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The Influence of Height and Weight on Gait: A Research Study

Anoop Anirudhan*
Assistant Professor, Department of Criminology and Police Administration, Forensic Science, Srinivasan College of Arts and Science, Bharathidasan University, India

***Corresponding author: Anoop Anirudhan**
Assistant Professor, Department of Criminology and Police Administration, Forensic Science, Srinivasan College of Arts and Science, Bharathidasan University, Tamilnadu, India.
Email: anoopalkmr@gmail.com

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Abstract

Gait analysis is the systematic analysis of locomotion and has played a key role in the advancement of forensic science for the identification of individuals. The term „gait analysis" refers to the scientific investigation of animal locomotion, particularly the human locomotion. Forensic gait analysis is a new discipline in forensic sciences but gaining popularity worldwide. Through gait analysis, kinematic and kinetic data are acquired and analyzed to provide information which describes fundamental gait characteristics. Besides, the analysis of human gait characteristics is important in the fields of clinical and medical studies, sports, rehabilitation and training. The human gait can vary over long durations due to many factors such as change in body weight, height, injuries and diseases. This study consists of the gait analysis in accordance with height and weight of the individuals. The gait features of taller persons are different from the shorter ones. These differences are analyzed based on some gait parameters such as stride length, step length and base of gait.

Keywords: Gait analysis; Forensic science; Kinematic data; Kinetic data; Gait characteristic

Introduction

Gait patterns are the important factor to understand the locomotion especially walking. Every individual has its own gait. There are many of the factors depending on the human gait such as height and weight of the body, injuries and diseases of the body and environmental conditions etc. Gait can also be categorized according to whether the person remains in continuous contact with the ground. Human gaits are various ways on which a human can move, either naturally or as a result of specialized training The nervous system controls the gait of the human which is admissible in the court of law [1]. Emotional and environmental status also plays a role in with speed, velocity and gait patterns that a child uses. Children of different genders will have different gait development. The gait patterns are velocity and age dependent. For example, as age increased so did velocity. Which means as age increases cadence (the rate at which a human walk that is measured in steps per minute) of the gait decreased. Normal gait requires that many systems, including strength, sensation and coordination function in an integrated fashion [2]. Gait is a behavioral biometric which can be perceived from a distance. It can be acquired without personal con- tact and cooperation. Iris and face biometrics have similar advantages but they need high resolution images and frontal view. However, it is possible to extract gait patterns from low resolution images. Human gait can vary over long durations due to many factors such as change in body weight, injuries and disease [3]. However, studies have indicated that it still possesses sufficient discriminatory power for personal recognition. In general, a gait is considered as being composed of a sequence of kinematic characteristics of human i.e. human motion. Compared to traditional biometric features, such as face, iris, palm print and fingerprint, Gait has many unique advantages such as noncontact, non-invasive and perceivable at a distance. However, variations in subject's clothing, footwear and hair styles over different days bring challenges to gait recognition, and the subject's physical and mental conditions, e.g., leg injury, carrying conditions, drunkenness, illness, fatigue, pregnancy, etc., distort the walking patterns. In spite of these challenges, gait has contributed too many potential applications in the field of visual surveillance, access control, forensics, biometric authentication and criminology [5].

Human Gait

Gait refers to locomotion achieved through the movement of human limbs. Human gait is defined as bipedal, biphasic forward propulsion of center of gravity of the human body, in which there are alternate sinuous movements of different segments of the body with least expenditure of energy. Different gait patterns are characterized by differences in limb movement patterns, overall velocity, forces, kinetic and potential energy cycles, and changes in the contact surface (ground, floor, etc.) [6]. Human gaits are the various ways in which a human can move, either naturally or as a result of specialized training. Gaits

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can be roughly categorized into two groups: the natural gaits that nearly every human will use without special training, and the specialized gaits which people train to use under specific conditions and situation Under forensic science, gait is studied through forensic gait analysis which includes the identification of the gait features and patterns of subjects seen on closed circuit television (CCTV) and from footprints forming a gait pattern left at the scene of crime [7].So, the gait pattern of the Athlete comes under the category of, the specialized gait and whereas the gait pattern of the Non-Athlete comes under the category of, the normal gait. Gait analysis is the systematic study of human walking using the eye and the brain of experienced observers, augmented by instrumentation for measuring body movements, body mechanics, and the activity of the muscles. Human gait refers to locomotion achieved through the movement of human limbs. Human gait is defined as bipedal, biphasic forward propulsion of center of gravity of the human body, in which there are alternate sinuous movements of different segments of the body with least expenditure of energy.

The Gait Cycle

The gait cycle is defined as the time interval between two successive occurrences of one of the repetitive events of walking. Although any event could be chosen to define the gait cycle, it is generally convenient to use the instant at which one-foot contacts the ground (initial contact). If it is decided to start initial contact of the right foot, then the cycle will continue until the right foot contacts the ground again. The left foot, of course, goes through exactly the same series of events as the right, but displaced in time by half a cycle.

The duration of a complete gait cycle is known as the cycle time, which is divided into stance phase and swing phase [8].

The sequences for walking that occur may be summarized as follows [9]:

1. Registration and activation of the gait command within the central nervous system.

2. Transmission of the gait systems to the peripheral nervous system.

3. Contraction of muscles.

4. Generation of several forces.

5. Regulation of joint forces and moments across synovial joints and skeletal segments

Classification of the gait cycle involves two main phases: The Stance phase and the Swing phase. The stance phase occupies 60% of the gait cycle while the swing phase occupies only 40% of it. Gait involves a combination of open- and close-chain activities.

A more detailed classification of gait recognizes six phases:

- Heel Strike
- Foot Flat
- Mid-Stance
- Heel-Off
- Toe-Off
- Mid-Swing

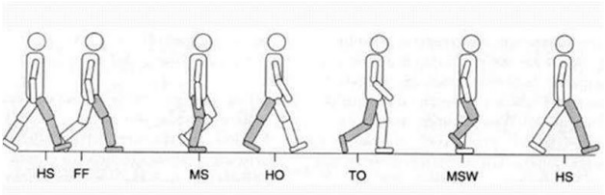


Figure 1: Six phase.

An alternative classification of gait involves the following eight phases [10].

Stance Phase

- Initial Contact
- Loading Response
- Mid-stance
- Terminal Stance
- Pre swing

Swing Phase

- Initial Swing
- Mid Swing
- Late Swing

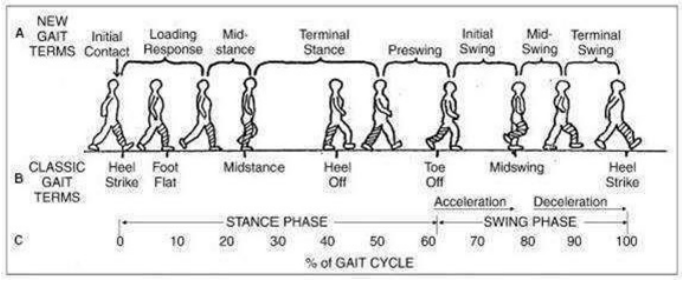


Figure 2: Eight phases.

Stance phase: Stance phase begins with the heel strike - this is the moment when the heel begins to touch the ground but the toes do not yet touch. In the mid-stance phase, we can see settlement of the foot at the lateral border. During the change from mid-stance to toe-off stance, the 5 metacarpophalanges contract. The toe-off phase is also named the propulsive phase. When the stance phase ends, the swing phase begins.

Swing phase: This phase is the phase between the toe off phase and the heel strike phase [11]. In the swing phase we can recognize two extra phases - acceleration and declaration. The acceleration phase goes from toe-off to mid-swing, while declaration goes from mid-swing to heel strike. In the acceleration phase, the swing leg makes an accelerated forward movement with the goal of propelling the body weight forward. The declaration phase breaks the velocity of this forward body movement in order to place your foot down with control. Between these two phases, the mid-swing phase occurs. In this phase, both feet are under the body, with the heel next to each other in recent advances, gait analysis has become a widely used tool to provide kinematic and kinetic data required by the physical therapist and doctors for choosing suitable treatment for their patients [12]. Since the 1960's, study of gait analysis became famous in clinics compared to research labs, as gait measurements were found useful in management of patients with walking disorders. The study of human locomotion has been conducted for many decades that describe the relationship between the motion and the muscles. Full understanding

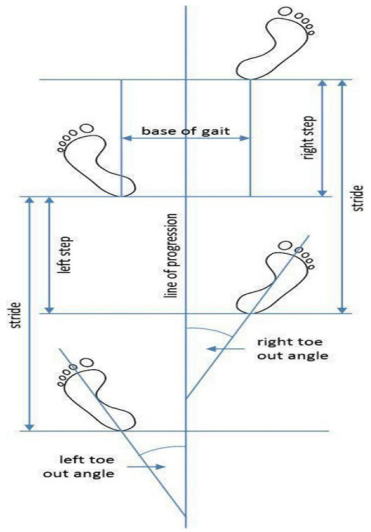
of normal gait includes study of muscle activities during different phases of gait cycle. The ability to walk is essential for independent living and the speed of walking declines with age. Height is one of the many factors that influences gait speed [3]. The health advantages of greater height have long attracted scientific interest. In humans, taller stature is associated with lower risk of disease. From the gait study we can determine the approximate height of the individual. And also, it is helpful to understand the normal gait pattern of the individual based on their height. Taller person walks faster with longer legs playing a role [2] Gait involves a combination of open and close chain activities. When we study the way the person walks or runs, we can identify individual's unique movements, determine normal gait patterns, diagnose issues causing pain and also implement and evaluate treatments to correct abnormalities. Gait analysis is used to assess and treat individual with conditions affecting their ability to walk. It is also commonly used in sports to help athletes run more efficiently and to identify movement related problems in people with injuries.

Some persons have the gait abnormalities which will be affects their normal walk. The gait abnormalities are different types. It depends on many of the factors.

Some of the gait abnormalities are [13]:

- Sensory gait
- Ataxic gait
- Parkinsonian gait
- Neuropathic gait
- Myopathic gait
- Choreiform gait

Some measurement of the gait such as step length, stride length, base of gait, gait cycle, and toe out angle during analysis are mentioned in the following figure (Figure 3).



Properties of Gait

During gait, there is some properties of gait can be seen. Some of them are heel strike, Toe-off, forefoot contact and heel lift.

Figure 4: Heel strike. The foot contacting the ground heel-first during the foot strike phases of walking.

Figure 5: Forefoot contact. The point in a person‟s walk at which the front part of the foot touches the ground.

Figure 6: Heel lift. The heel of the foot rises from the door during walking.

Figure 7: Toe- off. The point in a person‟s walk (gait) at which the foot rises from the floor.

The Scientific Basis of Forensic Gait Analysis

In forensic gait analysis, comparisons are made between gait features of a perpetrator and suspect(s). For a feature to be useful in differentiating between subjects it should be consistent within an individual, different between individuals and those differences should be measurable. This requires knowledge of differences in gait features within and between subjects, i.e. of intra- and inter-subject variability‟s.

In forensic practice, however, gait speed of a perpetrator and suspect are likely to differ. Therefore, we can determine whether and when in the gait cycle joint angles of a perpetrator and suspect can be compared if their speed differs. Importantly, in our opinion, comparing joint angles from two-dimensional (2D) video footage is meaningless with current techniques. Nevertheless, we think that even for observer-based forensic gait analysis, knowledge of gait speed effects may be important [9]. Joint angles were most invariant for gait speed at midstance and mid-swing (around 30% and 80% of the gait cycle). During the remainder of the gait cycle, especially at toe-off (50%–60% of the gait cycle), gait is too variable to compare joint angles separately. Front-view joint angles and higher gait speeds are more suitable for comparison than side-view angles and lower gait.

The presence, absence or size of features derived from the gait of a perpetrator and suspect can then serve as evidence. However, forensic gait analysis methods are not capable of identification. Therefore, gait is only used as supportive evidence Literature review is a survey of scholarly sources (such as books, journal articles and thesis) related to a specific topic. Literature review helps in identifying what is already known about an area of study. Review of literature is an assessment of a body of research that addresses a research question. The scope of this review is confined to experiments with adult participants. This nature of the walking environment is important, since it has been claimed to be a critical factor for facilitating the skill transfer to everyday movements.

Walking is affected by a wide variety of factors including heel height, heel size, and the shape of the insole and outsole (Kim, 2008; Lee and Hong, 2005; Lin *et al*., 2013). After wearing the shoes with the HEIs for 4 hour for adaptation, the subjects performed controlled activities in a designated place, and then were measured their gait pattern, the muscular activities of the lower limb and the lumbar spine, and the perceived comfort [14]. Gait features can also be used for gender classification and some prominent researchers have worked on it. An early gait based- gender classification is developed by Kozlowski and Cutting (L.T. Kozlowski *et al*., 1977).

In gait, the Base of the Support (BoS) is formed by those parts of the feet that are in contact with the floor at any point in time. During human walking the Centre of mass (CoM) is outside the base of support for most of the time, which poses a challenge to stabilizing the gait pattern [15]. In this section, they also address the requirements in terms of the sensory information and the motor strategies that can implement such control, as well as the part of the central nervous system that may be involved

A simple external marker system and algorithms for computing lower extremity joint angle motion during level walking were developed and implemented on a computer-aided Video Motion Analysis System (VICON). Angular motion of the hip, knee, and ankle joints and of the pelvis were obtained throughout a gait cycle utilizing the three- dimensional trajectories of markers [16].

The clinical application of gait analysis allows the clinician to evaluate quantitatively the degree to which an individual‟s gait has been affected by an already diagnosed disorder, that is, clinical gait analysis is presently an evaluation tool and not a diagnostic tool (Brand and Crowninshield, 1981). They collected the data by videotaping, physical evaluation and measurement, marker placement, static offset measurement and Electromyographic assessment [17].

Older healthy subjects had lower values for walking speed and stride length than younger subjects. The absolute values for walking speed are lower in women than men at all ages [18]. In this calculation, the men yields 34% for decline in walking speed and 42% for decline in stride length. In conclusion, preferred walking speed and stride length decline with age in healthy people. Patients with joint disease tend to walk slowly and with a short stride, it is essential that normal ranges for gait parameters should be defined with reference to speed of walking [19]. They concluded that the stride length is probably best basis for deciding the normal range for a particular measurement.

Observational gait analysis is best done by systematically concentrating first on one body part and then another. The gait analysis system includes electro goniometers, video technology, manual digitization, automated motion tracking system and marker systems. In this, during gait there is a formation of kinetic energy (movement of body segments) as well as the potential energy (ligaments) [20].

From this, I concluded that the gait analysis is the systematic measurement, description, assessment of those quantities thought to characterize human locomotion. Through gait analysis, kinematic and kinetic data are acquired and analyzed to provide information which describes fundamental gait characteristics [21]. Advances in computer-based data acquisition systems and analysis techniques likely will further improve the application of gait analysis.

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the study of methods and principles associated with a branch of knowledge. Typically, it encompasses concepts such as theoretical model, phases, paradigm and qualitative or quantitative techniques. The methodology is the general research strategy that outlines the way in which research is to be undertaken and among other things, identifies the methods to be used in it.

The methodology provides the necessary training in choosing methods, materials, scientific tools and training in techniques relevant for the problem chosen. It aims to give the work plan of research. These methods, described in the methodology, define the means or modes of data collection or sometimes, how a specific result is to be calculated. Methodology does not define specific methods, even though much attention is given to the nature and kinds of processes to be followed in a particular procedure or to attain an objective.

Aim of the Study

The aim of the study is to identify the gait pattern of individuals in accordance with their height and weight while walking normally. It helps to determine why runners have more overload injuries when compared to the normal gait. This provides the comparative element regarding the study and further helps in identification of gait pattern found at the scene of crime based on the foot placement of gait pattern.

Statement of the Problem

With the above aim or purpose for the present study the „statement of the problem‟ has been discussed as “A STUDY ON GAIT ANALYSIS IN ACCORDANCE WITH HEIGHT AND WEIGHT OF INDIVIDUALS”.

Objectives Of the Study

The objectives of the study are identified as follows:

- To identify the distinctive gait pattern of individuals and its features.
- To identify and compare the foot placement of individuals in relation with their height and weight.
- To determine the regular walking pattern of individuals.
- To determine the movement of limbs and joints during a gait cycle.
- To explore the effect of body mass or weight in the gait analysis.

Research Questions

The research questions for the study are given as follows;

- What is the distinctive gait pattern of individuals having different stature?
- What is the effect of regular exercise on walking pattern?
- What is the difference in foot placement for every individual?
- How the body weight affects the gait pattern?
- What is the gait feature of individuals having similar height?

Universe of the Study

The samples for the study had been chosen from the college, NOORUL ISLAM CENTRE FOR HIGHER EDUCATION, KUMARACOIL, THUCKALAY, KANYAKUMARI (DT), TAMILNADU (ST).

Sampling Technique

Purposive sampling technique has been adopted for the study which is a type of non-probability sampling technique. This type of sampling technique is used because, the samples that are selected based on the height and weight of the body of individuals.

Sample size: Both males and females were included in this study, who is also selected as stated above for the present study from the universe. The height of person was considered from the range of 150cm to 175cm (10 samples for each). The height was measured in centimeter. The weight of an individual taken in kilogram which are comes under the respective height categories.

- The total number of sample taken as 50.
- The height of the individual taken from 150cm to 175cm.

Sampling:

- 150cm-155cm
- 156cm-160cm
- 161cm-165cm
- 166cm-170cm
- 171cm-175cm

Research Tool: Foot placement is the research tool used to conduct this study. And the materials used for this study are mentioned below.

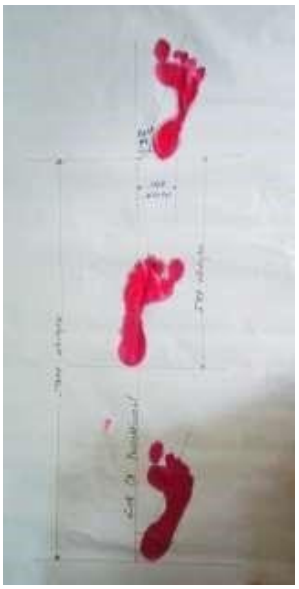
Materials required: Colored liquid

- Long sheet paper
- Scale, pencil, marker (geometric measurements)
- Measuring tape
- DSLR camera (photography)
- Light source

Proper measurements and calculations were needed for conducting the analysis.

Pilot Study

The piolet study for the gait analysis were conducted are given below. A few samples were used for this purpose.



Data Collection

We collected the data through a systematic procedure. The samples were asked to provide their gait pattern (foot prints) by dipping their foot in the tray containing colored liquid and asked the samples to walk normally on a drawing sheet with a particular distance marked. Each walk was tested twice. This gait assessment protocol was performed at ground level. Finally, the photographs were taken using proper geometry and later the measurements required were calculated.

Analysis of Data

Gait analysis is a systematic procedure used to assess and treat individuals with conditions affecting their ability to walk. At a gait analysis appointment we capture the movement pattern of individual's leg by photography. The data collected was measured and calculated utilizing the simple statistical and geometrical techniques that was presented in the following chapter.

The data analysed as a result of the gait experiment which includes right foot walking and left foot walking. With the samples being able to repeat iterations of the procedure if they thought that they were conducting the walk abnormally. The test (walk) with the left and right foot was separated by simply conducting a test focusing on either foot at a time. The samples were used different energy of forces (pressure) and these differences in pressure peaks are also affected by the different foot types of the subjects.

The right and left foot walking data are overlaid with a given offset so as to provide an approximate gait cycle. This is an approximation as the first force (heel strike) of the opposite foot occurs at two-thirds through the stride of the other foot. During walking the Centre of force (CoF) travels to support the weight of the body for balancing and propelling forward. When the heel strikes the ground, the force rises sharply.

As the weight of the person is distributed on the heel, the force stops growing and begins to fall as the weight is distributed to the entire foot. The pressure may then grow as the weight shifts forward and spikes as the weight is focused on the mid-stance and toe. As the heel and toe lift, the force may drop again.

Observations

During gait analysis, the properties such as heel lift, heel strike, forefoot contact and toe off can be seen found. Heel strike is also an initial contact, is a short period which begins the moment the foot touches the ground and is the first phase for double support. The heel of the loaded limb lifts off the floor and the body weight moves forward past the forefoot.

Once the foot becomes flat, that is the forefoot comes in contact with the ground the next phase commences. Mid stance is the phase of gait where the foot assumes more of a support and overall stability role.

The toe off simply defines like the name says, the toes leave the ground. This represents the start of the swing phase or the last event of contact during the stance phase. Heel off, push off, and toe off these are happens when the heel lifts off the ground.

Gait Cycle Timing

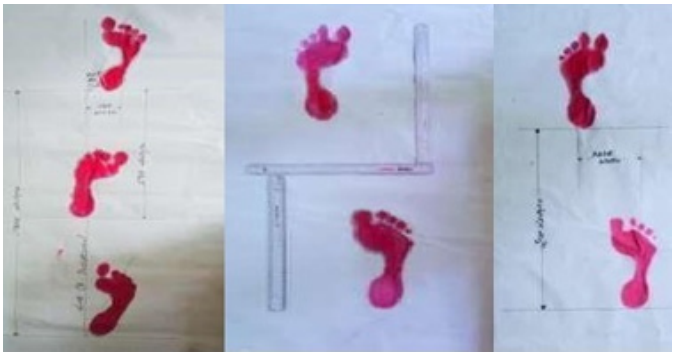
The timings of initial contact and toe off for both feet during a little more than one gait cycle. Right initial contact occurs while the left foot is still on the ground and there is a period of double support between initial contacts on the right and toe off on the left. In each double support phase, one foot is forward, having just landed on the ground, and the other one is backward being just about to leave the ground.

There is another period of double support, until toe off on the right side. In the double support phase during a gait cycle, the leg in front is usually known as the “leading” leg and the leg behind as the “trailing” leg.

The data collected was measured and analysed utilizing simple statistical and geometrical technique. The samples having height ranging from 140cm to 195cm are mentioned below due to the availability of samples related to the situations. They are given in the following table.

Table 1: Gait analysis of individuals.

SL No	Samples	Height (Samples-cm)	Base (width) of Gait (cm)	Step Length (cm)
1	S(a)	145	7	37.5
2	S(b)	160	12.5	49.5
3	S(c)	170	18	53.4
4	S(d)	157	3	47
5	S(e)	193	18	56
6	S(f)	165	16	52.5
7	S(g)	142	7	36



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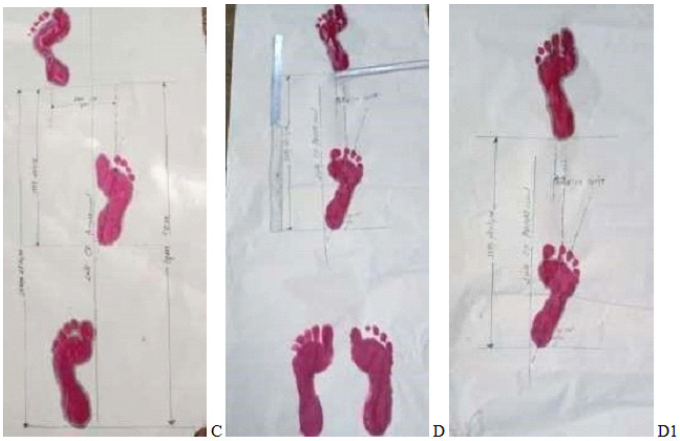
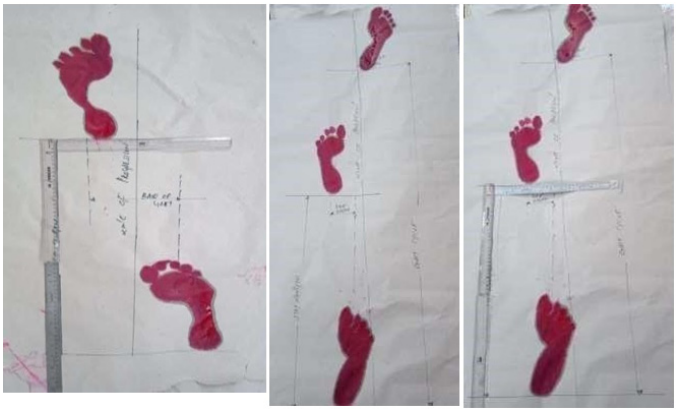


C D D1

E E1 F



F1 G G1

From this, we can understand the different types of walking patterns of the individuals. Everybody can have their own gait features. They may dependent on their personal height. The base of the gait otherwise the step width may independent to the step length. The gait cycle is the total measurement of both left and right step length and is also known as one stride length. The lateral distance between the midline of the footfall during a person‟s normal gait, which may be usually measured at the midpoint of the heel.

The stride length, base of the gait, step length and the toe out angle (left, right) are some of the gait variabilities which may describe the gait features. When the step length is more, the person will be taller. The step length may increase the stride length. This indicates the gait features may changes with height.

Discussion

None of the examined walking parameters showed any significant training effect for the duration of the experiment. The walking performance during height exposure may be characterized by a reduction of walking speed, cadence, stride length, and swing phases whereas, stance phases and stride time were increased.

Gait variability parameters (i.e., the intrinsic fluctuation within the walking pattern contains relevant information about the instability of walking pattern) were normal in subjects susceptible to the height when they walked with the head in a natural position. Many of the subjects did not show increased magnitudes of gait variability which indicates a preserved capacity to avoid falls even if the fear of falling is pronounced in the subjects. The above discussed alterations make up the basic pattern of the gait at height (cm) and body weight (kg).

Hence, we understood that the gait pattern of the individuals may depend on their height. Simply put, tall people are naturally more efficient walkers. Of course, there is a lot more to walking pattern in relation with individual height.

Conclusion

This paper studied the gait analysis in accordance with the height of individuals. The current and future directions in gait analysis will include more sophisticated tools for the analysis and interpretation of gait patterns. Taller individuals walk faster than the shorter ones and there are multiple mechanisms underlying this association. To our knowledge, no other study has examined the impact of height on age related change in gait speed. Therefore, we can only form an opinion about the reasons behind our findings. Gait patterns change with age and height which includes stride length reduces and the gait become irregular, step wider, and foot clearance more problematic. In contrast to the traditional methods, which depend on the specialist experience the different parameters being studied can now be objectively quantified From this work, we concluded that the gait cycle is a repetitive pattern involving steps and strides. A stride is a whole gait cycle; A step is one single step. The step time is the time from one foot hitting the floor to the other foot hitting the floor. One of the main things regarding the gait analysis is the Centre of the body moves both side to side and up and down during gait. The gait cycle has two phases such as stance phase and swing phase where in running, there is also just one stance phase while in stepping there are two. This explains why runners have more overload injuries.

The gait pattern of the individuals may vary depending up on their height. When the height increases, the gait feature changes with respect to it. The step length is inversely directed to the base of the gait or gait width. The longer people can have greater toe out angle when compared to the shorter ones. And also, the step length increases in the case of longer one. As a result, the gait cycle changes. Hence, we may prove that the gait pattern of individuals depends the personal height. During gait, the pressure exerted by the body is also a factor to vary the gait features.

This study represents a general review on gait analysis and the main concern of this is to illustrate the gait characteristics; various gait parameters and their contributions in performing balanced movements. The study of gait analysis also points out its importance in research, clinical observations, sports performance analysis, dance performance measurements, rehabilitation, and in the field of robotic research such as gait training and gait enhancement for medical uses as well as military applications. In conclusion, it is well known that taller persons may have longer legs and walk faster. Therefore, we now provide robust evidence in the court of law.

Suggestions

The gait speed is also an important factor to determine the human locomotion. Everyone have their own gait features. The patterns and features of the gait during walking may depend on the individual height. Likewise, it will be a possible matter regarding the speed of gait in relation with height. And also the gait speed may change in accordance with age. There may be a relation between gait speed and the age of individuals having similar height. For further studies, the proper analysis with gait measurements will be necessary to test this hypothesis. As part of future work, the gait speed of individuals having same height to be required for comparison of gait characteristics of individuals. This will be very useful in future events.

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