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original article

Gait stability in young adults under different visual conditions: a pilot study

Estabilidade da marcha de adultos em diferentes condições visuais: estudo piloto

Mateus Corrêa Silveira[1,2]
Luiz Fernando Cuozzo Lemos[2]
Gabriel Ivan Pranke[2]
Carlos Bolli Mota[1,2]

Abstract – The visual system is fundamental for the control of gait stability. Visual deprivation or impairment can deteriorate walking stability in adults; however, in daily life, adults are exposed to different light intensities rather than visual deprivation. The objective of this study was to investigate gait stability in young adults exposed to different visual conditions. Ten adults without visual problems participated in the study. The subjects walked at two speeds (self-selected and 30% faster) under four visual conditions: normal vision and using three different masks covered with automotive film to reduce the passage of light to the eye (50% > 20% > 5% – lowest light passage). Stability parameters (margin of stability – MOS, center of mass separation – COM_{SEP}, and time-to-contact – TtC) obtained by analysis of the COM displacement relative to the base of support, and spatiotemporal parameters (step length, gait velocity, and support time) were assessed. The different visual conditions did not affect gait stability or spatiotemporal parameters at the two walking speeds studied. The variations in stability between visual conditions relative to normal vision were not expressive for MOS (< 4%), COM_{SEP} (< 7%), or TtC (< 6%) at the two walking speeds. This lack of changes in stability may have been due to maintenance of the spatiotemporal characteristics because of the strong association between these characteristics. The adults studied can control stability without changing their gait patterns under different visual conditions, and lower light intensities do not increase the risk of falls.

Key words: Postural balance; Vision; Walking.

Resumo – *O sistema visual é fundamental no controle estável da marcha. A privação ou perturbação da visão pode deteriorar a estabilidade da caminhada em adultos, porém, diariamente, eles estão submetidos a diferentes luminosidades e não nas situações desafiadoras citadas. O objetivo do estudo foi investigar a estabilidade da marcha de adultos em diferentes condições visuais. Dez adultos sem problemas visuais participaram do estudo. Os sujeitos caminharam em duas velocidades (autosselecionada e 30% mais rápida) e quatro condições visuais: visão normal e usando três diferentes máscaras envolvidas por película automotiva, permitindo passagem de níveis reduzidos de luz até o olho (50% > 20% > 5% – menor passagem de luz). Os parâmetros de estabilidade (margem de estabilidade – MOS, separação do centro de massa – COM_{SEP}, tempo até o contato – TtC), obtidos, analisando os deslocamentos do centro de massa relativos à base de suporte, e espaço temporais (comprimento de passo, velocidade da marcha e tempo de apoio) foram mensurados. As diferentes condições visuais não modificaram os parâmetros de estabilidade e espaço temporais da marcha em ambas as velocidades. As variações na estabilidade entre condições visuais relativas à visão normal não foram expressivas para MOS (< 4%), COM_{SEP} (< 7%) e TtC (< 6%) nas duas velocidades de caminhada. Esta ausência de mudanças na estabilidade pode ter ocorrido devido à manutenção das características espaço temporais, pela forte relação entre ambas. Os adultos analisados podem controlar a estabilidade sem alterar os padrões da marcha em diferentes condições visuais, com menores luminosidades não aumentando o risco de quedas.*

Palavras-chave: *Caminhada; Equilíbrio postural; Visão ocular.*

1 Universidade Federal de Santa Maria. Santa Maria, RS. Brasil

2 Universidade Federal do Rio Grande do Sul. Porto Alegre, RS. Brasil

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INTRODUCTION

Gait stability is controlled by the relationship between dynamic changes in the base of support (BOS) and displacements of the center of pressure and center of mass (COM), modeling this system as an "inverted pendulum"[1-3]. Dynamic stability can be evaluated using equations that describe the conditions of gait stability and posture maintenance during standing[4,5]. Variables such as margin of stability (horizontal distance between the projection of the COM on the ground and the BOS boundary) and time-to-contact (time necessary for the COM to reach the BOS boundary) are used for this purpose[6]. The margin of stability and time-to-contact, respectively correspond to the distance and time when a new step needs to be performed to recover stability. Parameters such as walking speed, step length and cadence are also related to gait stability[7,8].

The visual system plays a key role in the control of this stability during walking, contributing to the orientation of locomotion and route planning[9]. In adults, visual deprivation during walking induces negative changes in the spatiotemporal patterns of gait, such as a reduction in walking speed and step length and an increase in double support duration[10-12]. The same gait adaptations are observed in children walking in the dark[13], in subjects walking in a virtual reality environment which induces conflicts to the visual system[14,15], and in subjects with visual problems[12,16,17]. Apparently, these patterns are adopted as a strategy to keep the COM close to the BOS, maintaining a careful gait as seen when walking in situations with an increased risk of slipping[7] or in elderly populations with a history of falls[18,19].

However, the level of dependence of gait stability characteristics on vision is unclear. Most gait changes induced by alterations in the visual condition are evaluated in situations of normal vision or visual deprivation, whereas in daily life subjects are only exposed to environments with different light intensities. A reduction in the levels of light can be responsible for kinematic alterations, such as the angle of visual focus during walking in the elderly[16]. In contrast, in adults, visual deprivation has a lower impact on gait characteristics and posture control compared to other groups[10], suggesting that adults can maintain gait stability even at lower levels of light. Therefore, the objective of the present study was to evaluate gait stability in young adults exposed to different visual conditions (levels of light). The hypothesis was that dynamic stability will be reduced in the presence of a partial reduction in the level of light. This was a pilot study conducted to obtain preliminary results that would permit the estimation of sample size for future studies.

METHODOLOGICAL PROCEDURES

Participants

Ten young adults (seven men, three women; mean ± standard deviation: age, 25.6 ± 3.3 years; height, 176.4 ± 8.2 cm; body weight, 77.1 ± 18.6 kg) participated voluntarily in this pilot study. The number of subjects was based on a previous study including the same number of subjects of the population analyzed (10 young adults plus 13 older adults) and using the same gait variables[20]. Criteria for inclusion in the study were age of 18 to 30 years and good visual acuity, corresponding to 20/20 in the Snellen test performed prior to data collection. Subjects with vestibular problems and musculoskeletal injuries were excluded. The data were obtained by application of a questionnaire at the beginning of the study. The study was approved by the local Ethics Committee (Protocol No. 08437612.8.0000.5346) and all subjects agreed to participate in the study by giving informed consent.

PROCEDURES

All subjects walked barefoot on a 5-m long course without obstacles in a room with standard illumination. The subjects were asked to walk at four different levels of light: normal vision and using a mask covered with automotive film (Figure 1) which permitted the passage of 50% light (V50%), 20% light (V20) and 5% light (V5) to the eye (V50 > V20 > V5 – lowest passage of light). For all conditions, two attempts were performed at a self-selected velocity (V_{SELF}) and two subsequent attempts at a 30% faster velocity (margin of error ± 10%) than the mean V_{SELF} obtained (V_{FAST}) to induce changes in spatiotemporal gait patterns. The walking speed was obtained with photocells positioned along the course. The number of attempts was chosen to avoid the effect of fatigue based on a previous study of walking on a treadmill[21]. The order of the visual conditions was randomized for each subject before data collection.

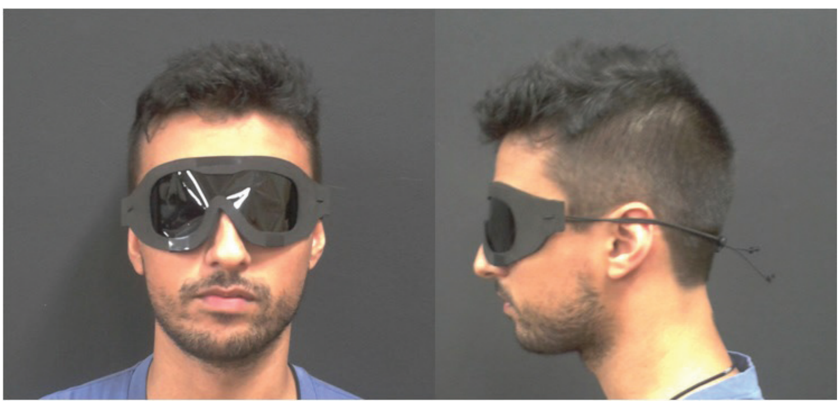

Figure 1. Mask covered with automotive film to reduce the level of light.

Data processing

Kinematic data were obtained with the Vicon system (Vicon Motion Systems, Oxford, UK) using seven cameras operating at a sampling frequency of 100 Hz. For the acquisition of movements, 39 reflective markers (14 mm in diameter) were attached to the subject's anatomical landmarks (segments of the head, trunk, pelvis, upper and lower limbs, hands, and feet). The COM position was calculated using the PlugInGait Fullbody model of the system, with the signals passing through a fourth-order zero-lag Butterworth low-pass filter (cutoff frequency of 8 Hz). The gait events, toe off (TO) and heel strike (HS), were detected using two AMTI OR6-6 2000 force platforms (Advanced Mechanical Technologies, Inc.) positioned at the level of the ground, with an acquisition frequency of 1,000 Hz. The instruments were synchronized during data collection using the central processing unit (Giganet) of the Vicon system to which the systems were connected.

Spatiotemporal and dynamic stability parameters

The following spatiotemporal gait parameters were evaluated: single and double support time, step length, and average gait velocity. These variables were analyzed since they are direct indicators of stability due to their strong association with the latter.

Dynamic stability was evaluated using the extrapolated center of mass (XCOM) concept proposed by Hof[3]. In HS, when the COM was within the BOS, the shortest distance between the anterior BOS boundary (marker of the heel touching the ground) and XCOM was referred to as the margin of stability (MOS). In TO, when the COM was outside the BOS, the distance between the posterior BOS boundary (marker of the support heel) and XCOM was referred to as COM separation (COM_{SEP})[18]. Both variables were only determined in the anteroposterior direction and were calculated as follows:

$$MOS = BOS_{MAX} - XCOM$$

$$COM_{SEP} = BOS_{MAX} - XCOM$$

where BOS_{MAX} is the base of support boundary and XCOM is the extrapolated center of mass in the anteroposterior direction ($XCOM = COM_{AP} + COM_{VEL}/wo$), with COM_{AP} corresponding to the horizontal (anteroposterior) component of COM projection on the ground, COM_{VEL} to the instantaneous horizontal velocity of COM, and *wo* is the frequency of the gait pendulum, which depends on the acceleration of gravity (g) and distance (l) between COM and the ankle joint center of the supporting limb in the sagittal plane ($wo = \sqrt{g/l}$).

The time-to-contact (TtC) was also evaluated as a parameter of dynamic stability[3,6]. This parameter was calculated in two ways: dividing MOS by the instantaneous COM velocity (TtC_{XCM}) and considering an instantaneous position of COM (TtC_{VEL}):

$$TtC_{XCM} = MOS/COM_{VEL}$$

$$TtC_{VEL} = BOS_{MAX} - COM \,/\, COM_{VEL}$$

TtC was observed during the events of TO (TtC_{XCM} TO and TtC_{VEL} TO) and HS (TtC_{XCM} HS and TtC_{VEL} HS). In HS, higher values of MOS, TtC_{XCM} and TtC_{VEL} indicate greater stability. In TO, higher values of COM_{SEP}, TtC_{XCM} and TtC_{VEL} suggest a better capacity of recovering the COM located outside the BOS, although they indicate a less stable instantaneous configuration.

Statistical analysis

First, the mean value of each variable obtained during one walking attempt was calculated. Next, the mean value of two attempts of each visual condition per velocity (of each subject) was obtained for comparison. The Shapiro-Wilk test was used to test the normality of the data. The data were parametric, except for double support time and TtC which were submitted to logarithmic transformation. The variables were only compared between visual conditions (the effects of velocity were not evaluated) by repeated measures ANOVA at each velocity. The need for using the Greenhouse-Geisser correction factor was indicated by the Mauchly test (TtC_{XCM} and TtC_{VEL} in HS and TO). The *post hoc* LSD test identified differences between variables under the different visual conditions. A level of significance of $\alpha = 0.05$ was adopted for all tests.

RESULTS

No significant differences in MOS (Figure 2A) at V_{SELF} ($F(3,27) = 1.939$; $p = 0.147$) and V_{FAST} ($F(3,27) = 2.078$; $p = 0.127$) or COM_{SEP} (Figure 2B) at V_{SELF} ($F(3,27) = 1.652$; $p = 0.201$) and V_{FAST} ($F(3,27) = 1.403$; $p = 0.263$) were observed between the different visual conditions. There was also no difference spatiotemporal parameters (Table 1) or TtC between visual conditions at V_{SELF} (Table 2) and V_{FAST} (Table 3). The actual values of the variables are reported in the tables.

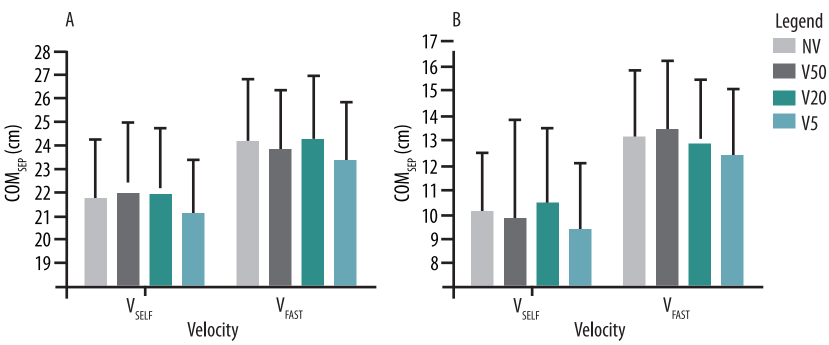

Figure 2. Margin of stability (MOS) (A) and center of mass separation (COM_{SEP}) (B) obtained for each visual condition at self-selected (V_{SELF}) and 30% faster (V_{FAST}) walking velocities. NV: normal vision; V50, V20 and V5: masks covered with automotive film permitting the passage of 50%, 20% and 5% of light, respectively.

Table 1. Descriptive measures and results of repeated measures ANOVA of the spatiotemporal parameters.

	V_{SELF}					V_{FAST}				
	NV	V50	V20	V5	p	NV	V50	V20	V5	p
AV (m/s)	1.37 (0.20)	1.41 (0.27)	1.40 (0.21)	1.32 (0.15)	0.16	1.78 (0.27)	1.83 (0.35)	1.83 (0.27)	1.71 (0.19)	0.16
SL (cm)	72.11 (6.25)	72.64 (8.56)	72.98 (7.48)	70.83 (5.22)	0.35	81.91 (6.97)	82.54 (8.07)	82.73 (8.04)	80.43 (7.51)	0.49
SST (ms)	428 (36)	423 (44)	429 (32)	434 (25)	0.54	397 (32)	398 (39)	396 (28)	404 (31)	0.32
DST (ms)	94 (18)	97 (31)	90 (22)	94 (19)	0.69	70 (14)	66 (18)	70 (16)	70 (13)	0.57

Values are the mean (standard deviation). V_{SELF}: self-selected velocity; V_{FAST}: 30% faster than V_{SELF}; NV: normal vision; V50, V20 and V5: masks covered with automotive film permitting the passage of 50%, 20% and 5% of light, respectively; AV: average velocity; SL: step length; SST: single support time; DST: double support time.

Table 2. Descriptive measures and results of repeated measures ANOVA of time-to-contact (TtC) at the self-selected velocity (V_{SELF}).

	V_{SELF}				
	NV	V50	V20	V5	p
TtC_{XCM} HS (ms)	158.72 (22.66)	159.76 (24.92)	156.77 (20.62)	159.08 (18.22)	0.873
TtC_{VEL} HS (ms)	161.78 (22.68)	162.83 (24.92)	159.83 (20.63)	162.15 (18.26)	0.873
TtC_{XCM} TO (ms)	67.83 (15.16)	63.81 (20.02)	68.78 (15.95)	64.71 (15.38)	0.208
TtC_{VEL} TO (ms)	70.88 (15.17)	66.87 (20.04)	71.83 (15.96)	67.76 (15.39)	0.209

Values are the mean (standard deviation). HS: heel strike; TO: toe off; NV: normal vision; V50, V20 and V5: masks covered with automotive film that permitted the passage of 50%, 20% and 5% of light, respectively; TtC_{XCM}: time-to-contact relative to XCOM; TtC_{VEL}: time-to-contact relative to instantaneous COM velocity.

Table 3. Repeated measures ANOVA of time-to-contact (TtC) at a velocity 30% faster than the self-selected velocity (V_{FAST}).

	V_{FAST}				
	NV	V50	V20	V5	p
TtC_{XCM} HS (ms)	136.24 (19.84)	133.69 (23.54)	136.09 (20.46)	136.39 (15.42)	0.640
TtC_{VEL} HS (ms)	139.31 (19.85)	136.76 (23.64)	139.16 (20.46)	139.47 (15.44)	0.645
TtC_{XCM} TO (ms)	70.03 (12.66)	71.39 (12.86)	68.67 (12.95)	68.72 (12.31)	0.391
TtC_{VEL} TO (ms)	73.08 (12.65)	74.45 (12.86)	71.71 (12.94)	71.77 (12.30)	0.390

Values are the mean (standard deviation). HS: heel strike; TO: toe off; NV: normal vision; V50, V20 and V5: masks covered with automotive film that permitted the passage of 50%, 20% and 5% of light, respectively; TtC_{XCM}: time-to-contact relative to XCOM; TtC_{VEL}: time-to-contact relative to instantaneous COM velocity.

DISCUSSION

This study investigated the influence of visual condition on gait stability in young adults. During daily activities, a change in visual condition can occur when using sunglasses or in challenging situations such as walking in low light environments. However, the results suggest no alterations in spatiotemporal parameters or gait stability with changing visual condition.

Unstable gait is associated with slower walking[7,18]. The lack of differences in walking stability may be explained by the maintenance of gait velocity. This is probably the most significant result of the study, since total visual deprivation reduces self-selected gait velocity[10,12,13] and the occlusion of peripheral vision leads to a decrease in walking speed[22] and an increase in the risk of falls[23]. This fact indicates that a partial reduction in lighting in subjects with good visual acuity may not be sufficient to reduce gait velocity. Slower gait usually causes a reduction in step length as an adaptation to prevent falls[7]. The lack of changes in step length may therefore be due to the maintenance of gait velocity.

The relationship between spatiotemporal variables and COM displacement may explain the lack of changes in the gait stability parameters. Since gait velocity is strongly correlated with COM_{VEL}[24], the maintenance of velocity under the different light conditions maintained all stability parameters related to COM_{VEL}. In the case of adaptation to slower walking speeds, step length should decrease to prevent the loss of stability and risk of falls[7].

Visual perturbations do not impose changes during walking, but rather cause motor adaptations characterized by relatively individual responses to permit gait control[15]. During visual deprivation, these alterations in gait correction are seen in situations of overcoming obstacles[22] and in the control of gait termination[25]. Therefore, the level of perturbation caused by the use of the mask was not sufficient to visualize changes in the normal gait pattern. Since gait stability can be obtained step by step, or rapidly within the step in a walking cycle[8], gait control may have occurred by changing the kinematics of the segments during walking. As a consequence, dynamic stability can even be observed during short periods of gait instability[26].

It should be noted that the small number of participants studied does not permit to generalize the conclusions drawn from the results obtained for the adult population. Additionally, the determination of COM displacement using kinematic methods is reliable, but may result in small measurement inaccuracies. Therefore, the inaccuracy of the method and the proximity of values between visual conditions may have masked differences. However, the preliminary results obtained in this pilot study permit to question the influence of visual condition on gait stability in adults, in addition to providing estimates for the calculation of sample size in future studies analyzing the same variables. Further studies need to identify additional differences in the kinematic parameters of the trunk and lower extremities, since COM_{AP} position is strongly correlated with the interaction between trunk angle and step length[7].

CONCLUSIONS

Changes in visual condition did not modify gait stability in the group of young adults studied here. The trend of assuming a more careful gait pattern in a darker environment was not observed. This finding might be related to the maintenance of the spatiotemporal pattern adopted, irrespective of the level of light reaching the eye.

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Corresponding author

Mateus Corrêa Silveira
Universidade Federal de Santa Maria
Centro de Educação Física e Desporto,
Laboratório de Biomecânica,
Bairro - Camobi, km 9,
97105-900, Santa Maria, RS. Brasil.
Email: mm.biomec@gmail.com