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Walking Speed Gender Differences in Prepubertal Children: An Observational Study

Shahin Ahmedov[1], Figen Yaman Lesinger[1], Musa Oytun[2], Barış Filiz[3], Fatih Kerem Özkan[4]

[1]School of Physical Education and Sports, Cyprus Health and Social Sciences University, Morphou, North Cyprus
[2]Faculty of Sports Sciences, Near East University, Nicosia, North Cyprus
[3]Sports Sciences, Gedik University, İstanbul, Turkey
[4]Fitness Soul Entertainment Spors Complex, İstanbul, Turkey

Abstract

BACKGROUND/AIMS: Walking speed associates with a person's functional status and balance confidence, both of which diminish with age. The difference in children's body composition and prepubertal metabolic rate suggested gender variability in their walking parameters.

MATERIALS AND METHODS: The preferred step length, cadence, and overall walking speed of 457 school children (256 boys) aged 12.65±2.16 years old were assessed during a 20 meter walk. The participants' height, weight, and heart rate values were also collected.

RESULTS: The preferred walking speed analysis demonstrated that the girls, despite their shorter height and age, moved faster than the boys (1.35±0.22 m/sec in boys. 1.43±0.22 m/sec in girls, $p<0.01$). The girls' baseline heart rate correlated with their final walking speed ($n=177$, $r=0.202$, $p<0.05$). Although, as expected, the children's step length positively correlated with their height ($n=457$, $r=0.42$; $p<0.05$), with an increase in the child's height, the step-to-height ratio decreased significantly ($n=457$, $r= -0.40$; $p<0.05$). The average walking speed in prepubertal children (1.39±0.22 m/sec) was the highest among all population groups.

CONCLUSION: Girls demonstrated better walking performance compared to boys. The preferred walking speed allows for a quick assessment of the child's physical development necessary for effective exercise programs.

Keywords: Child, gender, health, walking speed, cadence

INTRODUCTION

The step is the primary assessment unit for walking, i.e., the most common body movement form.[1] Intuitively, the step is highly distinguished and deeply embedded in the automated movement pattern of the central nervous system (CNS). As one of the essential characteristics of locomotion, step analysis is used today in health assessment and rehabilitation programs.[2,3] With the introduction of pedometers into the monitoring of physical activity, it has become possible to determine the number of steps taken per day, the total distance covered throughout the day, and other related ambulatory parameters.[4,5] Unlike self-reported information on physical activity, pedometers allow for an objective assessment of a person's level of daily activity. The total distance traveled per day depends on step length, cadence, and step velocity.[6] These variables result from the work of the CNS to control the maintenance of body balance during walking. The cadence, also called the step frequency, is determined relatively accurately by the electric circuit of the pedometer, which periodically

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ORCID IDs of the authors: S.A. 0000-0002-2492-5900; F.Y.L. 0000-0002-9556-4305; M.O. 0000-0002-0048-0281; B.F. 0000-0003-4372-7659; F.K.Ö. 0000-0002-5046-9961.

Address for Correspondence: Shahin Ahmedov
E-mail: sahin.ahmedov@kstu.edu.tr
ORCID ID: orcid.org/0000-0002-2492-5900

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opens and closes due to the movement of the foot extended for a step. Since step length is a determining factor in measuring total distance, its appropriate assessment contributes to determining the distance measured by a pedometer during the day.

It is assumed that the walking step length at the chosen pace is precise[7] and comprises 42% of a person's height.[8] Most body mass is located high enough above the ground[9] that human height acts as an essential independent variable for the preferred step length; however, the gender difference in leg length[10] entails a different center of gravity from the ground, leading to possible gender differences in step length. A previous meta-analysis demonstrated that height-matched women have slightly faster preferred walking speeds than men.[11]

Recent studies have revealed an association between walking velocity and general health and decreased walking velocity with increasing age.[12] Since the metabolic rate ultimately determines the energy expenditure during walking,[13] walking speed, as a complex functional activity, might be another vital sign of personal health status.[14-16]

This study aimed to analyze the walking steps taken by children to define possible gender differences in step length and other mentioned walking parameters. We also planned to identify the walking speed norms for children, that is, the population still unaffected by personal habits, fitness level, and age.

MATERIALS AND METHODS

A total of 457 school children (256 boys) aged 12.65±2.16 years old from three high schools in Northern Cyprus participated in this study. High schools in North Cyprus are divided into state, advanced state, and private high schools. Considering that the difference in the curriculum might affect the children's activity levels, each selected school represented one of the three categories. The total number of students in the selected schools ensured for obtaining a statistically reliable result. After receiving permission from the corresponding educational authorities and the parents' informed consent, an analysis of walking was conducted in the school gyms. Participants had to walk 20 meters twice at their preferred speed, during which the test instructor recorded the number of steps taken and the time spent walking the distance. The step length, cadence, and walking speed were calculated from the average of the recorded data. Step length was defined as the total distance (20 meters) divided by the number of counted steps, cadence (step frequency) represented the number of steps taken divided by the time spent to cover the distance, and walking speed was the distance in meters covered per second.

Additionally, we determined each participant's height and weight using a stadiometer and a weighing scale. At the start and end of the walking test, the participants had their heart rate (HR) measured in beats per minute. The independent t-test for gender differences between values and Pearson's correlation coefficient for the association between HR and the walking parameters were utilized, and the statistical significance threshold was established at $p<0.05$. The Ethics Committee of the Near East University approved this study under the reference number YDU/2021/90-1323 and date 29.04.20.2021.

RESULTS

A summary of the anthropometric and walking parameters of the boys and girls is shown in Table 1. Our observations did not confirm to the accepted assumption that step length directly correlates with an individual's height. Despite the boys' height advantage (160.93±13.51 cm in boys versus 154.66±10.89 cm in girls, $p<0.01$), there was no gender difference in step length (69.64±7.38 cm in boys versus 70.22±6.67 cm in girls, $p>0.1$). Moreover, the girls' step length-to-height ratios were significantly higher (43.4%±4.5% in boys versus 45.5%±4.3% in girls, $p<0.01$).

The girls also outperformed the boys in cadence (1.87±0.18 step/sec in boys versus 1.95±0.18 step/sec in girls, $p<0.01$) and spent less time covering the walking distance (14.31±2.41 sec for girls versus 15.23±2.63 sec for boys, $p<0.01$). These two facts ultimately contributed to their advantage in walking speed (1.35±0.22 m/sec in boys versus 1.43±0.22 m/sec in girls, $p<0.01$).

Although the children's step length positively correlated with their heights as expected ($n=457$, $r=0.42$; $p<0.05$), the step-to-height ratio decreased significantly with an increase in the child's height ($n=457$, $r=-0.40$; $p<0.05$, Figure 1).

The participants' HR evaluations also demonstrated gender differences. The girls had higher HRs compared to the boys both before and after the walking step test (Table 2). At the end of the test, the heart rates in both groups correlated with walking speed, while only the girls' baseline HR correlated with their walking speed ($n=177$, $r=0.202$, $p<0.05$).

DISCUSSION

The human body is a complex biological system where all the closely interconnected organs are in constant interaction with each other, the surrounding environment, and the social environment. The human body is a single self-regulating and self-developing system that ensures human psychological, structural, and biochemical functions' interaction with various environmental conditions.

Without knowledge of the human body's structure and the characteristics of the vital processes of its organs and organ systems, it is impossible to ensure its health, to properly organize the processes of physical education, physical development, and improvement, and to determine the volume and intensity of the loads during physical exercises. With a low level of physical performance, walking is an effective tool to increase aerobic performance.

Walking is a natural type of movement in the open air in which many muscles, ligaments, and joints are involved. It improves metabolism in the body and facilitates cardiovascular, respiratory, and other body systems. Walking intensity is easily affected by the current health condition and physical fitness level. The walking impact on the human body depends on the stride length, walking speed, and duration.

Walking speed is associated with a person's functional status[12] and balance confidence,[17] both of which diminish with age. Walking speed values gradually decrease from 1.31 m/sec in a 20-year-old to 1.06 m/sec in the elderly.[18] Our study has shown that the walking speed in the earlier, namely, prepubertal period, exceeds those of other age groups with an average of 1.39 m/s.

Despite the advantage of boys in age and height, they yielded to girls in almost all walking parameters, including speed, where girls' HRs were higher than boys' HRs. A previous study conducted with 2241 children demonstrated higher HRs for girls than for boys, starting from the age

Table 1. Anthropometric and 20-meter ambulatory parameters obtained from 457 children			
Variables	**Boys (n=256)**	**Girls (n=201)**	**Total (n=457)**
Age (years)*	12.90±2.10	12.32±2.18	12.65±2.16
Height, (cm)*	160.93±13.51	154.66±10.89	158.17±12.80
Weight (kg)*	57.95±16.98	49.52±11.87	54.25±15.52
Step number	28.17±3.23	27.62± 3.06	27.93±3.17
Step length (cm)	69.64±7.38	70.22±6.67	69.89±7.07
Step length/height ratio (%)*	43.40±4.50	45.50± 4.30	44.33±4.50
Time (sec)*	15.23±2.63	14.31±2.41	14.82±2.57
Cadence (step/sec)*	1.87±0.18	1.95±0.18	1.91±0.18
Speed (m/sec)*	1.35±0.22	1.43±0.22	1.39±0.22

*Statistically significant gender differences ($p<0.05$), n: number.

of three years up to adolescence.[19] Scientists attribute this difference to several reasons. While both genders have the same cardiac myocyte number, male cells undergoing a more significant hypertrophy form larger hearts than those in females.[20] Due to this smaller heart size, a girl's heart must contract faster than a boy's. Another reason is the difference in the pacemaker rhythmicity.[21]

The cardiovascular system contributes to the regulation of homeostasis during physical activity. The researchers, however, identified gender differences in the heart's response to stress. While the main contributor to cardiac output in males is stroke volume, the determining factor in increasing cardiac output in females is HR.[22,23] The latter may explain the girls' baseline HR correlating with their walking speed in our study.

As one of the primary reasons for their faster walking speeds, the higher cadence in girls might be ascribed to findings demonstrated in earlier research. The cardiovascular system's response to submaximal exercise revealed a higher mechanical efficiency in females for the same load compared to males. This was reported to be due to an increase in peripheral oxygen extraction and could be a blunted response of the sympathetic nervous system in pronounced compensatory vasodilation on the restricted stroke volume in females.[24] Additionally, the difference in walking speed could also reflect the possible increase in metabolic rate in girls due to the earlier onset of puberty.[25,26]

An additional explanation for girls' superior walking performance may be their skeletal characteristics, which favor balance confidence during ambulation. Girls' lower position of the gravity center from the base of support, defined by the higher sitting height-to-leg length ratio[27] and their wider pelvic size[28] compared to boys could serve as an explanation for girls' being more confident in their walking balance. Observations have demonstrated differences in the male versus female biomechanics of the lower extremities during walking and running. These differences were associated with the ratio of pelvic width to leg length.[29]

Height, as expected, was the decisive factor in stride length; however, the child's step-to-height ratio decreased as height increased, apparently caused by the distance of the center of gravity from the base of support in tall children (Figure 1).

Table 2. Heart rate gender differences during walking step test			
Walking step test	**Boys (b/min)**	**Girls (b/min)**	**Significance**
Heart rate before	92.97±17.98	102.13±16.76	$p<0.01$
Heart rate after	101.79±21.20	106.37±18.65	$p<0.05$

As this work has shown, universal formulas should be treated cautiously due to differences in biomechanics, physical form, and other variables. This analysis of children's preferred walking speeds showed that height and age do not give the expected advantages in step length and movement speed in the prepubertal age. Although the girls were inferior to the boys in terms of height and age and had equal step lengths, they walked faster. The latter in children results from values dependent on metabolism and body morphology; height and shape impact balance confidence.

Another important implication to consider is that the step length and cadence are essential determinants of running speed. Studies that have analyzed the effect of stride length and frequency on lower limb injuries in runners have shown that increased stride frequency reduces the risk of sports injury during running.[30] Perhaps this is one reason for the more frequent trauma of the lower limb in all of its joints in men than in women.[31]

An essential part of the general population's physical fitness assessment is accomplishing various dynamic tests requiring certain conditions and equipment for their implementation. Measurement of the preferred walking speed, the steadiness and individuality of which have been confirmed by several scientific studies, makes it possible to quickly and easily determine the physical development in various groups of the population, including children. While poor posture, orthopedic conditions, obesity, mental issues, and overall development might contribute to a child's preferred walking speed, the walking speed of both sexes directly depends on the calf muscle strength.[32] Since an increase in muscle mass is an essential indicator of healthy age-related

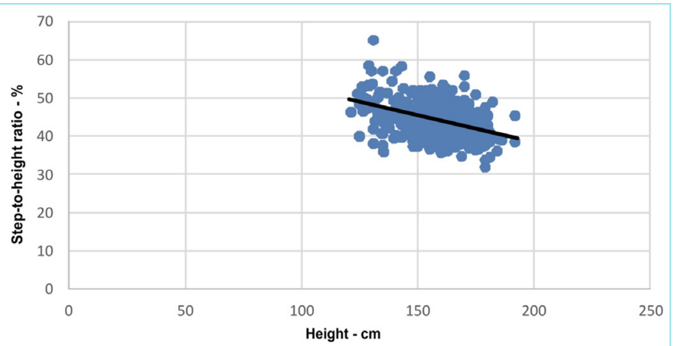

Figure 1. Association between children's height and step-to-height ratio (n=457, r= -0.40, $p<0.05$).

dynamics of the musculoskeletal systems of children, the preferred walking speed test might be used to assess the general development of a child.

The walking speed issue has become especially relevant today as the problem of coronavirus disease-2019 (COVID-19) has acquired the character of a pandemic. This year's research has confirmed the importance of walking speed as an independent risk factor for coronavirus. Even for those of average body weight, individuals with slow walking speeds had a greater risk of contracting COVID-19.[33]

Step length is a determining parameter of walking speed. In this regard, the relative dependence of the step length on body height and the decreased former-to-latter ratio with increased height observed in our study deserves special attention. The distance of the gravity center from the base of support, rather than the individual's height, determines walking step length. Studies indicate that short stature is a positive factor in reducing disease incidence and increasing life longevity in the population.[34,35] Given the advantage in the high speed of ambulation of people of short stature, it seems reasonable to define the relationship between body proportions (e.g., the ratio of leg length to body height) and stride rates in a healthy population and people with pathology. Further studies are necessary to clarify this suggestion.

CONCLUSION

In summary, the age and gender-specific walking differences may serve as a valuable reference for the early detection of various health problems and appropriate decision-making in favor of suitable corrective exercise programs.

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MAIN POINTS

- Prepubertal girls outperformed boys in terms of preferred walking speed and cadence, despite having younger age and lower stature.
- Both at the beginning and at the end of the test, the girls' heart rate was higher and the girls' pretest heart rate correlated with their preferred walking speed
- Although the step length is proportional to height, the step length-to-height ratio decreases as height increases.
- The walking speed test might be used to assess the general development of a child.

ETHICS

Ethics Committee Approval: The Ethics Committee of the Near East University approved this study under the reference number YDU/2021/90-1323 and date 29.04.20.2021.

Informed Consent: After receiving permission from the corresponding educational authorities and the parents' informed consent, an analysis of walking was conducted in the school gyms.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: S.A., F.Y.L., Design: S.A., F.Y.L., M.O., Supervision: S.A., Data Collection and/or Processing: F.Y.L., M.O., B.F., F.K.Ö., Analysis and/or Interpretation: S.A., M.O., Literature Search: S.A., F.Y.L., Writing: S.A., Critical Review: F.Y.L.

DISCLOSURES

Conflict of Interest: No conflict of interest was declared by the authors.

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