Basics of Human Gait Analysis

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Abstract. Gait analysis is the systematic study of locomotion, particularly focusing on human movement. It combines observations made by trained individuals with instrumentation that measures body movements, mechanics, and muscle activity. Gait analysis is employed to assess and treat individuals whose ability to walk is impacted by various conditions. This field encompasses the measurement, presentation, and investigation of quantifiable aspects of walking, as well as the interpretation of individual gait patterns. The fundamental ideas and language needed to comprehend human gait are covered in this chapter. The human gait cycle and the types of human gait parameter monitoring and assessment are provided. As each topic is covered in the subsequent chapters, the resources presented in this chapter will be utilized repeatedly.

Keywords: Human Gait, Gait Cycle, Gait Analysis, Observational Gait Analysis

1 Terminology

This chapter presents the fundamentals of gait analysis, including the human gait cycle, gait parameters, gait disturbance, and gait analysis approaches.The materials presented in this and the next chapter have been found over the years to be useful and necessary for gaining a deep understanding of a large variety of human gait monitoring methods.

- **Walking:** This is the most widespread human locomotor pattern and a specific type of gait [1]. Walking is a vital component of our everyday mobility and a significant health indicator. It is the most popular kind of exercise that adults do in their free time.

- **Ambulation:** It refers to a broad category of movement. It is more frequently used in a therapeutic context to describe a person's ability to walk independently or with the aid of a gadget.

- **Gait:** A person's gait is the way they walk [2]. It is also described as a particular type of running, jogging, or walking. The seven elements that constitute the functional foundation for how we walk start from the central nervous system and end with the external forces [3].

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– **Gait Cycle:** The gait cycle is a repeated pattern of steps and strides or the interval between the time the heel of one foot contacts the ground and the time the same heel touches the ground again (Figure 1). There are two phases in the gait cycle, each of which is further subdivided into smaller phases. The stance phase refers to the period when one leg is on the ground supporting the body's weight, while the swing phase occurs when one leg is off the ground and moving forward [4, 5].

– **Pose Estimation:** Pose estimation is a computer vision technique that tracks the position of a person's body parts in an image or video [6]. It is used to understand human actions and can be applied in fitness, rehabilitation, surveillance, and more.

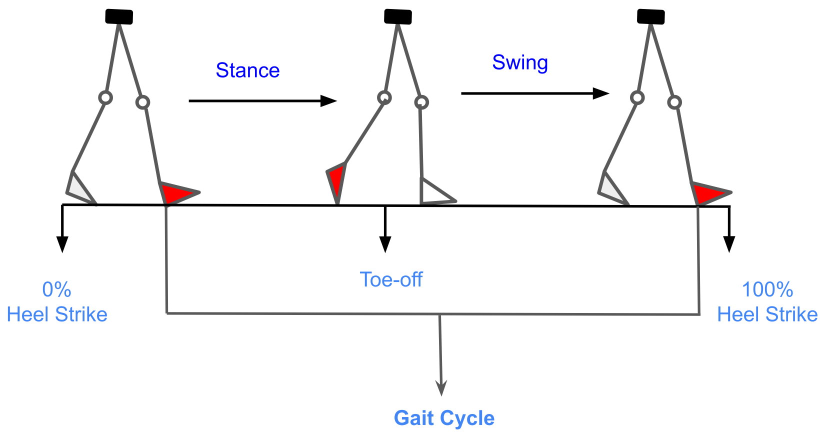

Fig. 1. Overview of a human gait cycle.

1.1 Gait parameters

Gait parameters refer to metrics utilized to assess and measure human locomotion. Understanding gait parameters in a categorized manner allows for a more structured approach to gait analysis[7]. By categorizing these parameters, we can better assess and interpret the mechanics of walking and running, as shown in Figure 2. These parameters are categorized into various groups such as:

Temporal Parameters Temporal parameters refer to the timing aspects of gait. They include:

– **Stride Time:** The time taken to complete one full stride.

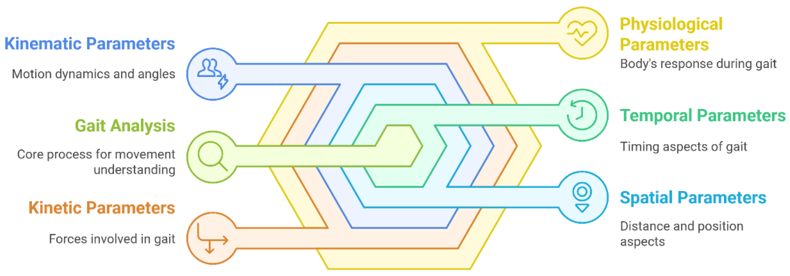

Fig. 2. Gait Parameter Categories

- **Step Time:** The time taken for one step, from heel strike to heel strike of the same foot.
- **Cadence:** The number of steps taken per minute. Healthy adults average about 90-120 steps per minute for a comfortable walking speed [8].
- **Velocity:** The speed of walking or running, typically measured in meters per second.

Spatial Parameters Spatial parameters focus on the distance aspects of gait. They include:

- **Stride Length:** The distance covered in one stride, measured from heel strike of one foot to heel strike of the opposite foot. For healthy persons, stride length is approximately double the step length [9].
- **Step Length:** The distance between successive points of contact of opposite feet. The average step length is around 70 cm [10].
- **Base of Support:** The distance between the feet during walking, which affects stability.
- **Foot Angle:** The angle at which the foot strikes the ground, influencing gait efficiency.

Kinematic Parameters Kinematic parameters describe the motion of the body without considering the forces involved. They include:

- **Joint Angles:** The angles at various joints (hip, knee, ankle) during the gait cycle.
- **Pelvic Tilt:** The forward or backward tilt of the pelvis during walking.
- **Trunk Rotation:** The rotation of the upper body in relation to the lower body.
- **Arm Swing:** The movement of the arms during gait, which can affect balance and momentum.

Kinetic Parameters Kinetic parameters involve the forces that cause motion. They include:

- **Ground Reaction Forces (GRF):** The forces exerted by the ground on the body during walking or running.
- **Joint Moments:** The rotational forces at the joints during gait.
- **Power Generation:** The amount of energy produced at different phases of the gait cycle.
- **Energy Expenditure:** The metabolic cost associated with walking or running, often measured in calories burned.

Physiological Parameters Physiological parameters relate to the body's response during gait. They include:

- **Heart Rate:** The heart's response to physical activity during walking or running.
- **Oxygen Consumption:** The amount of oxygen utilized during gait, indicating aerobic fitness.
- **Muscle Activation:** The level of muscle engagement during different phases of the gait cycle.
- **Fatigue Levels:** The impact of prolonged walking or running on physical endurance.

The spatiotemporal gait parameters, especially walking velocity, cadence, and step/stride length, were the most relevant characteristics for gait analysis in a healthy adult population, according to a 2017 systematic review [11, 12].

1.2 Gait Disturbances

Any change from normal walking or movement is referred to as a gait disturbance or gait disturbance [13]. Because gait abnormalities can result in a loss of personal mobility and a lower quality of life, identification is crucial. Additionally, there may be signs of falls and, consequently, serious injuries in the elderly.

1.3 Gait Analysis

The study of walking movement and functioning is termed as gait analysis. It is the study of how a person walks or runs, often used to understand movement patterns and identify any problems. It looks at things such as how your legs and feet move, how fast and smoothly you walk, and how your body stays balanced[14].

A typical workflow of the gait analysis is shown in Figure 3. The input is given in the form of patient information, walking test, or forms of the data. This type of data can be collected from various sources such as sensors on the body, pressure mats, or other methods. These data are analyzed by finding patterns in the walking, and finally, some treatment is given by the experts.

Doctors, therapists, or sports experts might use cameras, sensors, or even just careful observation to see if there is anything unusual or off. This helps diagnose issues such as joint pain, muscle weakness, or neurological conditions, and guides treatments such as physical therapy, custom shoe inserts, or surgery. It is also used in sports to improve performance or recovery, making it a valuable tool for both medical care and fitness.

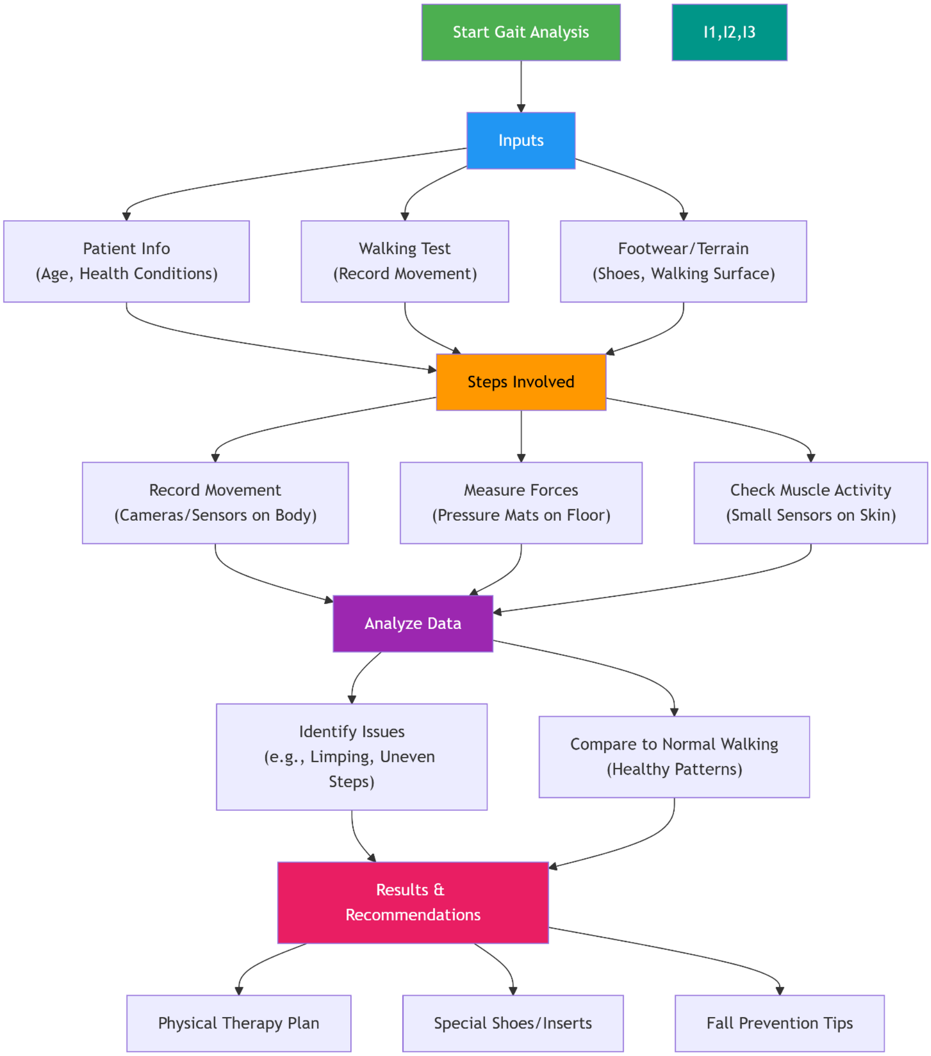

Fig. 3. Flow for Gait Analysis

2 Human Gait Measurement Techniques

In order to derive conclusions about the subject's walking patterns, gait analysis entails measurement, analysis, and interpretation of measurable parameters. The gait cycle and the measurement parameters associated with adults under normal conditions, along with the relevant terminologies, are essential for understanding human movement[15]. Any of the following methods can be measured as part of the analysis as mentioned in the following tables:

Type of Devices	**Types of Measurements**
Foot Switches	Cadence, Timing
Glass Plate Views	Pressure Distribution
Pressure Plates	Pressure Distribution
Pressure Insoles	Pressure Distribution Inside a Shoe
Force Plates	Net Force, Centre of Pressure

Table 1. Measurement Capabilities of Different Devices

Type of Device	**Type of Measurements**
Goniometers	Range of Motion
Electro Goniometers	Joint Angle at Successive Instants
Observational Gait Analysis (Video Walkway)	Stride Length, Cadence, Velocity, Dynamic Base
High-Speed Video	Stop Motion Measurements
Accelerometers	Accelerations
Gyroscopes	Change in Orientation
Electromagnetic Field Systems	All Possible Kinematic Measures (Qualitative, May Be Noisy)
Fine Wire and Needle EMG	Muscle Activation (More Accurate, Isolates a Single Muscle, Penetrates Skin)

Table 2. Types of Devices and Their Kinematic or Electromyographic Measurements

3 Conclusion

This chapter outlines essential terminologies and the standard conditions associated with gait cycle measurements. Understanding an individual's walking patterns through AI analysis requires careful consideration of these normative conditions for typical gait patterns. The corresponding framework[16] will enhance the ability to interpret and assess diverse walking behaviors effectively.

Term	Definition
Gait Cycle (Synonym: Stride)	The fundamental unit to describe gait — the period from heel contact to the next heel contact of the same foot.
Operational Definition	Duration from heel strike of one foot to heel strike of the same foot.
Phases of Gait Cycle	**Two Phases:** **Stance Phase:** Heel strike to toe-off (Contact period, Midstance period, Propulsive period). **Swing Phase:** Toe-off to heel strike (Acceleration, Mid-swing, Deceleration).
Step Length	Average: 35–41 cm
Stride Length	Average: 70–82 cm
Cadence	Average: 111 steps/min
Velocity	Average walking speed: 82 m/min

Table 3. Components and Parameters of the Gait Cycle

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