

Effect of treadmill-based gait training on the stationary balance of elderly individuals

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Abstract

Introduction: The purpose of the present study was to compare stationary balance between a group of elderly women and young adult women using stabilometric parameters.

Material and methods: Sixty elderly women with an average age of 67.6 ±4.7 years and 60 young adult women with an average age of 25.1 ±2.2 years participated in the study. A Mediateurs quartz/piezoelectric force platform (Loran Engineering™) was used for data collection, with the sampling frequency set at 50 Hz. The experimental protocol consisted of the analysis of individuals in bipedal support, with their feet on the platform in an orthostatic position and the upper limbs in extension alongside the body. The data collection time was standardized as 20 s. Data were exported to the Microcal/Origin (version 6.0) environment for processing and interpretation. The following variables were analyzed by means of this software program: i) Center of Pressure Displacement Velocity (P) and ii) Radial Displacement of Center of Pressure (Rd).

Results: The elderly individuals exhibited a significant decrease in *p* and Rd values under both conditions (eyes open and closed) following treadmill-based gait training. The elderly group exhibited a significant reduction in center of pressure displacement velocity under both experimental conditions (eyes open and closed) following the treadmill-based gait training.

Conclusions: The results of the present study indicate that a specific exercise program, such as treadmill-based gait training, which is a dynamic activity, can improve stationary balance in successful elderly women.

Key words: elderly, balance, stabilometry, treadmill.

Introduction

The increase in the elderly population brings forth the discussion on incapacitating events in this age group, especially the occurrence of falls [1, 2]. The risk of falls is related to ageing, which is characterized by a series of physical alterations, including an alteration in balance in an orthostatic or dynamic posture due to deficiencies in the postural control system [3]. Rehabilitation protocols have demonstrated to be quite effective in minimizing the harmful effects of the physiological ageing process, principally in improving this system in the elderly population [4, 5].

Treadmill-based gait training currently stands out among the methods that seek improved balance and coordination. The success of this protocol

is attributed to its practicality, safety and experimental control during rehabilitation [6]. Indeed, the fundamental resource of this rehabilitation model is the perturbation generated by the ground to stimulate improvement in anticipatory responses during walking [7]. The net result of this work is a reduction in the number of bodily oscillations in the performance of the task of locomotion [8].

A large number of studies have shown that the number of oscillations generated during movement is one of the factors that predispose elderly individuals to falls [9]. The greater incidence of falls is known to occur in elderly women during the performance of dynamic activities, such as walking, and not due to the demand of control while maintaining an orthostatic position [10].

Thus, the aim of the present study was to investigate the influence of treadmill-based gait training on stationary balance parameters in successful elderly women under two distinct experimental conditions and compare these values to those of young adult women. The hypothesis of the study is centered on the correlation between improved stationary balance and the performance of dynamic work carried out simply by walking on a treadmill.

Material and methods

Sample

The sample was made up of 120 women divided into two groups. The first group was composed of 60 successful, non-institutionalized women with an average age of 67.6 ± 4.3 years, who frequented the COMAS Municipal Social Action Center and students of the Senior Citizen Open University of the city of São José dos Campos (SP, Brazil). The second group (control) was made up of 60 young adult women with an average age of 25.6 ± 2.2 years.

The inclusion criteria for voluntary participation in the study were:

- I) female gender;
- II) age between 60 and 70 years (elderly group) or between 20 and 30 years (young adults);
- III) independent locomotion without a gait assistance device.

The exclusion criteria were:

- I) impossibility of responding to the questionnaires proposed for the assessment due to severe hearing impairment or severe communication deficiency;
- II) unstable angina and/or acute myocardial infarction having occurred within one month prior to the execution of the tests;
- III) verbal or written refusal following clarification and contact with the term of informed consent.

Instrument

A Medicapteurs quartz/piezoelectric force platform (model Twin 99 version 2.08), 90 cm in length and 75 cm in width, was used for data collection. This platform has 1600 sensors for gathering information on body oscillations in two vectors of movement [z (medial-lateral) and x (anterior-posterior)], with the sampling signal at a frequency of 50 Hz (Figure 1).

Experimental procedure

All participants signed terms of informed consent, fulfilling the requirements of the Research Ethics Committee of the Universidade do Vale do Paraíba, in compliance with Resolution 196/96 of the National Board of Health (Health Ministry) under process nº L085/2005/CEP. The participants were instructed to remain barefoot in an orthostatic position (bipedal support) on the platform and to seek a position that provided the

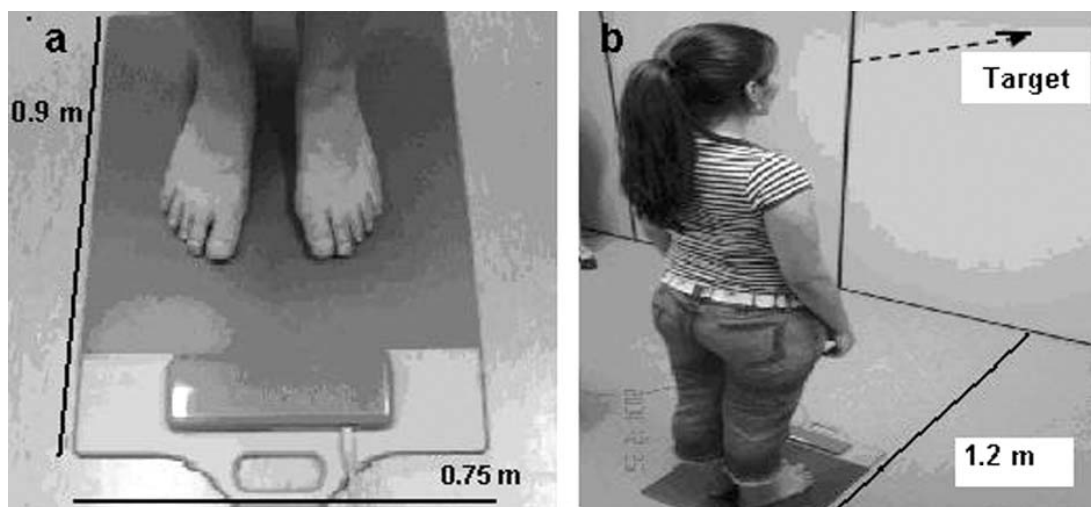


Figure 1. Figure 1a illustrates the positioning of the participant in relation to the dimensions of the stabilometric platform. Figure 1b illustrates how participants were positioned in relation to experimental control

greatest sensation of stability, with upper limbs extended alongside the body and the feet parallel to one another. The participants were asked to focus their eyes on a target placed in front of them at a distance of 1.2 m, following the procedure established in the current literature [11]. Data collection was performed under two distinct experimental conditions: eyes open and eyes closed. The initial collection with the participant's eyes open was performed for 20 s, followed by a 1-min interval and a second collection was performed with the participant's eyes closed for an additional 20 s [12].

After the initial data collection, only the elderly individuals performed the gait training on a treadmill, which was adapted from a study carried out by Wernig *et al.* [13] and consisted of the women walking at a comfortable pace for 60 min. In order for the participants to experience different terrain conditions, moments of upward and downward slope were added. The training time was divided into the following order:

- I) walking on a horizontal plane with no slope for 15 min;
- II) walking at a 5% upward slope for 15 min;
- III) walking at a 5% downward slope for 15 min and
- IV) walking on a horizontal plane with 0% slope for 15 min.

The complete training period was eight weeks, with a weekly frequency of three sessions, each separated by one to two days. After this period, data collection was performed on the elderly individuals again under the same experimental conditions in order to determine the influence of gait training on the balance of the participants. All phases of the experiment were performed at the Gait and Balance Laboratory of the Research and Development Institute of the Universidade do Vale do Paraíba.

Variable and analysis procedure

Postural oscillation of the center of pressure of the right and left feet in the anterior-posterior (x) and medial-lateral (z) directions under both experimental conditions was calculated from the values obtained in the stabilometric analysis with the patients in orthostatic posture, using the following mathematical equation:

$$P = \frac{f}{(N-1)} \sum_{i=1}^{N-1} \sqrt{[(x_{i+1} - x_i)^2 + (z_{i+1} - z_i)^2]}$$

for the *center of pressure displacement velocity* (P). This is the mean distance traveled per second during the sampling period, in which f is the frequency of the sample (N/T), with N as the

number of o points recorded, x_i and z_i are the locations of the center of pressure at each instant in the medial-lateral and anterior-posterior directions, respectively, in sample index i .

Radial displacement of the center of pressure (Rd) demonstrates the oscillation of the center of pressure from the formula below:

$$Rd = \frac{1}{N} \sum_{i=1}^N \sqrt{[(x_i - x_c)^2 + (z_i - z_c)^2]}$$

where:

$$x_c = \frac{1}{N} \sum_{i=1}^N (x_i) \quad z_c = \frac{1}{N} \sum_{i=1}^N (z_i)$$

which are the coordinates of the centroid, and x_i and z_i are the displacements around this point.

The entire sequence of data analysis and calculation of the equations was performed on the Origin version 6.0 (Microcal) software program.

Statistical analysis

From the mean values of the data collection, the inter-group effect (effect of the variables between samplings) and the intra-group effect (effect of the experimental conditions on each sample) were investigated using two-way analysis of variance (ANOVA). The *post hoc* Tukey test was used to identify where these possible differences may be representative in the different variables. Statistical significance was defined as $\alpha \leq 0.05$.

Results

Center of pressure displacement velocity

The elderly group exhibited a significant reduction in center of pressure displacement velocity under both experimental conditions (eyes open and closed) following the treadmill-based gait training. These differences were more pronounced during the analysis of the variables with eyes closed. There were no significant differences when comparing the results obtained from the elderly individuals following gait training and those obtained by the control group (Figure 2, Table I).

Radial displacement of center of pressure

Similarly to the previous variable, the elderly group exhibited a significant reduction in radial displacement of the center of pressure under both experimental conditions (eyes open and closed)

following the treadmill-based gait training. These differences were more pronounced during the analysis of the variables with eyes closed. There were no significant differences when comparing the results obtained from the elderly individuals following gait training and those obtained by the control group (Figure 3, Table I).

Anterior-posterior oscillation of center of pressure

The elderly group exhibited a reduction in anterior-posterior oscillation of the center of

pressure under both experimental conditions (eyes open and closed) following the treadmill-based gait training. However, significant differences remained between the values obtained by the elderly individuals and the control group (Figure 4, Table I).

Medial-lateral oscillation of the center of pressure

The elderly group exhibited a reduction in medial-lateral oscillation of the center of pressure under both experimental conditions (eyes open and closed) following the treadmill-based gait training. However, the values of the control group continued to be lower than those achieved by the elderly individuals, even after having performed the treadmill-based gait training (Figure 5, Table I).

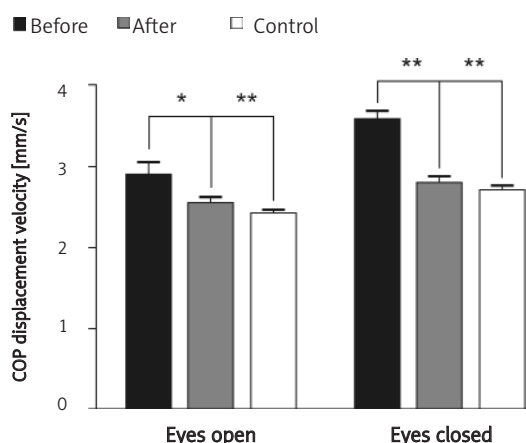


Figure 2. Results of the center of pressure displacement velocity under distinct experimental conditions (eyes open and closed) in elderly individuals before and after treadmill-based gait training. The values achieved by the elderly women were compared to those achieved by young adult women, revealing a significant improvement following gait training under both conditions analyzed

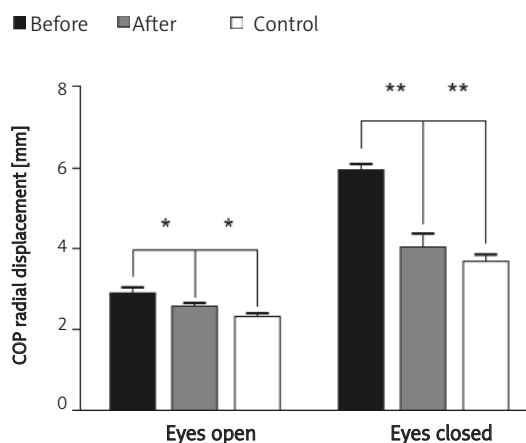


Figure 3. Results of radial displacement of center of pressure under distinct experimental conditions (eyes open and closed) in elderly individuals before and after treadmill-based gait training. The values achieved by the elderly women were compared to those achieved by young adult women, revealing a significant improvement following gait training under both conditions analyzed

Discussion

Assessing balance and related it to falls among the elderly is a complex task due to physiological, psychological and social alterations in these individuals. The reduction in functional decline among the elderly, especially among elderly women, is an urgent healthcare need. Thus, it is of summary importance to identify factors that contribute to this functional decline, one of which is postural stability, especially during gait. The ageing process leads to a deficiency in postural control and maintenance of balance. Consequently, functional and structural changes occur, leading to lower functional performance and an increased risk of falls in this population. Most falls occur due to deficient anticipatory postural control. Elderly individuals do not have adequate reaction time and end up falling after an unexpected perturbation [14].

This demonstrates the importance of treatment protocols that stimulate anticipatory postural control among the elderly, with a consequent improvement in balance and reduced risk of falls. In the present study, we present a treadmill-based training rehabilitation protocol that has been used in the rehabilitation of individuals who exhibit postural control alterations due to diverse neurological pathologies [15-17].

Following the treadmill-based gait training exercises, there was a significant reduction in center of pressure displacement velocity values under both experimental conditions (eyes open and closed). Moreover, there were no significant differences between the results obtained in the elderly group after training and those obtained in the control group. Another result concerned radial displacement, for which the anterior-posterior and medial-lateral oscillation values diminished in the elderly group following training under both conditions analyzed (eyes open and closed). This result suggests the treadmill-based gait training

improved postural oscillation and functional performance among the elderly individuals. Such improvement leads to a lower risk of falls during activities of daily living.

The present study corroborates the findings described by Shimada *et al.*, who investigated the effects of unexpected perturbation on the prevention of falls among healthy elderly individuals. To stimulate postural reactions, one group used a treadmill for training and another group used an exercise protocol. After 6 months of training, the group that used the treadmill demonstrated a greater improvement in balance and reaction time when compared to the other

group. The study revealed that the group that underwent treadmill-based training had a greater reduction in falls when compared to the group that underwent the exercise protocol [18].

In a previous study, with no type of training, carried out on healthy young people, healthy elderly individuals and elderly individuals with Parkinson's disease, it was demonstrated that with open eyes, even the healthy elderly exhibited center of pressure displacement as well as a greater displacement velocity when compared to the healthy young people [19]. Following the treadmill training in the present study, there was a significant reduction in center of pressure

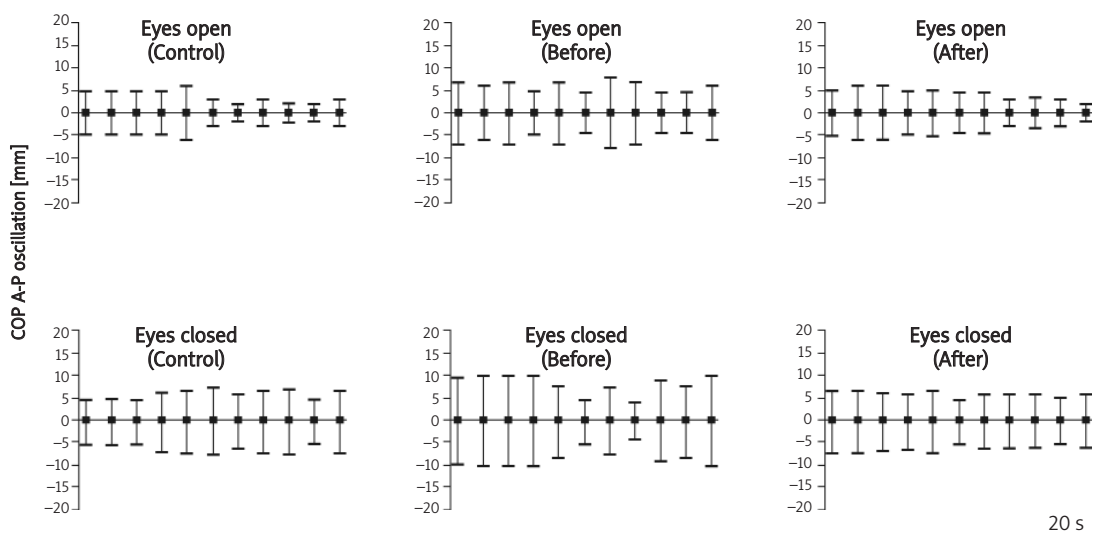


Figure 4. Results of anterior-posterior oscillation analysis, revealing that treadmill-based gait training in the group of elderly women led to lower values under both conditions (eyes open and closed), but remained significantly different from the control group

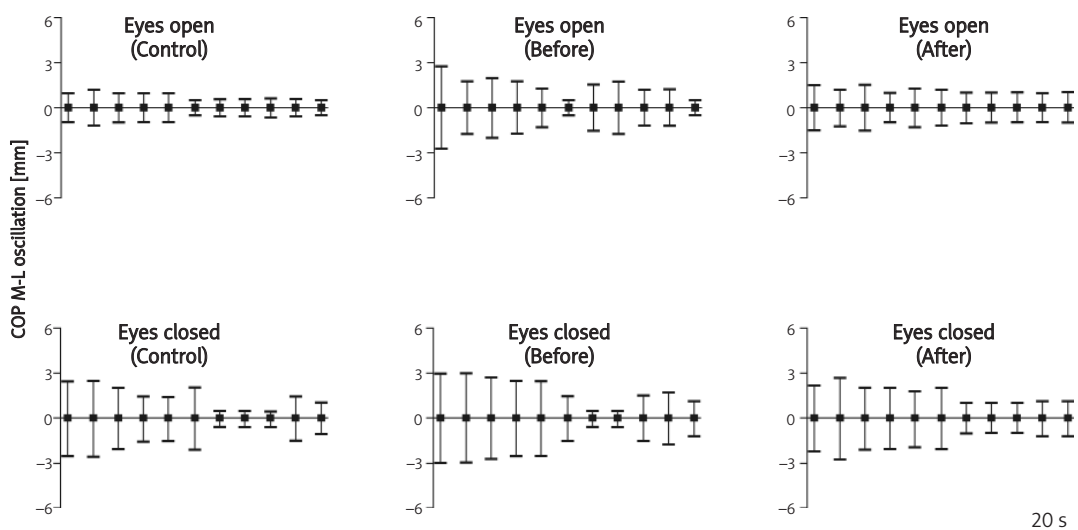


Figure 5. Results of medial-lateral oscillation analysis, revealing that treadmill-based gait training in the group of elderly women led to lower values under both conditions (eyes open and closed), but remained significantly lower in the control group, even the elderly group had performed gait training

Table I. Results of the inter-group effect (effect of the variables between samplings) and intra-group effect (effect of the experimental conditions on each sample), using two-way analysis of variance (ANOVA). The *post hoc* Tukey test was used to identify where these possible differences may be representative in the different variables. Statistical significant was defined as $\alpha \leq 0.05$

N	Age [years]	Condition	D-S [mm/s]	R-D [mm]	A-P [mm]	M-L [mm]	Bf. vs. Af. (α) value	Cc. vs. Af. (α) value	Cc. vs. Bf. (α) value
60	25.1 ±4.7	Eyes open	2.42 ±0.03	2.30 ±0.07	3.63 ±1.40	0.77 ±0.26	0.01*(D-V)	0.09 (D-V)	0.001***(D-V)
60	67.6 ±2.2	Eyes open	2.87 ±0.17	2.87 ±0.17	6.04 ±1.25	1.47 ±0.64	0.01*(R-D)	0.1 (R-D)	0.01*(R-D)
		Eyes open	2.50 ±0.07	2.45 ±0.05	4.22 ±1.19	1.15 ±0.20	0.001***(A-P)	0.08 (A-P)	0.01*(A-P)
		Eyes open					0.001***(M-L)	0.01*(M-L)	0.01*(M-L)
60	25.1 ±4.7	Eyes closed	2.71 ±0.04	3.75 ±0.19	6.19 ±0.97	1.40 ±0.82	0.001***(D-V)	0.2 (D-V)	0.001***(D-V)
60	67.6 ±2.2	Eyes closed	3.53 ±0.1	5.98 ±0.17	8.33 ±2.10	1.86 ±0.94	0.001***(R-D)	0.11 (R-D)	0.001***(R-D)
		Eyes closed	2.80 ±0.07	4.12 ±1.06	6.16 ±0.69	1.62 ±0.60	0.001***(A-P)	0.095 (A-P)	0.001***(A-P)
		Eyes closed					0.001***(M-L)	0.01*(M-L)	0.01*(M-L)

D-V – center of pressure displacement velocity, R-D – radial displacement of center of pressure, A-P – anterior-posterior oscillation, M-L – medial-lateral oscillation, Cc. – control, Bf. – before, Af. – after

displacement velocity in the elderly group with eyes closed. This is important, as previous studies have demonstrated that elderly individuals exhibit sensory deficiencies, such as in proprioception, with vision being an important sensory mechanism for such individuals to maintain balance [20-23].

The results of the present study may be explained by theoretical evidence and previous studies that suggest adaptive motor control for anticipatory adjustments is successful in the prevention of a loss of balance and that this control can be acquired through treadmill-based gait training. This is because anticipatory adjustments are predominantly made through feed-forward control, which is an anticipatory postural adjustment with the function of minimizing the disequilibrium caused by a self-generated focal movement and maintaining body stability. This mechanism is initiated prior to beginning the main movement, but undergoes a delay in elderly individuals [24-27].

Different exercise modalities have been described in the literature and the results have not been effective in improving balance among elderly individuals. Brown and Holloszy found no significant improvement in balance during gait in volunteers aged 60 to 71 years after training involving a general physical activity program [28]. Combined exercise programs, especially those with a multi-sensory approach, may be more effective in improving balance when compared to programs focused on a single modality, such as aerobics, strength training or flexibility training. Telian *et al.* report that vestibular rehabilitation was effective in increasing stability [29]. Tanaka *et al.* state that a training program designed to

stimulate both sensory as well as motor function is effective in improving balance in the elderly [30].

During gait on a treadmill, different sensory and motor stimuli are given with safety and in a continuous fashion. Thus, the environment does not interfere during training. However, we suggest the development of studies to identify the optimum duration, frequency and specific intensity for this population. As with other modes of exercise, it is expected that results would be better with a longer duration, greater frequency and greater intensity. There is also a need to compare the effects of different training modes in order to determine the most effective approach to improving balance in elderly individuals.

We also suggest future studies to identify the alterations in postural stability among elderly individuals in a more complete manner, associating the stabilometric test to electromyography and thereby obtaining further information on the muscle strategies used by such individuals for maintaining balance. The sample should also be increased to include elderly men as well in order to analyze their postural stability and compare it to that encountered in elderly women.

In conclusion, the results of the present study indicate that a specific exercise program, such as treadmill-based gait training, which is a dynamic activity, can improve stationary balance in successful elderly women.

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