while the other is in the air [3].

- The *walking base* (also known as the 'stride width' or 'base of support') is the side-to-side distance between the line of the two feet, usually measured at the midpoint of the back of the heel but sometimes below the center of the ankle joint. The pattern of walking known as 'tandem gait' involves walking with the heel of one foot placed directly in front of the toes of the other, i.e. with a walking base close to zero.
- The *toe out [5]* (or, *toe in*) is the angle in degrees between the direction of progression and a reference line on the sole of the foot. The reference line varies from one study to another; it may be defined anatomically but is commonly the midline of the foot, as judged by eye.

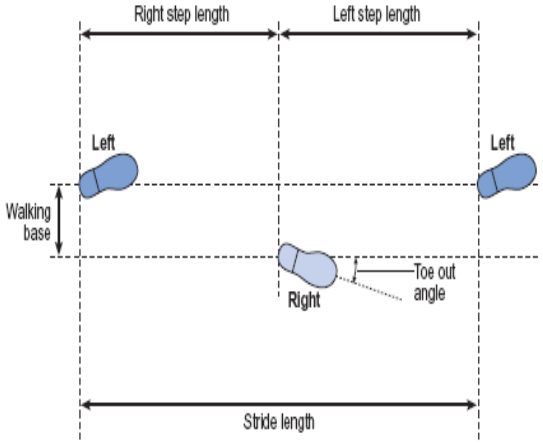


Figure 4: stride and step length

## 4. GAIT PARAMETERS

- The *cadence* is the number of steps taken in a given time, there are two steps in a single gait cycle, and the cadence is a measure of half-cycles.

The *cycle time*, also known as the 'stride time', in seconds:

**cycle time (s) = 120/cadence (steps/min) eq (1)**

- *Walking speed* is the distance covered in a given time. The instantaneous speed varies from one instant to another during the walking cycle, but the average speed is the product of the cadence and the stride length. The cadence, in steps per minute, corresponds to half-strides per 60 seconds or full strides per 120 seconds. The speed can be calculated using the formula:

**speed (m/s) = stride length (m) × cadence steps/min)/120 eq(2)**

If cycle time is used in place of cadence, the calculation becomes much more straightforward:

**speed (m/s) = stride length (m)/cycle time (s) eq(3)**

The walking speed thus depends on the two step lengths, which in turn depend to a large extent on the duration of the swing phase on each side. When pathology affects one foot more than the other, an individual will usually try to spend a shorter time on the 'bad' foot and correspondingly longer on the 'good' one. Shortening the stance phase on the 'bad' foot means bringing the 'good' foot to the ground sooner, thereby shortening both the duration of the swing phase and the step length on that side. Thus, a short step length on one side generally means problems with single support on the *other* side.

## 5. PHASES OF GAIT

In order to[6] provide the basic functions required for walking, each stride involves an ever-changing alignment between the body and the supporting foot during stance and selective advancement of the limb segments in swing. These reactions result in a series of motion patterns performed by the hip, knee and ankle. Each stride contains eight functional patterns. Technically these are sub phases, as the basic divisions of the gait cyc1e are stance and swing, but common practice also calls the functional intervals *phases.*

Analysis of a person's walking pattern by phases more directly identifies the functional significance of the different motions occurring at the individual joints. The phases of gait also provide a means for correlating the simultaneous actions of the individual joints into patterns of total limb function. This is a particularly important

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approach for interpreting the functional effects of disability. The relative significance of one joint's motion compared to the other's varies among the gait phases. Also, a posture that is appropriate in one gait phase would signify dysfunction at another point in the stride, because the functional need has changed. As a result, both timing and joint angle are very significant. This latter fact adds to the complexities of gait analysis.

Each of the eight gait phases has a functional objective and a critical pattern of selective synergistic motion to accomplish this goal. The sequential combination of the phases also enables the limb to accomplish three basic tasks. These are weight acceptance (WA), single limb support (SLS) and limb advancement (LA).

Weight acceptance begins the stance period and uses the first two gait phases (initial contact and loading response). Single limb support continues stance with the next two phases of gait (mid stance and terminal stance). Limb advancement begins in the final phase of stance (pre-swing) and then continues through the three phases of swing (initial swing, mid swing and terminal swing).

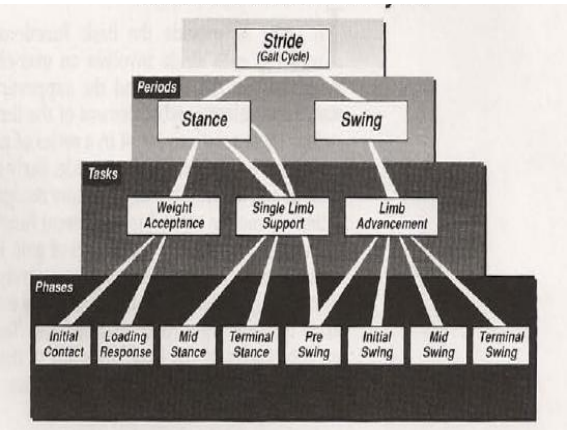


Figure 5: Division of Gait Phases

### 5.1 Weight Acceptance

This is the most demanding task in the gait cycle. Three functional patterns are needed: shock absorption, initial limb stability and the preservation of progression. The challenge is the abrupt transfer of body weight onto a limb that has just finished swinging forward and has an unstable alignment. In this task Two gait Phases are involved, initial contact and loading response.

**Phase l-Initial Contact**

In this phase the hip is flexed, the knee is extended; the ankle is dorsiflexed to neutral. Floor contact is made with the heel. Shading indicates the reference limb. The other limb (clear) is at the end of terminal stance.

This phase includes the moment when the foot just touches the floor. The joint postures present at this time determine the limb's loading response pattern.

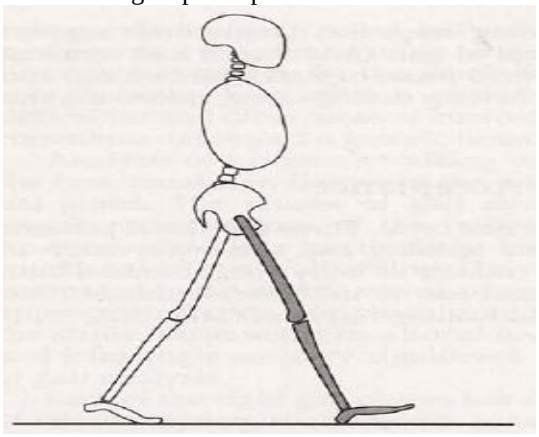

Figure 6: Initial Contact

**Phase 2-Loading Response**

In this phase the Body weight is transferred onto the forward limb. Using the heel as a rocker, the knee is flexed for shock absorption. Ankle plantar flexion limits the heel rocker by forefoot contact with the floor. The opposite limb (clear) is in its pre-swing phase.

This is the initial double stance period. The phase begins with initial floor contact and continues until the other foot is lifted for swing.

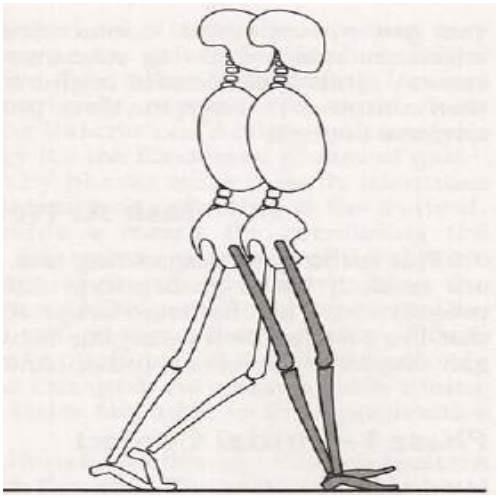

Figure 7: Loading Response.

### 5.2 Single Limb Support

Lifting the other foot for swing begins the single limb support interval for the stance limb. This continues unti1 the opposite foot again contacts the floor. During the

resulting interval, one limb has the total responsibility for supporting body weight in both the sagittal and coronal planes while progression must be continued. Two phases are involved in single limb support: mid stance and terminal stance. They are differentiated primarily by their mechanisms of progression.

**Phase 3-Mid Stance**

In the first half of single limb support, the limb advances over the stationary foot by ankle dorsiflexion (ankle rocker) while the knee and hip extend. The opposite limb is advancing in its mid swing phase. This is the first half of the single limb support interval. It begins as the other foot is lifted and continues until body weight is aligned over the forefoot.

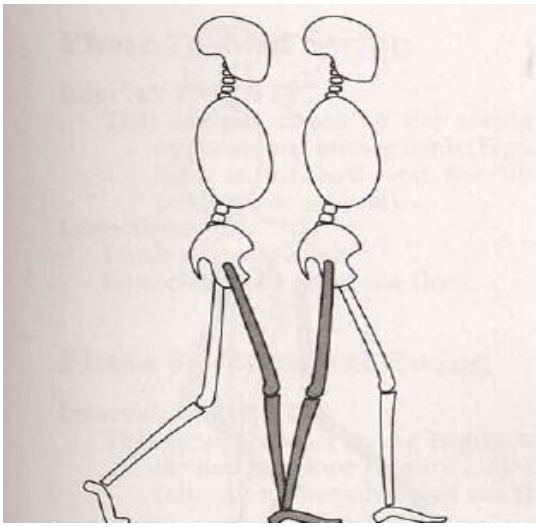

Figure 8: Mid Stance.

**Phase 4- Terminal Stance**

During the second half of single limb support, the heel rises and the limb advances over the forefoot rocker. The knee increases its extension and then just begins to f1ex slightly. Increased hip extension puts the limb in a more trailing position. The other limb is in terminal swing.

This phase completes single limb support. It begins with heel rise and continues until the other foot strikes the ground. Throughout this phase body weight moves ahead of the forefoot.

**5.3 Limb Advancement**

To meet the high demands of advancing the limb, preparatory posturing begins in stance. Then the limb swings through three postures as it lifts itself, advances and prepares for the next stance interval. Four gait phases are involved: pre-swing (end of stance), initial swing, mid swing and terminal swing.

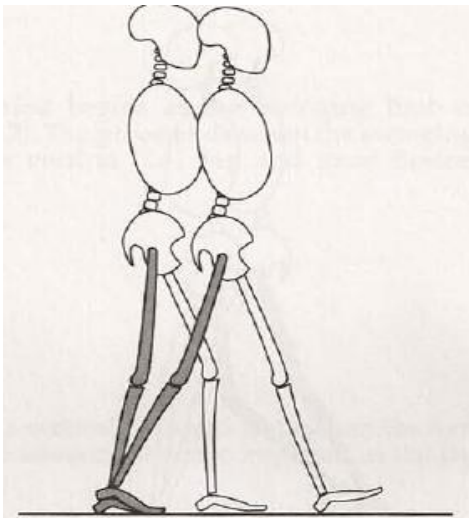

Figure 9: Terminal Stance.

**Phase 5-Pre-Swing**

Floor contact by the other limb has started terminal double support. The reference limb responds with increased ankle plantar flexion. Greater knee flexion and loss of hip extension. The opposite limb is in Loading Response.

This final phase of stance is the second (terminal) double stance interval in the gait cyc1e. It begins with initial contact of the opposite limb and ends with ipsilateral toe-off. This phase is also known as *Weight release* and *weight transfer phase*. While the abrupt transfer of body weight promptly unloads the limb, this extremity makes no active contribution to the event. Instead, the unloaded limb uses its freedom to prepare for the rapid demands of swing. All the motions and musc1e actions occurring at this time relate to this latter task.

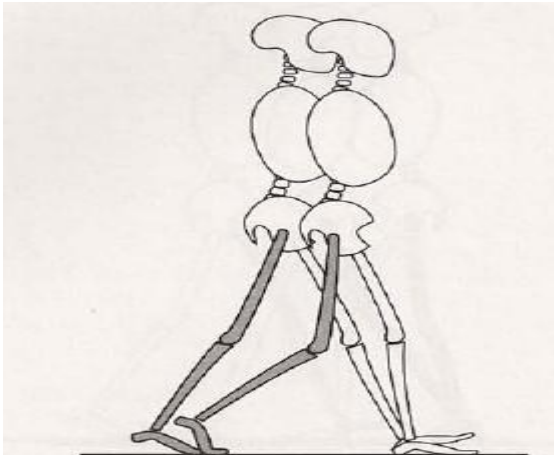

Figure 10: Pre-Swing.

**Phase 6-Initial Swing**

The foot is lifted and limb advanced by hip flexion and increased knee flexion. The ankle only partially dorsiflexes. The other limb is in early mid stance.

This first phase is approximately one-third of the swing period .It begins with lift of the foot from the floor and ends when the swinging foot is opposite the stance foot.

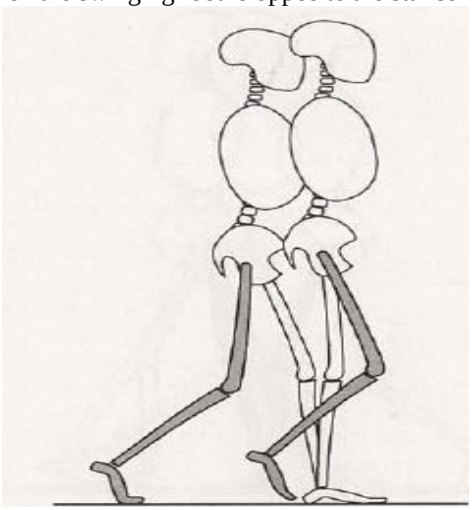

Figure 11: Initial Swing.

**Phase 7-Mid Swing**

Advancement of the limb anterior to the body weight line is gained by further hip flexion. The knee is allowed to extend in response to gravity while the ankle continues dorsiflexing to neutral. The other limb is in late mid stance. This second phase of the swing period begins as the swinging limb is opposite the stance limb. The phase ends when the swinging limb is forward and the tibia is vertical (i.e., hip and knee flexion postures are equal).

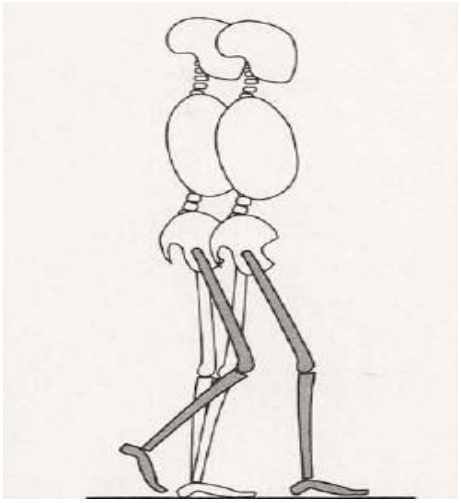

Figure 12: Mid Swing.

**Phase 8- Terminal Swing**

Limb advancement is completed by knee flexion. The hip maintains its earlier flexion. And the ankle remains dorsiflexed to neutral. The other limb (clear) is in terminal stance.

This final phase of swing begins with a vertical tibia and ends when the foot strikes the floor. Limb advancement is completed as the leg (shank) moves ahead of the thigh.

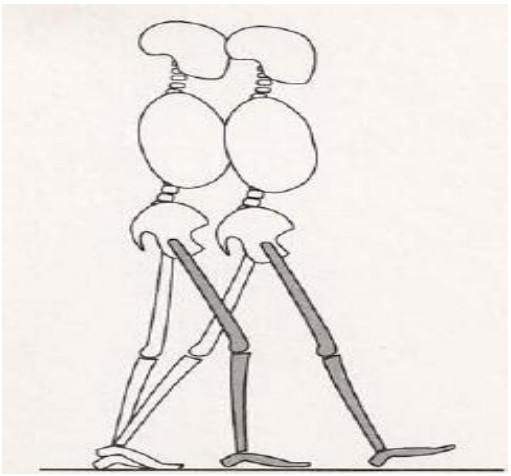

Figure 13: Terminal Swing.

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