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Static and dynamic postural control in low-vision and normal-vision adults

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OBJECTIVE: This study aimed to evaluate the influence of reduced visual information on postural control by comparing low-vision and normal-vision adults in static and dynamic conditions.

METHODS: Twenty-five low-vision subjects and twenty-five normal sighted adults were evaluated for static and dynamic balance using four protocols: 1) the Modified Clinical Test of Sensory Interaction on Balance on firm and foam surfaces with eyes opened and closed; 2) Unilateral Stance with eyes opened and closed; 3) Tandem Walk; and 4) Step Up/Over.

RESULTS: The results showed that the low-vision group presented greater body sway compared with the normal vision during balance on a foam surface ($p \leq 0.001$), the Unilateral Stance test for both limbs ($p \leq 0.001$), and the Tandem Walk test. The low-vision group showed greater step width ($p \leq 0.001$) and slower gait speed ($p \leq 0.004$). In the Step Up/Over task, low-vision participants were more cautious in stepping up (right $p \leq 0.005$ and left $p \leq 0.009$) and in executing the movement ($p \leq 0.001$).

CONCLUSION: These findings suggest that visual feedback is crucial for determining balance, especially for dynamic tasks and on foam surfaces. Low-vision individuals had worse postural stability than normal-vision adults in terms of dynamic tests and balance on foam surfaces.

KEYWORDS: Low Vision; Postural Balance; Motor Control.

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INTRODUCTION

The visual system plays a major role in postural control, and postural sway increases in the absence of vision (1-3). Visual impairment is associated with a reduction in postural control (4) and is an important factor in falls and related injuries (5-7).

Low vision is considered a condition with an impairment of visual function, despite treatment and correction of ordinary refractive errors, and is defined as a visual acuity reduced to 20/60 visual fields or less than ten degrees from the fixation point. Patients with low vision use or have the ability to use vision for planning or executing tasks (8).

The influence of the visual system on postural control (8) has been documented in several studies (9,10), especially its influence in individuals with low vision (10). Patients with visual dysfunction must place a greater demand on somatosensory and vestibular information to maintain postural stability, establish and connect movement patterns and adjust to positions in space to compensate for low-functioning visual systems (10,12-14).

Studies comparing blind and seeing individuals in static and dynamic balance tasks confirmed that approximately 80% of an individual's sensory perception is gathered by the visual system (14), which processes and integrates other sensory inputs to select a balancing strategy (15).

Currently, only a few studies have examined postural stability by comparing low-vision and normal-vision adults (3,15,16). It has been previously demonstrated that restricted vision could increase body sway and postural instability (16). Although balance appears to be affected in individuals with low vision, this relationship has not been fully explored in the literature, particularly regarding unstable surfaces, single-leg stances, dynamic tasks and tasks with eyes opened compared with eyes closed.

We hypothesized that adults with sub-normal vision have an affected postural balance due to the decreased efficiency of the vision systems compared with individuals with normal vision.

To further understand the balance of low-vision individuals and provide evidence for future interventions focused on reducing falls in this population, the objective of this

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study was to test whether low-vision adults are able to maintain postural control and to compare these subjects with normal-vision adults during stable surface tasks and more challenging tasks. To this end, we compared the postural control of low-vision and normal-vision adults in static and dynamic conditions using posturography. Additionally, we investigated the influence of reduced visual information on the postural control systems in both groups.

METHODS

This was a descriptive, cross-sectional, observational study conducted without intervention. Written consent was mandatory for study participation. The study was performed with approval granted by the Ethics Committee number 550/06.

Participants

Twenty-five low-vision and twenty-five normal-vision individuals participated in the study. The low-vision group was composed of eleven males and fourteen females with a mean age of 28.6±6 years (range 20-37 years), mean height of 164±7 cm (range 151-179 cm), mean body mass of 65.5±14.2 kg (range 48-104.2 kg) and mean body mass index (BMI) of 24.2±4.4 (range 19.1-34.6). The participants were recruited from vision impairment centers.

The etiology of low vision in the low-vision group was either congenital (twelve participants) or acquired (thirteen participants). The participants had a visual acuity of less than 6/18 but equal to or better than 3/60 or had a corresponding visual field loss of less than twenty degrees in the better eye with the best possible correction, in accordance with the International Statistical Classification of Diseases, Injuries and Causes of Death, 10th Revision (ICD-10). The causes of visual impairment of the participants included optic nerve abnormalities, disorders of the retina, glaucoma, Stargardt's disease, standard macular degeneration, retinitis pigmentosa and congenital toxoplasmosis. All participants underwent a low-vision screening test, which included a medical history, optimal visual acuity measurement and ophthalmoscopic ocular screening.

The normal-vision group was a convenience sample selected from the community after an assessment using Snellen's optometric scale. This group included seven males and eighteen females. The mean age was 26.1±4 years (range 20-37 years). The mean height was 162±9 cm (range 147-183 cm), and the mean body mass was 60.6±11.3 kg (range 44.5-92.9 kg). The mean BMI was 22.7±2.5 (range 17.3-27.7). No significant differences between the groups were found.

The following criteria were used to select study participants: no current or past medical diagnosis of injury affecting balance within the last three years; no medications affecting the central nervous system or known to affect balance or coordination; no current symptoms of dizziness or light-headedness; no orthopedic or neurologic diagnoses or symptoms suggestive of vestibular or neurologic disorders; and no symptoms requiring the participant to be sedentary. Participants in the low-vision group were defined as independent if they were able to move by themselves within all environments.

Procedures

Participants were required to complete a structured, self-administered questionnaire written for this study concerning a history of falls, fractures, stumbling, dizziness and the perception of disequilibrium.

The subjects were then tested using the NeuroCom Balance Master ® force platform system (NeuroCom International, Inc., Clackamas, OR, USA). which includes a computer with a force plate that records data with the aid of piezoelectric crystal transducers. Force-plate data included the X (±0.08 cm) and Y (±0.25 cm) positions of the center of vertical force and total vertical force (±0.1 N) at a sampling rate of 100 Hz. With this system, the transducers transmit pressure to the computer every 10 ms; then, the dynamic center of gravity of the subject is calculated, and the sway velocity during a certain period is obtained. Sway velocity (degrees/second) measures the angular change of the center of gravity per unit of time. The sway velocity is an appropriate dependent measure for determining postural stability (16).

All tests were performed by the same evaluator and standardized in terms of positioning and testing.

The NeuroCom Balance Master System has multiple testing protocols designed to examine balance. This study used the Modified Clinical Test of Sensory Interaction on Balance, Unilateral Stance, Tandem Walk and Step Up/Over protocols. The equipment has been demonstrated to have good reliability and reproducibility (ICC 0.53 to 0.81) (17).

Static balance protocol

Modified Clinical Test of Sensory Interaction on Balance. This test quantifies sway velocity in degrees per second (°/s) with the subject standing in four test conditions: 1) a firm surface with the eyes open; 2) a firm surface with the eyes closed; 3) a foam surface with eyes open; and 4) a foam surface with eyes closed. Three ten-second trials were recorded for each of the test conditions, with a ten-second rest between each trial. The average sway velocity of the subject's center of gravity was calculated for each trial and averaged for each test condition.

Unilateral Stance. The Unilateral Stance test quantifies sway velocity in degrees per second (°/s), with the subject standing on one leg in the following four conditions: 1) on the right leg with eyes open; 2) on the right leg with eyes closed; 3) on the left leg with eyes open; and 4) on the left leg with eyes closed. The subject was instructed to keep the non-test leg in a position of 0° of hip flexion and 90° of knee flexion. Three ten-second trials were recorded for each leg, with a ten-second rest between each trial. The trials were performed on a firm surface, and testing was terminated if the subject experienced a loss of balance. Mistrials were not scored. The center of gravity sway velocity was recorded for each leg.

Dynamic balance protocols

Tandem Walk. This test quantifies characteristics of gait while the subject walks the length of a force platform in a heel-to-toe manner. The measured parameters include step width, speed and end sway velocity. Subjects were instructed to stand heel-to-toe steadily at the starting position, look straight ahead and tandem walk at the sound of ''Go'' along a 153 cm straight line on the force plates. Participants were told to walk as quickly as possible, stop at the end of the force plates and hold that position as steadily as possible until the command ''Stop'' was announced. The test consisted of three trials that each lasted ten seconds, with a ten-second rest between each trial. End sway velocity (degrees/second) was measured when the forward movement stopped.

Step Up/Over. Three variables were analyzed in the Step Up/Over test: lift-up index, movement time and impact index. Each subject's movement time was recorded in seconds from the initiation of the step up to contact of the first leg (the non-test leg) with the platform. The lift-up index was recorded by the percentage of body weight exerted to lift the leading leg to the wooden step. The impact index was expressed as the percentage of body weight used to step down onto the force plate. The Step Up/Over test was performed using a twenty-centimeter wooden step placed in the center of the platform. Subjects stood a comfortable distance behind the step, which was determined during a practice trial. The subjects were told to look straight ahead and at the sound of ''Go'', to step up with the test leg, swing the other leg up and over the step and then step down with the test leg. Participants were asked to hold that position as steadily as possible until they heard the command ''Stop''. Subjects held their positions for five seconds after the test leg descended to the step. The test consisted of three trials that each lasted ten seconds, with a ten-second rest between each trial.

Data analysis

For the sample size calculation, we assumed the following parameters for the two-tailed hypothesis: alpha value (type 1 error probability) of 5%; beta value (type 2 error probability) of 10%; a test power of 90%; and a difference between the groups regarding the main outcome of 5%. To meet these conditions, at least seventeen subjects were necessary.

Static balance protocol. Modified Clinical Test of Sensory Interaction on Balance - The data were analyzed using a 2 (group) × 2 (eye condition) for firm and foam surface ANOVA separately.

Unilateral Stance protocol - The data were analyzed using a 2 (group) × 2 (eye condition) ANOVA for the right and left sides separately.

An exploratory data analysis method was used in both tests when necessary.

Dynamic balance protocol. Tandem Walk - To determine differences between the low-vision and normal-vision groups, the data were analyzed using one-way ANOVA.

Step Up/Over - The data were analyzed using a 2 (group) × 2 (right leg, left leg) ANOVA for lift-up index, impact index and movement time separately.

The Chi-Square test was used to determine differences between the normal-vision and low-vision groups with regard to the self-reported variables.

Data analysis was performed using SPSS version 17.0 for Windows. Statistical significance was set at $p<0.05$.

Approval was granted by the Ethics Committee of the Faculdade de Medicina da Universidade de São Paulo (number 933/06).

RESULTS

The low-vision group had a significantly greater lifetime number of falls and perception of disequilibrium compared with the normal-vision group (Table 1).

Table 1 - Comparison between the low-vision and normal-vision groups through anamnesis.

Variables	Low-vision N (%)	Normal-vision N (%)	*p*-value
Lifetime falls	23 (92)	12 (48)	**0.006**
Balance difficulty	9 (36)	0 (0)	**0.002**
Easily losing balance	8 (32)	0 (0)	**0.009**
Recent falls	2 (8)	3 (12)	0.63
Stumbling	9 (36)	5 (20)	0.20
Dizziness	0 (0)	0 (0)	1.00
Fractures	2 (8%)	2 (8)	1.00
Other injuries	3 (12%)	2 (8)	0.63

Static balance

Table 2 shows the mean values for the Modified Clinical Test of Sensory Interaction on Balance according to surface type and eye conditions and for the Unilateral Stance according to the test leg and eye condition across groups. Comparisons between groups showed significant differences regarding foam surface.

For the Modified Clinical Test of Sensory Interaction on Balance on a firm surface, a significant effect of group (F(1.48) = 0.43, $p<0.05$, $\eta^2 = 0.13$) but not eye condition (F(1.48) = 0.047, $p>0.05$, $\eta^2 = 0.001$) was observed, but no significant interaction between eye condition and group (F(1.40) = 1.3, $p>0.05$, $\eta^2 = 0.027$) was observed. On the foam surface, significant effects of eye condition (F(1.48) = 69.10, $p<0.05$, $\eta^2 = 0.59$) and group (F(1.48) = 69.10, $p<0.05$, $\eta^2 = 0.59$) were observed, as well as a significant interaction between eye condition and group (F (1.48) = 61.18, $p<0.05$, $\eta^2 = 0.56$). The analysis revealed a difference between eye condition on the foam surface for the normal-vision group, as tasks were more difficult for these participants on the foam surface with eyes closed (M = 1.41, SD = 0.30) compared with tasks on the foam surface with eyes open (M = 0.62, SD = 0.12) (Table 2).

For the Unilateral Stance on the left leg, a significant effect of the eye condition (F(1.48) = 39.26, $p<0.05$, $\eta^2 = 0.45$) and a significant interaction between group and eye condition (F(1.48) = 20.29, $p<0.05$, $\eta^2 = 0.05$) were observed, but no group effect (F(1.48) = 2.70, $p>0.05$, $\eta^2 = 0.05$) was found. For the right leg, an effect of the eye condition (F(1.48) = 54.46, $p<0.05$, $\eta^2 = 0.53$) and a significant interaction

Table 2 - Comparison between the low-vision and normal-vision groups according to eyes, surface and side leg stance in terms of the static balance protocol.

	Eyes open	Eyes closed	*p*-value
	M (SD)	M (SD)	
mCTSIB (degrees/sec)			
Firm surface			
Low vision	0.24 (0.08)	0.21 (0.09)	0.17
Normal vision	0.23 (0.11)	0.27 (0.27)	0.47
Foam Surface			
Low vision	1.25 (0.31)	1.27 (0.32)	0.77
Normal vision	0.62 (0.12)	1.41 (0.30)	**<0.001***
US (degrees/sec)			
Right leg stance			
Low vision	1.80 (0.20)	2.58 (0.97)	0.001*
Normal vision	0.08 (0.20)	2.98 (1.73)	**<0.001***
Left leg stance			
Low vision	2.07 (0.95)	2.93 (1.73)	0.09
Normal vision	0.80 (0.18)	2.42 (1.73)	<0.001

between group and eye condition (F(1.48) = 11.75, $p<0.05$, $\eta^2 = 0.19$) was also observed, but no group effect (F(1.48) = 1.60, $p>0.05$, $\eta^2 = 0.03$) was found. The exploratory analysis demonstrated that there was a difference between the eye conditions in both single-leg stances in the normal-vision group; that is, tasks were more difficult with eyes closed than eyes open condition for both legs. In the low-vision group, a difference between the eye conditions was only observed in the left leg test, with tasks being more difficult with eyes closed than eyes open. (Table 2).

Dynamic balance

For Tandem Walk task, the ANOVA results indicated that the step width and speed of the normal-vision and low-vision groups were significantly different. The normal-vision and low-vision groups did not differ in sway velocity (Table 3).

For the Step Up/Over task, the ANOVA results indicated significant effects for leg side (F(1.48) = 24.50, $p<0.05$, $\eta^2 = 0.33$) and group (F(1.48) = 8.86, $p<0.05$, $\eta^2 = 0.15$), but the results indicated no significant interaction effects. The time results for the Step Up/Over task indicated an effect for group (F(1.48) = 26.08, $p<0.05$, $\eta^2 = 0.97$) but not for the right or left leg (F(1.48) = 2.14, $p>0.05$, $\eta^2 = 0.04$), and no interactions were observed. For Step Up/Over impact, the ANOVA results indicated no effect for leg side or group (F(1.48) = 1.17, $p>0.05$, $\eta^2 = 0.02$ and F(1.48) = 0.56, $p>0.05$, $\eta^2 = 0.01$, respectively). An exploratory analysis demonstrated that there was a difference between the low-vision and normal-vision groups for lift up and time in both leg sides; that is, tasks were more difficult for the normal-vision group than the low-vision group (Table 3).

DISCUSSION

In our study, the reduced visual information influenced postural stability on a foam surface and in dynamic conditions for the low-vision group. The eyes open condition was easier (a smaller sway was observed) for the normal-vision group than the low-vision group for tasks performed on the foam surface. The low-vision group was more cautious compared with the normal-vision group when performing the Tandem Walk and Step Up/Over tasks (slower walking velocity, increased step width and smaller lift-up). Duarte and Zatsiorsky (18) reported that the dependence of visual information on balance control is greater when the individual is in unipodal support or on an incline than in a normal or neutral position. According to those authors, the proprioceptive information from mechanoreceptors on the soles of feet would likely be reduced during the most challenging tasks, and the postural control system would need to rely more on visual and vestibular information to control balance in an inclined position and on vestibular information only in conditions of low-vision or non-vision.

Table 3 - Comparison between the low-vision and normal-vision groups in terms of the dynamic balance protocol.

	Low-vision	Normal-vision	p-value
	M (SD)	M (SD)	
Tandem Walk			
Step width (cm)	11.0 (3.75)	7.36 (1.18)	≤0.001
Speed (cm/sec)	12.2 (3.33)	16.45 (4.21)	≤0.004
End SV (degrees/sec)	4.5 (1.45)	3.86 (3.21)	0.23
Step up/over			
Lift-up index (% weight)			
Right leg	37.40 (12.48)	46.32 (8.33)	**0.005**
Left leg	34.05 (11.72)	41.12 (5.67)	**0.009**
Movement time (sec)			
Right leg	1.89 (0.33)	1.49 (0.18)	**<0.001**
Left leg	2.01 (0.47)	1.51 (0.35)	**<0.001**
Impact index (% weight)			
Right leg	42.34 (17.22)	44.68 (18.61)	0.64
Left leg	42.63 (20.76)	44.68 (18.61)	0.71

In agreement with the literature, the low-vision individuals demonstrated less postural stability than those with normal vision (16). Several studies have suggested that vision impairment can increase postural instability (5,20,21) and that the interaction between the central nervous, muscle and peripheral sensory systems is fundamental for calibrating sensory maps and adjusting balance (3,15,23).

The results revealed an interaction between the test's surface type and eye condition for the normal-vision group. This group was less stable on a foam surface and in the unilateral stance tests when the subjects' eyes were closed. This finding has been corroborated by previous studies in healthy individuals (3,4,14,15,24). Other studies have demonstrated that standing on a single limb is more difficult without vision, indicating that the more challenging the task, the more the balance control mechanisms rely on vision (25).

No interaction was observed between the surface type and the eye condition in the low-vision group, except for with tasks involving the left leg. This finding may indicate that visual proprioceptive information would be more sensitive than mechanical proprioceptive information from the vestibular system and somatosensory systems (15), and in the low-vision group, these systems had physiologic habituation and an adaptation response to maintain postural control (14).

In relation to the left leg test, the low-vision group had greater difficulty performing the test with eyes closed compared with open. Very few studies have examined the postural control of low-vision subjects in a single-leg stance under different eye conditions. The proprioception inputs could be overloading the left leg, as previous studies have suggested that unilateral stance tasks might depend on some neuromuscular requirement (25) and muscular strength (3,12,13). The ability of the postural control system to select a higher joint configuration variance (2,28) can contribute to the maintenance of postural stability by correcting lower extremity movements in individuals with vision impairments.

In the Tandem Walk protocol, the low-vision group showed slower speed and greater step width compared with the normal-vision group. These results are in accordance with previous studies (29). This finding suggests that in walking, visual proprioception normally plays a lead role in the postural control system and can be partially compensated for by improving somatosensory and peripheral vestibular processing (14,21,30).

In the Step Up/Over task, the low-vision group was more cautious when stepping up and executing the movement than the normal-vision group, as observed in previous studies. This result verified that these adaptations occur to increase kinesthetic information and compensate for unreliable/incomplete visual information (31). These adaptations may be associated with the risk or fear of falls (32). The dynamic balance can be greatly impaired by the loss of afferent visual information (33).

The results provide evidence for the need for interventions focused on reducing falls in this population.

Methodological limitations arise regarding the effect of central and peripheral vision in postural balance. According Berencsi et al. (34), central vision and peripheral vision contribute differently to upright posture control, and peripheral vision results in less postural sway than central vision, but both types of vision are essential for the maintenance of postural control. Future studies should analyze the postural balance in subjects with different losses in either central or peripheral fields of vision.

This study suggests that visual feedback could influence balance during challenging tasks, even during periods of prolonged vision impairment. Individuals with low vision had worse postural stability than normal-vision adults in dynamic tests and tests on foam surfaces.

AUTHOR CONTRIBUTIONS

Tomomitsu MS, Alonso AC and Morimoto E were responsible for data collection and manuscript writing. Bobbio TG was responsible for data analysis and the final correction of the manuscript. D'Andréa Greve JM oriented the work.

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