ORIGINAL ARTICLE

Analysis of the spatial-temporal and angular variables of gait of blind individuals

[1]Caroline Cunha do Espírito Santo, [2]Graziela Morgana Silva Tavares, [1]Thiele de Cássia Libardoni, [1]Larissa Sinhorim, [3]Gilmar Moraes Santos

ABSTRACT

Analyze and describe the spatial-temporal and angular variables of gait of total blind individuals. **Method:** The present study included 19 individuals with a mean age of 28±6 years, who were divided into two groups, the first composed of eight blinded individuals, and the second group of 11 individuals with normal vision. The variables were collected by the Peak Motus system and were analyzed with the Ariel Performance Analysis System Software. The subjects walked at a self-selected speed on a seven-meter long, obstacle-free route, until reaching six valid strides. For statistical analysis, the Student t test was applied, with significance level of $p \leq 0.05$. **Results:** The blind individuals showed a significant reduction of gait velocity, cadence, stride length, swing phase and maximum angle of knee flexion, as well as increased support phase and double-support period, compared to the subjects with normal vision. No significant difference was found for maximum hip extension angle between the groups. **Conclusion:** The findings of this study showed that the absence of visual information associated with postural and balance changes induce the blind subjects to have slower gait, with reduced stride length, angle of knee flexion and swing phase, and increased support phase and period of double-support, when compared to subjects with normal vision.

Keywords: Visually Impaired Persons, Biomechanical Phenomena, Gait

[1] Master in Physiotherapy, State University of Santa Catarina – UDESC.
[2] Adjunct Professor, Physiotherapy Course, Pampa Federal University – UNIPAMPA.
[3] Associate Professor, State University of Santa Catarina – UDESC.

Mailing address:
Universidade Federal do Pampa - UNIPAMPA
Graziela Morgana Silva Tavares
BR 472 - Km 585 - Caixa Postal 118
Uruguaiana – RS
CEP 97501-970
E-mail: grazielatavares@unipampa.edu.br

Submitted in January 9th, 2018.
Accepted in March 28th, 2018.

DOI: 10.5935/0104-7795.20170025

INTRODUCTION

It is currently estimated that there are 45 million visually impaired people in the world, with one to two million new cases each year.[1] In Brazil, visual impairment is the most common type of disability, up to around 7.2 million cases, among those, approximately 582,000 are blind.[2]

Visual impairment is defined as the state of irreversible decrease of visual response even after clinical and/or surgical treatment and conventional corrective lenses, due to congenital or acquired causes.[3,4] Loss of visual response classified as mild, moderate, severe and profound refers to individuals with low vision or subnormal vision, and the complete absence of such response characterizes blind individuals.[4]

According to the Brazilian Council of Ophthalmology (CBO),[5] the term blindness is used to classify the degree of visual limitation of the individual after corrected vision of the best of their eyes. This can be called partial or legal blindness, in which the individual even after the visual correction presents 20 or less degrees of visual angle according to the visual scale. The term total blindness or amaurosis, is used to classify individuals with complete loss of vision, that is, absence of light perception.[5]

The differentiation between congenital and acquired blindness is established by the exact moment of visual loss, therefore, it is considered congenital blind who is born without vision or loses it until the age of three, and acquired blindness stand for those who has visual loss after the age of three.[3]

Vision, constituent of the postural control system, is responsible for providing accurate information about the physical structure of the environment, the presence of objects or irregular surfaces, and is responsible for allowing anticipatory action of upcoming events, what allows proper safety by route planning for avoiding shocks, injuries and/or falls.[6,7]

In addition to vision, the postural control system requires information from the proprioceptive and vestibular system. Therefore, the total or partial absence of the vision entails automatic compensation of the other constituents of the postural control system.[8] Such compensation aims to maintain the motor control of the visually impaired persons similar to those of healthy individuals, however, it is known that part of the population does not move harmoniously.[3]

According to Mosquera et al.[3], the deficit in the visual system triggers a decline in gait making it insecure, unstable, as well as hindering orientation and mobility, forcing the individual to develop a mental map of the physical environment.

People with visual impairment have changes such as decreased walking speed,[8-10] decreased step length,[8,11] decreased cadence,[10] decreased of balance phase,[10] and decreased of hip extension angle during the impulse phase,[11,12] well as an increase in the duration of the support phase,[8] absence of initial contact with the heel in the ground, what is replaced by the entire sole of the foot,[11,13] and the stressing of the external rotation of the hip.[13]

Although there is already some evidence related to the difference between the gait of visually impaired individuals and individuals with normal vision,[8] few studies referring to this issue are found in the literature, mainly regarding the blind population of Brazil. Thus, gait measurement of blind individuals could help characterize their mobility and consequently help the development of strategies for the prevention of possible changes or the promotion or the rehabilitation of gait in this population.

OBJECTIVE

To analyze and describe the spatial-temporal and angular variables of blind individuals gait and compare them with individuals with normal vision.

METHODS

This is a descriptive, comparative and cross-sectional research,[14] conducted according to the guidelines of the 466/12 Resolution of the Brazilian Health Council and approved by the UDESC Ethics Review Board (approval number 19/2008).

All the subjects were informed regarding their participation and signed the informed consent form and an authorization for photographs and filming to voluntarily participate in the research.

PARTICIPANTS

A total of 19 individuals with a mean age of 28 ± 6 years were selected. The first group consisted of 11 individuals with normal vision (GNV) and the second group was composed of eight individuals with total blindness (GTB), all of whom admitted in a rehabilitation center for blind people. The visual loss time of two individuals with acquired blindness was 8 years and 10 years. Of the 19 participants, 12 were female (28 ± 7 years) and seven were male (29 ± 4 years). Anthropometric data and type of visual impairment are shown in Table 1.

To participate in the GTB, individuals should use a walking stick and present a diagnosis of total blindness in the institutional medical record in which they were properly admitted. In the GNV, those who did not present diagnosis or self-reported visual problems were included.

In this study, the following exclusion criteria were adopted for both groups: presence of neurological, musculoskeletal, labyrinthic, auditory, amputated, pregnant, diabetic, low vision or who had undergone surgery for visual correction.

Only one blind individual was excluded from the study because of clinically diagnosed hearing disorders.

Instruments

The anthropometric data were obtained by an electronic scale Filizola®, for measuring weight in kilograms with intervals of 50 grams, and a stadiometer coupled to the scale, graded in centimeters with intervals of one millimeter.

The acquisition of kinematic gait data in the sagittal plane (dominant side), the Peak Motus image acquisition system was used with a video camera of 60 Hz, which was fixed to a tripod at 1.03 meters of height from the ground. This camera was connected to an VCR (SVHS AG-5700 Panasonic), which allowed for recording images on VHS video tapes. The walking time was measured by a chronometer that was connected to four photocells fixed to the wall at a distance of 4 meters in-between them.

Table 1. Anthropometric data and type of visual impairment

Subjects	Age (years)	Height (m)	Weight (kg)	Type of visual impairment
GCT	31±7	1.59±0.07	64.5±14.5	6 (75%) congenital 2 (25%) acquired
GNV	27±5	1.66±0.06	64.7±12.5	---

Legenda: GCT= Grupo cegos totais; GNV= Grupo visão normal

A calibrator with four points measuring 1.2 x 1.2 x 1.2 x 1.2 meters and a fixed point placed at the top of the wall at approximately 3.5 meters from the initial spot of the image acquisition was used to calibrate the camera.

Data collection

Data collection was conducted at the Biomechanics Laboratory of the Health and Sports Science Center of the State University of *Santa Catarina*. It was divided in two stages. In the first one, GTB subjects performed a previous tactile recognition of the physical space before the beginning of the data collection and filled an individual identification form containing the anthropometric data and the type of visual impairment.

In the second stage, the following anatomical points were identified according to Perry[15] and marked with reflective markers: acromion, major trochanter of the femur, lateral epicondyle of the femur, fibular malleolus, calcaneus and fifth metatarsal head. Subsequently, the dominant limb was registered, which, for the GTB individuals was considering the side they use the long cane. To facilitate the visualization of the anatomical points, during the data collection they wore bathing suit and were bare feet.

Then, they were asked to walk on a seven-meter-long obstacle-free route, at a self-selected speed until six steps were considered valid. Every trajectory in which the reflective markers fell off, in which there was no horizontalization of the eyes in the case of GNV individuals, and in which the route became diagonal were considered invalid. A maximum of 10 attempts (pass) for each subject were allowed during data collection, and those who did not achieve a minimum of five valid attempts were automatically excluded from the study.

The data analysis was performed in the Ariel Performance Analysis System (APAS) software, according to the following order: selection of five valid passages, elimination of one gait cycle for each pass, which was considered as two sequential contacts of the same foot against the ground in our study.[16] As the gait velocity was calculated primarily and independent of the APAS, the five speeds closest to each other were considered the selection criteria for a total of 6 filmed passes.

After the cut, the gait cycle was divided into two phases for analysis, support and balance. For each of the phases an initial and an endpoint were previously established Chart 1.

The period from initial contact with the dominant limb to the pre-swinging phase of the contralateral limb, characterized as double-support (support phase) was also analyzed in this study.

As the results of the angular variables were obtained by the APAS, it is important to clarify that the negative angle of hip extension refers to the period of extension of this joint during gait.

Data analysis

The data were first compiled in the Microsoft Excel® 2007 program and later processed in the SPSS® program version 15.0. To test for normality, the Shapiro Wilk test was used. The mean, standard deviation, and frequencies were used in the descriptive data of the sample. To compare the difference in the mean of the temporal and angular space variables of the GTB group with the GNV group, the t test was used, with significance level of p≤0.05.

RESULTS

The results of the temporal and angular variables in the support and balance phases between GTB and GNV are presented in Table 2.

DISCUSSION

The results of this study showed a significant reduction in gait speed, cadence, stride length, duration of the balance phase and maximal angle of knee flexion, as well as prolongation of the support phase and double-support period in group of patients with total blindness in relation to the normal vision group. These data are in agreement with the study by Ribeiro et al.[17] who observed a reduction in gait length, gait and gait speed in subjects with visual impairment compared to subjects with normal vision.

However, similarity was observed in the maximal hip extension angle, occurring in the support phase, between blind (11.5°) and normal subjects (12.5°). According to Perry[15] and Nordin and Franquel,[18] these values are within the normal range of this angle (10º-15º). Additionally, in agreement with the results of out research, Hallemans and Aerts,[12] when analyzing the gait of blind young adults, they also found similar values, that is, an average of 11.2º for peak hip extension.

According to Perry,[15] the preservation of the hip extension at a 10º angle during the support phase (pre-swing) is able to hyper-extend the joint capsule and activate the protective contraction of the iliac muscle, which induces a rapid reversal of the extension position for hip flexion, what favors the progression of the limb and optimizes the balance phase.[19] Nonetheless, it is known that factors such as reduction of maximum knee flexion can directly interfere in the efficiency of the balance phase.

Perry[15] and Norkin[20] report that during one gait cycle the maximum knee flexion ranges from 60° to 65°, usually occurring in the swing phase (initial or middle balance). In this study, subjects with normal vision had a peak of knee flexion of 64.83° and fit the normality, according to the aforementioned

Chart 1. Initial and endpoints for gait phases[15]

Phases	Initial point	Endpoint
Support phase	First contact of the foot of the dominant limb to the ground	Clearance of the dominant limb fingers from the ground
Balance phase	Elevation of the dominant limb from the ground	Last contact of the dominant limb to the ground

Table 2. Mean and standard deviation of the spatial-temporal and angular variables

	¯XGTB* (± s)*	¯XGNV* (± s)*	p
Gait speed (m/s).	0.65±0.18	1.32±0.19	0.01*
Cadence (s/m).	135±0.27	169.2±0.18	0.01*
Stride length (m).	0.83±0.16	1.32±0.12	0.01*
Support phase (%)	65.7±1.08	61.0±1.87	0.01*
Double-support period (%).	14.0±1.08	10±1.87	0.01*
Balance phase (%).	34.3±2.25	39.0±1.36	0.01*
MAKF-GC (°)	50.93±9.12	64.83±5.83	0.01*
MAHE-GC (°)	-11.57±3.28	-12.55±10.89	0.81

GTB, individuals with total blindness; GNV, individuals with normal vision; s/m= steps per minute; MAKF-GC, maximum angle of knee flexion during gait cycle; MAHE-GC, maximum angle of hip extension during gait cycle.

literature. On the other hand, the blind subjects presented a reduction of this same angle, to reach an average of 51°.

This result agrees with those found by Hallemans and Aerts,[12] who, when analyzing the gait of healthy and blind young adults, reached mean values of 55° of knee flexion, what shows that visual disturbances are capable of influencing both the trajectory of the limb during the balance phase and the positioning of the foot.

Lord et al.[21] demonstrated the relationship between the visual system and the systems that control and coordinate balance and gait, at varying degrees of vision loss, and total blindness. The difficulty of the blind in flexing the knee in the swing phase would make it difficult to totally lift the toes[15] and consequently increase the risk of falls in this population, since the probability of hitting the foot at obstacle increases as the distance between the foot and the ground decreases.[22] Hence, it is believed that functional and rehabilitation orientations, with emphasis on greater knee flexion during the balance phase, should be one of the strategies for visually impaired subjects in order to prevent falls in this population.

It is the integrity of the visual system that allows the muscles responsible for the balance phase to anticipate their action towards imminent situations that were previously visualized.[23] For this reason, it can be observed that severe visual impairment is capable of interfering negatively in the anticipatory muscular action, since it impedes the acquisition of information regarding the surrounding environment[8,24] and reduces the functions of perception and control of the movement.[8]

Moreover, some authors report that the reduction of knee angular amplitude and its persistence during the balance phase impede the progression of the limb, making the step shorter.[25] This relationship made by the aforementioned authors could not be confirmed in the present study due to the absence of stride length measurements. However, the reduction of stride length was cited by Winnick,[11] as one of the changes found in the gait of blind individuals.

In conceptually, the length of the stride is equivalent to the length of two sequential steps in a walking cycle and therefore has its value increased or decreased according to the length of each step.[15] Therefore, it is assumed that there is a correlation between step length and stride length.

Hence, it is suggested that the reduced stride length in the blind subjects (0.83 meters) compared to the individuals with normal vision (1.23 meters) found in this study, is associated with a possible reduction in step length.

As the blind subjects were familiar with the route to be covered and used an assistive device during the gait analysis, it is believed that the reduction of step and consequent decrease of stride were related to the deficit of dynamic balance during gait, what has been described by Nakamura[8] and Hallemans and Aerts,[12] especially due to a backward inclination posture of the trunk.[26]

It is assumed that this inclination could compensate for the flexion position of the head, allow the center of gravity (CG) to be within or as close as possible to the heel-support base, and decrease the oscillation up and forward out of the CG, causing the gait to become more stable, as it would allow the foot to touch the ground more quickly, and hence replace the visual stimulus at the beginning of the support phase (touch of heel/foot onto the ground).

Although there is a need for further investigations to clarify the generated hypotheses, researchers argue that decreasing the length of step/stride implies a reduction in gait velocity of visually impaired individuals,[8,12,27] contrarily to individuals with normal vision.[17,28]

The results of the present study are consistent with the aforementioned condition since individuals with normal vision obtained an average of 1.32m/s and the totally blind subjects obtained an average of 0.65m/s. Nakamura[8], when comparing gait parameters between adults with preserved vision and blind subjects, obtained values of 1.50m/s and 0.86m/s for gait speed, respectively, suggesting that speed reduction is probably an adaptation to a reduced dynamic balance.

The difference in speed between both groups is justified when it is clear that vision allows sudden adaptations of body attitude when perceiving obstacles during the course to be covered, as well as in adverse situations, which is not possible for individuals with total blindness[10,29] who adapt to the locomotion environment with caution, assuming postures that may result in changes in gait parameters.[8]

The long cane is the most widely used assistive device for the mobility of visually impaired individuals, although it is unable to match the gait speed of the visually impaired with that of normal vision.[1] However, Clark-Carter[9] studies have shown that blind individuals who combine the long cane with a sound device reached 18% higher gait speed when compared with those who used only a long cane.

Reducing gait speed implies an extension of the support phase and consequently a reduction of the balance phase.[19] For Perry,[15] the support phase corresponds to approximately 60% of the normal gait cycle, the rest (40%) is considered balance phase at a self-selected speed, similar to the results of this study when it comes to individuals with normal vision, whose values obtained were 61% and 39%, respectively.

For blind individuals, total values of 65.7% and 34.3% were found in this study for the support and balance phases, respectively. These results match with those of Nakamura[8] and Hallemans and Aerts,[12] who found a prolongation in the support phase of blind individuals and in adults who have visual disabilities.

Visual impairment is an impact factor for dynamic stability[30] during gait,[12] which would justify a longer time in the support phase observed in blind individuals. Complementing, Ramsey[29] suggests in his studies that possibly visually impaired subjects antecipate the balance phase in order to achieve stabilization promoted by the dual support phase.

The efficiency of the support phase depends on the ability of the lower limb to support the body's weight and the ability of the limb to balance on one leg.[31] Of the total percentage of the support phase, 40% is considered as simple support, when only the right or left foot is in contact with the ground and 20% is considered double-support, when both the right and left feet touch the ground simultaneously for the transfer of body weight.[15,20]

Ramsey et al.[29] reports that increasing the duration of the double-support phase is the first indication that balance during gait is affected, however it was observed in this study that the percentage of the double-support phase for the blind and normal were, 14.0% and 10.1%, respectively. It is suggested, therefore, that the increase of the support phase in blind individuals is an adaptation associated to the reduction of gait velocity that provides greater contact time with the foot to the ground facilitating sensory exploration when the vision is absent.[32]

The speed changes can influence all gait parameters,[29] as the step length and consequently the step frequency. In their studies with young adults, Hallemans and Aerts,[12] found that the triad gait velocity, stride length, and cadence had their values reduced after visual disabilities. In this study, a significant difference was observed between the cadence of both groups (135 steps per minute for GTB and 169.2 for GNV).

Given the wide variation related to cadence values for subjects with normal vision,[33-35] it was not possible to establish a reference value. However, it was observed that the results of the present study are above those found in the literature, which suggests that the lack of visual information reduces cadence, but not to the point of being considered a mobility disability.

CONCLUSION

The findings of this study showed that the absence of visual information induces slower gait in blind subjects when compared to subjects with normal vision. Thus, it is believed that orientation in the functional and rehabilitation aspects, such as reeducation of gait and balance, should be strategies to visually impaired subjects in order to prevent falls in this population.

ACKNOWLEDGEMENTS

The authors of this study acknowledge and thank *CAPES* for their financial support. We declare there is no conflict of interest related to this article of any kind to be disclosed.

REFERENCES

1. West S, Sommer A. Prevention of blindness and priorities for the future. Bull World Health Organ. 2001;79(3):244-8.
2. Instituto Brasileiro de Geografia e Estatística. PNS 2013: Em dois anos, mais da metade dos nascimentos ocorreram por cesariana [texto na Internet]. Brasília: IBGE [citado 2017 Mar 03]. Disponível em: http://saladeimprensa.ibge.gov.br/noticias?view=noticia&id=1&busca=1&idnoticia=2965
3. Mosquera C. Educação física para deficientes visuais. Rio de Janeiro: Sprint; 2000.
4. Barbosa AMF. A educação especial para portadores de necessidades visuais: a difícil tarefa da inclusão [Monografia] Rio de Janeiro: Universidade Candido Mendes; 2004.
5. Taleb A, Faria MAR, Ávila M, Mello PAA. As condições de saúde ocular no Brasil: 2012. São Paulo: Conselho Brasileiro de Oftalmologia; 2012.
6. Ramos BMB. Influências de um programa de atividade física no controle do equilíbrio de idosos [Monografia]. São Paulo: Universidade de São Paulo; 2003.
7. Feitosa EA. Controle postural e locomoção em terrenos irregulares de crianças de 1 a 6 anos [Dissertação]. Rio Claro: Universidade Estadual Paulista; 2002.
8. Nakamura T. Quantitative analysis of gait in the visually impaired. Disabil Rehabil. 1997;19(5):194-7. DOI: http://dx.doi.org/10.3109/09638289709166526
9. Clark-Carter DD, Heyes AD, Howarth CI. The effect of non-visual preview upon the walking speed of visually impaired people. Ergonomics. 1986;29(12):1575-81. DOI: http://dx.doi.org/10.1080/00140138608967270
10. Johnson JT, Johnson BF, Blasch BB, de l'Aune WD. Gait and long cane kinematics: a comparison of sighted and visually impaired subjects. J Orthop Sports Phys Ther. 1998;27(2):162-6. DOI: http://dx.doi.org/10.2519/jospt.1998.27.2.162
11. Winnick J. Educação física e esportes adaptados. 3 ed. Barueri: Manole; 2004.
12. Hallemans A. Aerts P. In known contexts walking is not controlled by vision [abstract]. In: Congress International Society of Posture and Gait Research; 2007 July 14-18; Vermont, USA. Available from: https://www.ispgr.org/down/eJwFwYsJgDAMBcCNkpQYi27z%40KFobTEBwem92yPayOzHdXrgCXIlFHz1xus018Im6JEmmOog2ZJmkdzZSm3ZfqX3E9I%3D/Vermont%202007_%20Abstracts.pdf
13. Pogrund RL, Rosen SJ. The preschool blind child can be a cane user. J Vis Impair Blind. 1989;83(9):431-9.
14. Rudio FV. Introdução ao projeto de pesquisa científica. Petrópolis: Vozes; 2010.
15. Perry J. Análise de marcha. Barueri: Manole; 2005. v. 3.
16. Yang JF, Winter DA. Electromyographic amplitude normalization methods: improving their sensitivity as diagnostic tools in gait analysis. Arch Phys Med Rehabil. 1984;65(9):517-21.
17. Ribeiro SB, Santos LTA, Maciel SS, Santos HH. Características da marcha em sujeitos com deficiência visual. Ter Man. 2010;8(35):27-32.
18. Nordin M, Frankel VH. Biomecânica básica do sistema musculoesquelético. Rio de Janeiro: Guanabara Koogan; 2014.
19. Carr J, Shepherd R. Reabilitação neurológica: otimizando o desempenho motor. Barueri: Manole; 2008.
20. Norkin C. Análise da marcha: In: O'Sullivan SB, Schmitz TJ. Fisioterapia: avaliação e tratamento. 2 ed. São Paulo: Manole; 1993. p. 225-69.
21. Lord SR, Smith ST, Menant JC. Vision and falls in older people: risk factors and intervention strategies. Clin Geriatr Med. 2010;26(4):569-81. DOI: http://dx.doi.org/10.1016/j.cger.2010.06.002
22. Quevedo AAF. Avaliação cinesiológica de baixo custo aplicada à reabilitação da locomoção. Motriz. 1999;5(1): 28-35.
23. Viel E. A marcha humana, a corrida e o salto: biomecânica, investigações, normas e disfunções. São Paulo: Manole; 2001.
24. Patla AE. Understanding the roles of vision in the control of human locomotion. Gait Posture. 1997;5(1):54-69. DOI: http://dx.doi.org/10.1016/S0966-6362(96)01109-5
25. Blair I, Durward B, Baer G, Rowe P. Movimento funcional humano: mensuração e análise. São Paulo: Manole; 2001.
26. Blasch BB, Wiener WR, Welsh RL. Foundations of orientation and mobility. 2 ed. New York: AFB; 1997.
27. Hallemans A, Aerts P. The importance of vision in the control of walking in children [text on the Internet]. Amsterdam: European Workshop on Movement Science [cited 2009 Apr 24]. Available from: http://uahost.uantwerpen.be/funmorph/ann/EWOMSposter2007.pdf DOI: http://dx.doi.org/10.1007/s00221-009-1937-8
28. Mashimo AM, Caromano FA. A marcha em idosos saudáveis. Arq Ciênc Saúde Unipar. 2002; 6 (2):117-21.
29. Ramsey VK, Blasch BB, Kita A, Johnson BF. A biomechanical evaluation of visually impaired persons' gait and long-cane mechanics. J Rehabil Res Dev. 1999;36(4):323-32.
30. Rutkowska I, Bednarczuk G, Molik B, Morgulec-Adamowicz N, Marszałek J, Kaźmierska-Kowalewska K, et al. Balance Functional Assessment in People with Visual Impairment. J Hum Kinet. 2015;48:99-109. DOI: http://dx.doi.org/10.1515/hukin-2015-0096
31. Magee DJ. Avaliação musculoesquelética. Barueri: Manole; 2010.
32. Patla AE, Davies TC, Niechwiej E. Obstacle avoidance during locomotion using haptic information in normally sighted humans. Exp Brain Res. 2004;155(2):173-85. DOI: http://dx.doi.org/10.1007/s00221-003-1714-z
33. Chung TM. Avaliação cinética e cinemática da marcha de adultos do sexo masculino. Acta Fisiatr. 2000;7(2):61-7.
34. Estrázulas JA, Pires R, Santos DM, Stolt LRG, Melo SIL. Características biomecânicas da marcha em crianças, adultos e idosos. Lec Edu Fís Deport. 2005;10(88). Disponível em: http://www.efdeportes.com/efd88/biom.htm.
35. Mendes EF. Comparação de parâmetros cinemáticos da marcha entre indivíduos jovens e idosos em tarefas de alteração do comprimento preferido do passo [Dissertação]. São Paulo: Universidade de São Paulo, Escola de Educação física e Esporte; 2005.