JBACHS
Journal of Basic and Clinical Health Sciences

J Basic Clin Health Sci 2023; 7: 277-283
https://doi.org/10.30621/jbachs.1097400
RESEARCH ARTICLE

GENDER DIFFERENCES IN GAIT PARAMETERS OF HEALTHY ADULT INDIVIDUALS

Sinem Suner-Keklik[1], Gamze Çobanoğlu[2], Zeynep Berfu Ecemiş[2], Nevin A. Güzel[2]

[1] Sivas Cumhuriyet University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Sivas, Turkey
[2] Gazi University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Turkey

ORCID: S.S.K. 0000-0002-9506-3172; G.Ç. 0000-0003-0136-3607; Z.B.E. 0000-0001-8136-8218; N.A.G. 0000-0003-0467-7310

Corresponding author: Sinem Suner-Keklik, **E-mail:** s-suner@hotmail.com
Received: 02.04.2022; **Accepted:** 05.07.2022; **Available Online Date:** 31.01.2023

Cite this article as: Suner-Keklik S, Çobanoğlu G, Ecemiş Z B, Güzel N A. Gender differences in gait parameters of healthy adult individuals J Basic Clin Health Sci 2023; 7: 277-283.

ABSTRACT

Purpose: Anatomical and biomechanical differences between male and female are also known to cause differences in gait patterns. However, the results of the studies are contradictory. Furthermore, these studies focused only on some of the spatiotemporal parameters, and pelvic movements were not analyzed. The aim of the present study is to reveal the difference in gait parameters between male and female.
Material and Methods: 44 female and 39 males were included in the study. BTS G-Walk system was used to evaluate the gait. After the accelerometer was placed, the participants were asked to walk 8 m. Spatiotemporal parameters and pelvic kinematics were recorded.
Results: Given the spatiotemporal parameters, it was found that male and female were similar in terms of speed, % stride length and step length (p>0.05), while gait cycle duration, stride length, swing phase and single support phases were higher in male; and stance phase, first double support phases, cadence were found to be higher in female (p<0.05). In pelvic kinematics, male and female were similar in terms of rotation total range, gait cycle, pelvic tilt, obliquity and rotation symmetry index (p>0.05), while pelvic tilt total range was higher in male and obliquity total range was higher in female (p<0.05).
Conclusion: The fact that gait differs not only in spatiotemporal parameters but also in pelvic oscillations due to anthropometric and biomechanical differences between male and female has shown that when evaluating individuals in the clinic, they should be compared and interpreted according to their own gender groups.

Keywords: Gender, gait analysis, pelvic kinematics, spatiotemporal parameter

INTRODUCTION

It is widely known that there are some anatomical structure and biomechanical differences between male and female (1). According to anthropometric research, there are significant gender differences in skeletal dimensions. Therefore, it is known that there are differences in the gait patterns of the two genders, but studies to identify significant gender differences in gait pattern and to uncover their possible causes through objective data analysis are still inadequate (2), and the study results are conflicting (3).

The evaluation of the gait is the main indicator not only in cases of illness or disability, but also for the comparison of typical movement behavior (condition) in changing conditions (4). Basic clinical gait analysis is mainly observational or takes gait speed in a wide population range as basis (5). However, these tests are not sufficient to evaluate other spatiotemporal parameters, such as derivative parameters such as cadence, step length and gait symmetry, which are considered necessary for a complete and accurate evaluation of the gait (6, 7). The BTS G-WALK sensor system (G-Walk) can be used to determine spatiotemporal parameters as well as pelvic movements (rotation, tilt and obliqueness) during gait (8). For this reason, it is a valid and reliable method that can be used for gait analysis (6, 9).

There are studies in the literature showing the differences between the genders in different joints during gait (10-12). However, to our knowledge, studies have generally focused on only some of the spatiotemporal parameters. No study was found comparing all spatiotemporal parameters and pelvic movements and pelvic symmetry between genders. Therefore, the aim of the present study is to reveal the difference of gait parameters between male and female in terms of both spatiotemporal and pelvic oscillations

MATERIAL AND METHODS

The patients to be included in the study were selected on a voluntary basis among individuals aged between 18 and 40 without any health problems. Exclusion criteria for the study was having any diagnosed orthopedic, rheumatic or neurological diseases that may affect movement and cause gait and/or balance problems and the presence of a recent new trauma. Prior to the study, participants were informed of the purpose and content of the study and had an Informed Consent Form signed that they would participate voluntarily.

In the study, the BTS G-Walk system (BTS G-Walk BTS Bioengineering Company, Italy) was used to evaluate the gait parameters of individuals. The BTS G-Walk device consists of hardware and software that allows objective and precise analysis of movements through a wearable inertia sensor. First, the name, height, body weight, age and gender data of the individuals were entered into the system, and then the G-Walk was placed at approximately L4-L5 intervertebral cavities with the help of a waist belt. Spina iliaca posterior superior (SIPS) point levels were used to determine this level, and L4-L5 intervertebral cavity were palpated, and it was made sure that the accelerometer was placed correctly. After the accelerometer was placed, the participants were asked to walk on 8 m gait track restricted with colored lines in normal gait rhythm and return to the starting position. The values of the acceleration in the anteroposterior and mediolateral axes and gait were transferred to the computer software program (G-Studio, BTS Bioengineering) via Bluetooth signals (13). The software used was BTS G-Studio. G-Studio is simple and easy-to-use software that can manage different capacities and automatically detail and report different analysis protocols. After each analysis, a report including all the parameters is automatically generated by the software (6).

As a result of the study, spatiotemporal parameters of the gait such as cadence (step/min), speed (m/s), step length (m), swing phase and double support phase duration (calculated as a percentage of the gait cycle) were analyzed. In addition, pelvic obliquity (up (positive) or down (negative) movement of the pelvis in the frontal (F) plane), pelvic tilt (forward or backward movement of the pelvis in the sagittal (S) plane) and pelvic rotation (internal (positive) or external (negative) movement of the pelvis in the transverse plane) parameters were used to measure the symmetry of pelvis movement during gait (14).

Statistical analysis

SPSS version 22.0 was used for statistical analysis. The compatibility of the parameters with the normal distribution was analyzed using visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/ Shapiro-Wilk tests). Descriptive analyses were provided using the median and interquartile range as the variables were not distributed normally. Since it was found that the parameters did not distribute normally, the variables were compared with the Mann Whitney-U test between the groups. The cases where the p value was below 5% were considered statistically significant.

Ethical Consideration

The study was carried out at Gazi University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation. For the present study, an ethical approval Nr. 2021-06/02 was received on 23.06.2021 from Sivas Cumhuriyet University, Ethics Committee for Non-Interventional Clinical Research.

RESULTS

In the post hoc power analysis for the study, the effect size calculated considering the cycle duration values was 0.98. When 44 women and 39 men were

Table 1: Comparison of demographic characteristics of female and male

	Female (n=44)	Male (n=39)	p
Age (years)	24 (23 / 27)	24 (23 / 28)	0.790
Body weight (kg)	58 (54.2 / 65)	72.65 (65 / 77.9)	**0.000***
Height (cm)	165 (162.5 / 168)	176 (174 / 180)	**0.000***
BMI (kg/cm²)	21.45 (20.25 / 23.24)	22.99 (21.46 / 24.49)	**0.019***

Data are presented Median (IQR). *p < 0.05, BMI: Body Mass Index

included in study, we calculated that the power of the study was 0.99.

While there was no age difference between the male and female participants in the present study (p>0.05; Table 1), the two groups were found to differ in body weight, height and body mass index (BMI) (p<0.05; Table 1). Body weight, height and BMI were higher in male than in female.

Given the spatiotemporal parameters of gait, it was found that male and female were similar in terms of speed, % stride length and step length on the right and left sides (p>0.05; Table 2), while it was observed that there were differences in terms of cadence, gait cycle duration, stride length, stance phase, swing phase, first double support phase, and single support phase on both sides (p<0.05; Table 2). The gait cycle duration, stride length, swing phase and single support phases on both sides were found to be higher in male than those in female. In contrast, the cadence, stance phase and first double support phases on the right and left sides were found to be higher in female than those in male.

In pelvic kinematics, male and female were found to be similar in terms of gait cycle symmetry index, pelvic tilt symmetry index, obliquity symmetry index, rotation symmetry index, pelvic rotation total range on the right and left sides (p>0.05; Table 3), while it was observed that there were differences in terms of pelvic tilt total range and obliquity total range on both sides (p<0.05; Table 3). It was found that the pelvic tilt total range both sides were higher in male than in female while the pelvic obliquity total range on both sides was higher in female.

DISCUSSION

As a result of the present study conducted to reveal the difference of gait parameters between male and female, it was found that there were differences between the genders in both the spatiotemporal parameters and the pelvic kinematics of the gait. It was determined that most of the parameters of gait were affected by gender.

The gait, which is an important activity of daily life, is a way of movement consisting of the double support phase, in which two feet come into contact with the ground, followed by the swing phase, in which the body swings forward by being supported on one foot (15). However, it is vital to evaluate spatiotemporal parameters, which include the speed of gait, stride time and length, stance phase and swing phase. These measurements are called "basic gait parameters" and "vital signs of gait" (16). This final expression reflects the fact that these measurements are important indicators that a gait pattern may be abnormal and if so, they are important indicators in indicating the cause of the problem (15).

As a result of a study that analyzed the gait differences of male and female using a wearable gait analysis system, the stride length and gait speed of male and female were found to be similar (3). In the present study, similar to the above-mentioned research, it was found that the gait speed and stride length were the same in male and female. In a study by Oberg et al. on healthy male and female in Sweden, the gait differences in between the genders at different gait speeds (slow-medium or fast gait) in the gait laboratory and it was found that the gait speed and stride length of female were lower than that of male (17). These results contradict our results revealing similar speed and stride length. This may be because we used different analysis systems and different methods. In addition, more detailed measurement results were obtained in the present study. In the study of Al-Obaidi et al., which was planned to determine the effects of ethnic and cultural factors on the gait in Kuwaitis, it was emphasized that gait speeds were different between the two genders due to the fact that male were taller, and therefore the speed should be normalized by being divided by height. As a result of the study, it was found that there were differences in gait speed between male and female for the moderate and fast gait speed of their choice. The speed was found to be similar in slow and

Table 2: Comparison of female and male in terms of spastiotemporal parameters of gait

	Female (n=44)	Male (n=39)	p
Cadence (steps / min)	117.9 (113.65 / 123)	110.5 (107 / 113.4)	**0.000***
Speed (m / s)	1.26 (1.1 / 1.37)	1.31 (1.18 / 1.43)	0.081
Right gait cycle duration (s)	1.03 (0.99 / 1.07)	1.09 (1.06 / 1.12)	**0.000***
Left gait cycle duration (s)	1.04 (0.99 / 1.06)	1.09 (1.06 / 1.13)	**0.000***
Right stride length (m)	1.29 (1.14 / 1.40)	1.45 (1.29 / 1. 55)	**0.001***
Left stride length (m)	1.3 (1.15 / 1.4)	1.44 (1.29 / 1.53)	**0.001***
Right % stride length (% height)	78.35 (73.35 / 85.45)	82.7 (73.4 / 88.9)	0.278
Left % stride length (% height)	79 (73.4 / 84.35)	81.4 (74.1 / 87.7)	0.320
Right step length (% str length)	50.05 (49.05 / 51.25)	50.9 (49.4 / 52.2)	0.077
Left step length (% str length)	49.95 (48.75 / 50.95)	49.1 (47.8 / 50.6)	0.077
Right stance phase (% cycle)	60.15 (59.2 / 61.6)	58.9 (58 / 60.1)	**0.000***
Left stance phase (% cycle)	60.5 (59.45 / 62)	59 (57.8 / 60.3)	**0.000***
Right swing phase (% cycle)	39.85 (38.4 / 40.8)	41.1 (39.9 / 42)	**0.000***
Left swing phase (% cycle)	39.5 (38 / 40.55)	41 (39.7 / 42.2)	**0.000***
Right first double support phase (% cycle)	10.8 (9.7 / 11.9)	9.1 (7.8 / 10.3)	**0.000***
Left first double support phase (% cycle)	10.15 (9.2 / 12.05)	9.2 (8 / 10.1)	**0.000***
Right single support phase (% cycle)	39.5 (38 / 40.5)	40.9 (39.6 / 42.2)	**0.000***
Left single support phase (% cycle)	39.75 (38.25 / 40.55)	40.9 (40 (42.2)	**0.000***

Data are presented Median (IQR). *p < 0.05

medium-speed gait, while male were found to be significantly faster at fast gait (15). Likewise, in a study on the gait of healthy young Canadians by normalizing the speed according to the height, it was found that female were slower than male at the slow, medium and fast gait speeds of their choice (18). In the present study, we only evaluated individuals during normal gait, and the gait speed was similar between male and female. The results are similar to those obtained by Al-Obaidi et al. in slow and medium-speed gait.

It is stated in the literature that the gait speed is affected by the stride length rather than the number of strides taken (19). In a study by Kerrigan et al., it was found that healthy male who walked at the same speed as healthy female had lower cadence and longer step length than female (20). As a result of the present study, it was observed that the right and left step length of male and female were similar, while the cadence values were higher in female compared to both groups. As a result of the study using the wearable analysis system, it was determined that the value of cadence in female was higher than in male, with no statistically significant difference (3). In the study by Oberg et al., it was shown that the frequency of female's strides was higher than that of male (17). Considering the frequency of steps equivalent to cadence, it can be said that the results are similar in this respect. A lower cadence value indicates that the gait is less efficient. Accordingly, it can be concluded that female take more strides per minute and walk more efficiently, regardless of stride length and speed.

A study comparing male and female in terms of gait found that stride length was longer in male than in female (18). Another study found that although stride length was found to be longer in male, the results were not statistically significant and were ultimately similar for both genders (3). In the present study, we showed that the length of the left and right stride (the distance between the two themes of the same foot) is longer in male. However, the distance between the two themes of the same foot obtained by normalizing the stride length on the right and left side according

Table 3: Comparison of female and male in terms of kinematic analysis of the pelvis

	Female (n=44)	Male (n=39)	p
Gait cycle symmetry index	97.5 (95.15 / 98.35)	97.1 (95.7 / 98.2)	0.848
Pelvic tilt symmetry index	71.2 (52.15 / 88.05)	60.1 (33.3 / 84.4)	0.213
Right pelvic tilt range (°)	4.75 (3.55 / 5.95)	5.8 (4.4 / 7.8)	**0.011***
Left pelvic tilt range (°)	4.75 (3.65 / 6.2)	5.7 (4.6 / 7.4)	**0.022***
Obliquity symmetry index	98.9 (97.6 / 99.1)	98.5 (97.3 / 98.8)	0.062
Right obliquity range (°)	12.8 (10.25 / 14.15)	8.6 (7.2 / 10.5)	**0.000***
Left obliquity range (°)	12.8 (10.15 / 13.9)	8.6 (7.2 / 10.5)	**0.000***
Rotation symmetry index	98.55 (97.65 / 98.95)	98.8 (98 / 99.1)	0.263
Right rotation range (°)	13.7 (10.95 / 15.95)	13.4 (10.4 / 16.3)	0.791
Left rotation range (°)	13.4 (11.1 / 16)	13 (9.8 / 16.5)	0.606

Data are presented Median (IQR). *p < 0.05

to the height of the individual was found to be the same in our stride length % study. Since male are taller and have longer legs, it is normal to have the same distance as female when this value is normalized with height length. Unlike the present study, in a study by Kerrigan et al. on the differences between the genders, it was found that stride length % values in female were higher than that of male (20). Gait cycle duration, which is expressed as the time between the two heel strokes of the same foot, was found to be longer than that of female in male both on the right and left sides. These results can explain why cadence is lower in male than in female, although they walk with the same stride length and speed. It can be concluded that the long gait cycle duration slowed down the completion of the gait cycle and reduced the number of strides taken per minute. In addition, the present study found that the single support phase for the right and left sides and the swing phase were longer in male. This can be interpreted as a (parallel) result associated with gait cycle duration and low cadence.

Although it was not found statistically significant as a result of a study that analyzed the gait differences between the two genders with a wearable analysis system, the double support phase in female was found to be longer than that of male (3). As a result of the present study, we found that both the right and left stance phase and the right and left double support phase were longer in female. The primary reason why these parameters are higher in female than in male may be because the balance of male is better (21), so the single support phases are long. Impairment of balance results in significant impact on gait performance. The time for standing on one foot is of great importance in balance. As the balance deteriorates, standing on one foot also deteriorates (22). It is also stated that leg muscle strength affects gait parameters (19). In other words, both standing and double support phases may be short and the only support phases associated with it may be long, as male's balance and muscle strength are probably better.

The BTS-G walk device provides information about pelvic kinematics as well as spatiotemporal parameters. The average value of the angles defined by the pelvis in 3 main body planes (sagittal, frontal and transverse) is defined in 3 graphs. Each chart has two overlapping curves, normalized on the left and right gait cycles, respectively. This allows instant evaluation of motion symmetry (23). Symmetry index (%), which measures how similar the profile of the right curve is to the profile of the left curve; ideally, is 100% if the two curves overlap perfectly. This means that the two curves have the same value squarely. Values above 40 for pelvic tilt can be considered normal. For pelvic obliquity and rotation, the normal value is 80–100 (14). According to these norm values, it was found that the symmetry indexes of the male and female in the present study are the same and are within the norm values. Moreover, it was determined that the total range of rotation (internal - external rotation of the pelvis) of male and female on the right and left sides was the same. However, the total range of the pelvic tilt on the right and left side was higher in male than in female. This may be related to the of gait cycle duration, the high swinging phase and also the long height lengths of male. The total range of the right and left side obliquity was found to be higher in female. The fact that the width of the pelvis is wide and the cadence is high in female may have caused the up and down movement of the pelvis to be high.

Since asymmetry in gait is usually analyzed in case of orthopedic or neurological injury or disease, this type of asymmetry in healthy individuals indicates biomechanical disorder instead of normal gait (24, 25). The significant difference in gait between male and female demonstrates the need to compare and comment on individuals' gender groups when evaluating them in the clinic. All the measurements made in the studies used for comparison in the discussion were carried out using different programs during the motion analysis. Due to the different ways of collecting data, the existing literature does not allow full comparison of the results. However, it provides the opportunity to determine certain outlines of the subject.

Strengths and Limitations

We only included people between the ages of 18-40 in our study. This is the limitation of our study. There is a need for studies in which kinetic and kinematic gait analyzes are performed in different age groups.

CONCLUSION

Although gait has many aspects to focus on, only gait speed has been assessed in many studies and it is recommended to use speed as a measure of condition and result (26, 27). However, the results of the present study revealed that focusing only on speed may lead to misinterpretation when conducting a gait analysis, and that gait should be assessed through multifaceted analysis and interpretation. As a result of the present study, many important factors will be overlooked if the fact that healthy male and female of similar age groups have similar gait speed is interpreted as similar gait characteristics. It can be said that even for the cadence closely related to gait speed, having the same gait speed is not enough, there are many parameters that affect it, and pelvic oscillations should not be overlooked during gait analysis.

Acknowledgement: None.

Author contribution: Sinem Suner-Keklik: Study Design, Manuscript Preparation, Data Interpretation, Literature Search. Gamze Cobanoglu: Study Design, Data Collection, Statistical Analysis, Data Interpretation, Critical Review. Zeynep Berfu Ecemıs: Data Collection, Providing Cases. Nevin A. Guzel: Data Interpretation, Critical Review.

Conflict of interests: The authors report no conflict of interest.

Ethical approval: For the present study, an ethical approval Nr. 2021-06/02 was received on 23.06.2021 from Sivas Cumhuriyet University, Ethics Committee for Non-Interventional Clinical Research.

Funding: No funding applied for or received.

Peer-review: Externally peer-reviewed.

REFERENCES

1. Obrębska P, Skubich J, Piszczatowski S. Gender differences in the knee joint loadings during gait. Gait Posture 2020;79:195-202.
2. Cho SH, Park JM, Kwon OY. Gender differences in three dimensional gait analysis data from 98 healthy Korean adults. Clin Biomech 2004;19(2):145-152.
3. Abualait TS, Ahsan M. Comparison of Gender, Age, and Body Mass Index Levels for Spatiotemporal Parameters of Bilateral Gait Pattern. Preprints 2021.
4. Gieysztor E, Kowal M, Paprocka-Borowicz M. Gait Parameters in Healthy Preschool and School Children Assessed Using Wireless Inertial Sensor. Sensors 2021;21(19):6423.
5. Middleton A,. Fritz SL, Lusardi M. Walking speed: the functional vital sign. J Aging Phys Act 2015;23(2):314-322.
6. De Ridder R, Lebleu J, Willems T, De Blaiser C, Detrembleur C, Roosen P. Concurrent validity of a commercial wireless trunk triaxial accelerometer system for gait analysis. J Sport Rehabil 2019;28(6):1-4.
7. Kraan CM, Tan A, Cornish KM. The developmental dynamics of gait maturation with a focus on spatiotemporal measures. Gait Posture 2017;51:208-217.
8. Buckthorpe M, Morris J, Folland JP. Validity of vertical jump measurement devices. J Sports Sci 2012;30(1):63-69.
9. Yazıcı G, Yazıcı M, Çobanoğlu G, et al. The reliability of a wearable movement analysis system (G-walk) on gait and jump assessment in healthy adults. JETR 2020;7(2):159-167.
10. Clément J, Toliopoulos P, Hagemeister N, Desmeules F, Fuentes A, Vendittoli PA. Healthy 3D knee kinematics during gait: Differences between women and men, and correlation with x-ray alignment. Gait Posture 2018;64:198-204.

11. Fukano M, Fukubayashi T, Banks SA. Sex differences in three-dimensional talocrural and subtalar joint kinematics during stance phase in healthy young adults. Hum Mov Sci 2018;61:117-125.
12. Mazzà C, Iosa M, Picerno P, Cappozzo A. Gender differences in the control of the upper body accelerations during level walking. Gait posture, 2009;29(2):300-303.
13. Awotidebe TO, Ativie RN, Oke KI, et al. Relationships among exercise capacity, dynamic balance and gait characteristics of Nigerian patients with type-2 diabetes: an indication for fall prevention. J Exerc Rehabil 2016;12(6):581.
14. Latajka A, Woźniewski M, Malicka I. Influence of surgical treatment of selected malignant tumours on gait kinematics–a pilot study. Physiother Quart 2018;26(4):33-39
15. Al-Obaidi S, Wall JC, Al-Yaqoub A, Al-Ghanim M. Basic gait parameters: A comparison of reference data for normal subjects 20 to 29 years of age from Kuwait and Scandinavia. J Rehabil Res Dev 2003;40(4):361-366.
16. Wall JC, Charteris J, Turnbull GI. Two steps equals one stride equals what?: the applicability of normal gait nomenclature to abnormal walking patterns. Clin Biomech 1987;2(3):119-125.
17. Oberg T, Karsznia A, Oberg K. Basic gait parameters: reference data for normal subjects, 10-79 years of age. J Rehabil Res Dev 1993;30:210-223.
18. Rosenrot P. The relationship between velocity, stride time, support time, and swing time during normal walking. J Hum Mov 1980;6:323-335.
19. Demura T, Demura S. Relationship among gait parameters while walking with varying loads. J Physiol Anthropol 2010;29(1):29-34.
20. Kerrigan DC, Todd MK, Della Croce U. Gender differences in joint biomechanics during walking: normative study in young adults. Am J Phys Med Rehabil 1998;77(1):2-7.
21. Błaszczyk JW, Beck M, Sadowska D. Assessment of postural stability in young healthy subjects based on directional features of posturographic data: vision and gender effects. Acta Neurobiol Exp 2014;74(4):433-442.
22. Ringsberg KA, Gärdsell P, Johnell O, Jónsson B, Obrant KJ, Sernbo I. Balance and gait performance in an urban and a rural population. J Am Geriatr Soc 1998;46(1):65-70.
23. BTS G Walk User Manual English Version 7.0.0. 2016.
24. Shin SY, Lee RK, Spicer P, Sulzer J. Does kinematic gait quality improve with functional gait recovery? A longitudinal pilot study on early post-stroke individuals. J Biomech 2020;105:109761.
25. Ismailidis P, Hegglin L, Egloff C, et al. Side to side kinematic gait differences within patients and spatiotemporal and kinematic gait differences between patients with severe knee osteoarthritis and controls measured with inertial sensors. Gait Posture 2021;84:24-30.
26. Bohannon RW. Comfortable and maximum walking speed of adults aged 20—79 years: reference values and determinants. Age Ageing 1997;26(1):15-19.
27. Boonstra AM, Fidler V, Eisma WH. Walking speed of normal subjects and amputees: aspects of validity of gait analysis. Prosthet Orthot Int 1993;17(2):78-82.