Original Article

Establishing Normative Height-Normalized Gait Speed in Indian Young Adults: Influence of Indoor and Outdoor Environments

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Abstract

Objective: The Primary objective is to establish normative data for height-normalized gait speed in healthy younger adults aged 18-25. The secondary objective is to assess the impact of environmental conditions on gait speed.

Methods: A cross-sectional observational study was conducted in Mysuru using convenience sampling. A total of 316 healthy participants underwent the 10-meter walk test in both indoor and outdoor settings. Descriptive statistics were used to derive normative values, while paired and independent t-tests compared indoor versus outdoor speeds and examined gender differences, respectively.

Results: Indoor mean gait speed 0.085 ±0.09 m/sec and outdoor mean gait speed 0.93±0.1 m/sec. Gait speed was significantly higher outdoors ($p<0.001$), with no significant gender difference ($p>0.005$)

Conclusion: Height-normalized gait speed allows physiotherapists to assess mobility more equitably across individuals with varying statures, enhancing diagnostic precision in both indoor and outdoor settings., It supports more personalized rehabilitation goals and progress tracking.

Keywords: Gait speed, height normalization,normative data,10-meter walk test,environmental influence

Introduction

Gait is defined as how a person walks, and it differs from locomotion, which refers to an individual's capacity to move from one place to another.[1]The fundamental unit of walking is the gait cycle, which can be defined using various parameters, including spatial (distance) and temporal (time) parameters.[1]Temporal parameters are cadence, gait speed, step time, stride time, duration of phases and sub-phases, while spatial parameters are step length, step width, stride length, and foot angle.[1]Numerous factors contribute to gait speed, including joint mobility, muscle strength, sensory function, neural control, cognitive status, and energy level,so it can reflect overall health.[1] Walking speed also correlates with functional ability, physiological changes, and balance confidence;hence, it can be used to assess an individual's functional mobility.[2] The gait speed in young adult men is between 1.27 m/sec to 1.44 m/sec, and in women, it is from 1.23 m/sec to 1.44 m/sec.[3]

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Gait speed is a significant determinant of health and is used as a predictor of decline in functional mobility.[1] Gait speed is used not only to evaluate physical function but also to assess the general health status[4].Gait speed can be measured both subjectively and objectively.[4] The traditional scales used to analyse gait parameters in clinical conditions are semi-subjective, carried out by specialists who observe the quality of a patient's gait by making them walk.[5] Objectively, gait speed is measured using automatic sensors and a manual stopwatch.[5] Non-Wearable Sensor(NWS) systems require the use of controlled research facilities where the sensors are located and capture data on the gait while the subject walks on a clearly marked walkway.[5] In contrast, Wearable Sensors (WS) systems make it possible to analyse data outside the laboratory and capture information about the human gait. There is also a third group of hybrid systems that use a combination of bothmethods.[5]

Gait speed in younger adults is important for optimizing physical activity programs and setting personalized exercise targets.[4] The variations in gait speed among young adults are associated with differences in physical and cognitive function, this highlights the importance of assessing gait speed and also it helps the healthcare providers can tailor physical activity programs to enhance endurance, strength and efficiency in walking.[6] Walking speed plays a vital role in setting physical activity goals, particularly in distinguishing moderate and vigorous intensity exercise.[6] Study suggests that brisk walking speed aligns with moderate-intensity activity, which is essential for cardiovascular and metabolic health.[7] Furthermore, engaging in higher gait speeds has been linked to increased engagement in vigorous physical activity, promoting overall fitness.[7] Additionally, gait speed assessments enable early detection of mobility issues, even in the younger population.[7] Slower than average gait speed may indicate neuromuscular inefficiencies or any other underlying health issues. [6]Regular monitoring of gait speed ensures that individuals can track their progress and adjust their activity levels.[7] Therefore, incorporating gait speed assessments into physical activity planning for younger adults provides a structured approach to improving fitness and monitoring health.[8] By setting specific speed targets, individuals can achieve optimal physical activity levels and maintain long-term mobility.[8]

Normative gait speed data provide essential benchmarks for assessing mobility, yet most existing studies are based on Western populations with limited representation of Indians.[910] Given that Indians generally have shorter stature and leg length than Europeans, their gait patterns may differ due to inherent anthropometric variations. Recent trends in urban India show gradual increases in height alongside rising BMI and obesity rates, both of which significantly influence gait speed and walking efficiency[11]. These evolving physical characteristics underscore the need for ethnicity-specific normative values that reflect the Indian population's unique profile. Establishing such data would enhance the accuracy of physical activity prescriptions and rehabilitation protocols. Therefore, a dedicated study is needed to develop normative gait speed values tailored to Indian demographics. Hence, the aim of this study is to establish the normative height normalised gait speed in younger adults in the Indian population between the age group of 18-25 years and to identify the effect of the environmental variable on gait speed.

Methods

A cross-sectional observational study was conducted to establish normative data for height-normalized gait speed and assess the influence of environmental factors in indoor and outdoor settings on gait speed in healthy young adults aged 18-25 years. This study was carried out in Mysuru, India over the span of one year. Data collection was conducted at predefined indoor and outdoor settings with a flat, obstaclefree 10-meter walkway.

Participants were recruited using convenience sampling based on their availability and willingness to participate to ease the access of the participants and overcome the time constraints. Ethical clearance was granted by the Institutional Research Committee of the Physiotherapy College in Mysuru, India. Inclusion was limited to healthy individuals aged 18 to 25 years, while those with

recent musculoskeletal injuries or surgeries, reliance on assistive devices such as orthoses, prostheses, insoles, or chronic illnesses were excluded. Written informed consent was obtained from all participants prior to participation in the study and the participants were recruited based on their availability and willingness to participate.

Each participant underwent a 10-meter walk test in both indoor and outdoor settings. To ensure accurate timing, 2-meter zones at the beginning and end of the walkway were excluded as acceleration and deceleration phases, and only 6-meter in between were timed in each environment. Rest intervals of approximately 90 seconds were provided between the trials to minimize fatigue. Gait speed was calculated as distance divided by time, and height-normalizedgait speed was obtained by dividing gait speed(meters/sec) by height (in meters).

The sample size was calculated using the formula for estimating a mean as: $n= (Z_{1-\alpha/2}\ \sigma/\ d)^2$.With $\sigma=0.098$ and $d=0.01$, the required sample was 370. A total of 316 participants completed the study.[12]

All data were entered into Microsoft Excel and analyzed using Jamovi (version 2.6.45). Descriptive statistics, including mean, median, and standard deviation, were used for height-normalized gait speed. A paired t-test was used to compare the gait speed between indoor and outdoor environments, and an independent t-test evaluated differences between genders. Effect size was calculated using Cohen's d to determine the magnitude of environmental influence on gait speed.

Results

The initial calculated sample was 370, however, 316 participants completed all the phases of data collection and were included for data analysis. 54 participants did not participate due to the incompletion of the phases, and some were not available on the date of data collection.

Table 1 presents the demographic characteristics of the study participants, categorized by gender (male and female). It includes the key variables of age, height, weight, and BMI, each with its respective standard deviation. The average age of the female participants is 20.58 years with the SD of 2.34, while males have an average age of 20.90 years with an SD of 2.13. The height measurements, which are measured in meters, showed that females have an average height of 1.70 meters (± 0.06), whereas males are taller with an average height of 1.70 meters (± 0.09). In terms of weight, females weigh around 56kg (± 11.07), whereas males have a higher average weight of 66.05kg (± 11.07). BMI values are nearly the same for both groups, with females at 22.40 (±4.73) and males at 22.40 (±4.23), indicating a similar body composition despite differences in height and weight.

Table 1. Demographic characteristics of the participants ± SD Standard Deviation

Demographic details	Female ±SD	Male ±SD
Age (in years)	20.58 ± 2.34	20.90 ± 2.13
Height (in meters)	1.58 ± 0.06	1.70 ± 0.09
Weight (in kgs)	56± 11.07	66.05 ± 11.07
BMI (kg/m²)	22.40± 4.73	22.40 ± 4.23

Height- Normalized Gait speed (Descriptive statistics)

Descriptive statistics were used to examine the distribution of height-normalized gait speed which is presented in Table 2, Figure 1

Table 2. Descriptive statistics for height-normalized gait speed

Height-normalized gait speed		Indoor			Outdoor		
Age (years)	**No. of participants**	**Mean SD**	**Median**	**Min-Max**	**Mean SD**	**Median**	**Min-Max**
18-21	206	0.085±0.09	0.88	0.75-1.10	0.93±0.1	0.932	0.76-1.15
22-25	115	0.897± 0.09	0.878	0.71-1.05	0.94±0.1	0.925	0.77-1.15

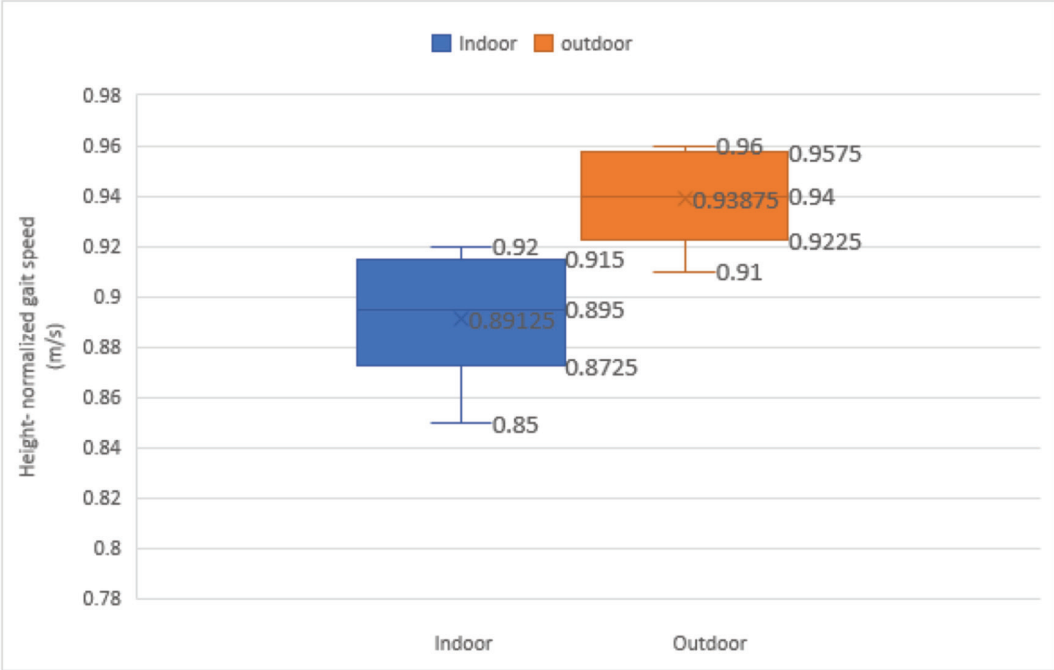

Figure 1: Comparison of height-normalized gait speed in indoor and outdoor environments

Table 2 represents the descriptive statistics for height-normalized gait speed among young adults from 18-25 years, comparing indoor and outdoor level surface walking. The mean gait speed varies across the age groups, mean value of 0.085±0.09 for 18-21 years and 0.897± 0.09 for 22- 25 years in indoor and mean value of 0.93±0.1 for 18-22 years and 0.94±0.1 for 22-25 years in indoor. This shows that outdoor gait speed appears to be higher than the indoor gait speed in the age group of 18-25 years. The standard deviations (SD) values, which indicate variability in gait speed, show relatively small differences, ranging from 0.07 to 0.14 and 0.09 to 0.15 in indoors and outdoors, respectively, suggesting that outdoor conditionshave slightly higher variability. The median values are closely aligned with the median, indicating that the data distribution is approximately symmetrical across both conditions. Minimum and maximum values of indoor gait speed range from 0.63 m/s to 1.10 m/s, while outdoor gait speed ranges from 0.73 m/s to 1.20 m/s.

The plot shows that the median and mean gait speed in the outdoor environment is higher than in the indoor setting, indicating that participants walked faster outdoors. The interquartile range (IQR) for indoor gait speed is slightly wider, suggesting greater variability in walking speeds indoors. The whiskers indicate the minimum and maximum gait speeds within each condition. This shows that walking outdoors results in higher gait speed compared to indoors.

Comparison of indoor and outdoor gait speed (Paired t-test)

A paired t-test was conducted to compare height-normalized gait speed in indoor and outdoor environments. Since the same participants were tested in both conditions, a paired test was appropriate to assess whether the environmental context significantly influenced gait speed. The results of the paired t-testare presented in Table 3.

Table 3. Paired t-test for indoor and outdoor gait speed

Condition	t- value	df	p-value	Effect size (cohen's d)
Indoor vs Outdoor Gait Speed	-17.88	320	<0.001	-1.00

df: degrees of freedom

As shown in Table 3, this indicates a statistically significant difference between indoor and outdoor gait speed, t-test- t-value of -17.88, p <0.001. The negative t- test value suggests that indoor gait speed is lower when compared to outdoor gait speed. Additionally, the effect size, Cohen's d= -1.00, suggests a large effect, indicating that the difference between the two conditions is substantial. Since the p-value is less than 0.001, the null hypothesis (which assumes no differences between indoor and outdoor gait speed) is rejected. This confirms that gait speed is significantly influenced by the environment, with outdoor conditions facilitating a faster gait speed compared to indoor conditions.

Gender difference in Gait speed (Independent t-test)

An Independent Sample T-Test was conducted to examine whether there were significant differences in gait speed between males and females in both indoor and outdoor environments. Although an attempt was made to ensure an equal distribution of male and female participants, the final sample was not evenly distributed. Despite this, the independent t-test was performed to assess whether gender had a significant impact on gait speed. The result of this t-test is represented in Table 4

Table 4. independent t-test for gender differences in gait speed in indoor and outdoor

Condition	t-value	Df	p- value
Indoor	1.63	319	0.105
Outdoor	0.87	319	0.382

Table 4 shows that there is no significant difference in gait speed between males and females for both indoor environments (t-value =1.63, df= 319, p=0.105) and outdoor environments (t-value = 0.87, df=319, p=0.382). Since both p-values are greater than 0.05, it fails to reject the hypothesis, suggesting that gender does not have a significant effect on gait speed in either environment. This finding shows that gait speed is relatively similar across genders in both indoor and outdoor conditions

The result indicated that there is no significant difference between males and females in both indoor and outdoor. Despite slight variations in mean values, both males and females exhibited the same gait speed in both environments. Overall, the findings suggest that young adults walk faster in outdoor environments compared to indoor settings, with no significant gender differences in gait speed. These results contribute to the understanding of gait speed variations in different conditions.

Discussion

This study was conducted to establish height-normalized gait speed for young adults in both indoor and outdoor environments. The study results obtained from our study are consistent with the results of previous studies conducted in different parts of the world. The average gait speed obtained is 0.73-1.14m/s in females and 0.76-1.14 m/s, which shows no gender difference. However, the results obtained contradict the study conducted in Qatar, the Gulf, and the Southeast Asia regions, by Majeed B et. al, Murtagh EM et.al, and Yang M et.al, respectively, which showed that the preferred walking speed for females is lower when compared to males. [4,13,14] In 2023, a study conducted by Keklik S S et.al, in Turkey, showed that there were no significant differences in gait speed by gender, which is similar to the study outcomeobtained.[15] Our study found that the gait speed is reduced in an indoor setup.The possible reason could be because of the restricted nature of walking space, where people walk faster outdoors may be due to individuals feeling freer and less restricted in a wider environment.[13] To the best of the author's knowledge, this is the first study in India assessing height-normalized gait speed in young adults within these two settings.

Strength of the study used standardized outcomes of the 10-meter walk test in both indoor and outdoor environments, ensuring consistency and precision in gait speed measurement. The dual-environment approach offers valuable insights into how environmental factors influence gait speed, which provides a reference value.

The normative height-normalized gait speed values established in this study provide a useful reference for evaluating functional mobility in

Indian young adults and can inform both clinical assessment and exercise prescription. The higher gait speeds observed outdoors highlight the importance of considering environmental context when planning assessments and designing interventions, while the absence of gender differences suggests that rehabilitation protocols may be applied uniformly across males and females. Incorporating outdoor walking into therapy or training routines may also enhance functional mobility and improve the ecological validity of rehabilitation programmes.

This study has several limitations. The use of a 10-meter walk test did not consider for fatigue effects, and although efforts were made to control confounding factors such as weather, footwear, and outdoor surface type, these variables may still have influenced gait speed outcomes. Additionally, the outdoor environment was levelled but not standardized, limiting the generalizability of findings to uneven or gradient terrains. The use of convenience sampling, a restricted geographic region within Mysuru, and a relatively small sample size further constrain the representativeness of the results.The planned sample was ~370, but only 316 participants were included; while this reduced sample size slightly decreased precision, it remains acceptable for exploratory normative data.To enhance external validity, future research should include larger, more diverse samples across multiple regions of India and utilize standardized outdoor conditions. Such efforts would strengthen the applicability of normative gait speed data to broader populations.

Conclusion

In conclusion, this study established normative data for both absolute gait speed and height-normalized gait speed in healthy young adults aged 18-25 years and provideda reliable reference value for self-selected walking speed, which can be used in clinical and research purposes.Moreover, by comparing indoor and outdoor walking conditions, we concluded that environmental factors have a significant impact on gait speed, where participants showed higher gait speed outdoors when compared to the indoor environment

Ethical Clearance: was obtained from Institutional Research Committee, JSS College of Physiotherapy on 18/06/2024. Ref no: JSSCPT/IRC/41/2023-2024

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Conflict of Interest: The authors declare no conflict of interest.

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