Severe Dizziness Related to Postural Instability, Changes in Gait and Cognitive Skills in Patients with Chronic Peripheral Vestibulopathy

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Abstract

Introduction Peripheral vestibular disorders can lead to cognitive deficits and are more common in elderly patients.

Objective To evaluate and correlate cognitive, balance and gait aspects in elderly women with chronic peripheral vestibular dizziness, and to compare them with elderly women without vestibular disorders.

Methods Twenty-two women presenting peripheral vestibular dizziness episodes for at least six months participated in the study. The individuals were categorized by dizziness severity level: moderate ($n = 11$) or severe ($n = 11$). The control group ($n = 11$) included women showing no vestibulopathy, light-headedness or dizziness. Cognitive assessments and semi-static and dynamic balance assessments were performed with the Balance Master (Neurocom International, Inc., Clackamas, OR), while the Dizziness Handicap Inventory provided a score for the severity of the symptoms. The groups were submitted to statistics of inference and correlation between cognitive, balance and stability variables.

Results The group with severe dizziness showed higher sway speed of the center of pressure in the anteroposterior direction, smaller step length, and slower gait than the control group. Regarding the cognitive variables, the group with severe dizziness symptoms presented significant correlations with stability and gait variables.

Conclusion The relationship between cognitive aspects, balance and gait was stronger in women with severe dizziness than in those with no vestibulopathy.

Keywords
- vestibular diseases
- aging
- dizziness
- rehabilitation

Introduction

Adequate postural control allows people to perform their functional activities succesfully, through the integration of perception and action systems and high-level processes. The vestibular system, which participates in the sensory processes, has the function of picking up information about head position, movement, acting forces and inertia during the execution of different activities.[1]

The proper function of the vestibular system may be impaired by vestibulopathies, whose symptoms, such as dizziness and imbalance, decrease the ability to perform ordinary and social activities.

According to the international classification of vestibular disorders of the Bárány Society, dizziness can be defined as a sensation of disturbance or impairment in spatial orientation, without a false or distorted sense of self-movement (of a

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rotational type). And vertigo is when there is a sense of self-movement (of the rotational type), even when there is no actual body movement on the axis itself or during normal head movement.[2] Studies have reported that the prevalence of dizziness increases with age, affecting ~ 14% of the population aged 18 to 39 years, and 28% of the population aged 40 to 59 years; the condition may affect up to 85% of the population aged 70 years or older.[3]

Another common symptom of aging is cognitive decline, which is characterized by loss of short-term memory and lack of concentration and attention, impairing the achievement of adaptive and anticipatory responses and the strategies used for navigation, disturbance management, and to avoid obstacles.[4]

Vestibulopathies can influence the interrelations in the central nervous system (CNS) through damage to the labyrinthine organ and the vestibular nerve up to its entrance in the brainstem, in which cases the dysfunction is peripheral, or through modifications in the vestibular nuclei, whose origin is central.[5] Considering these interrelations of peripheral and central origin, recent studies have reported the influence of the vestibular system in cognition, mainly related to the perception of self-motion, bodily self-awareness, spatial navigation, spatial learning, spatial memory, and object recognition memory.[6]

However, few studies[4,7,8] have tackled the details and complexity of each of these components. Little is known about the relationship between the vestibular system and distinct nonspatial cognitive aspects and its correlation with balance deficits; additionally, the severity of dizziness is often overlooked in the existing studies. Furthermore, studies describing vestibular disorders usually do not distinguish patients with different durations of symptoms; special attention should be given to the patients who have already been treated for otoneurological symptoms. This differentiation is paramount, because the cognitive, balance and functionality responses may vary depending on the clinical characteristics of the individuals. Taking these factors into consideration, the present study was designed to evaluate and correlate cognition, balance and gait in elderly women with chronic peripheral vestibular dizziness who had not responded to conventional vestibular rehabilitation (VR) and compare the results with data from elderly women without perception of dizziness or any vestibular disorder.

Material and Methods

Sample Definition

The sample consisted of 22 elderly women ($\geq$60 years old) who had peripheral vestibular dizziness episodes for at least six months. The diagnosis of peripheral dizziness was confirmed through anamnesis, caloric tests and computerized vector electronystagmography at the Department of Ophthalmology, Otorhinolaryngology and Head and Neck Surgery of Hospital das Clínicas, Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo (HC/FMRP-USP). These patients were divided into two groups according to their symptoms using the dizzness handicap inventory (DHI): the moderate dizziness group (MDG; $n = 11$) and the severe dizziness group (SDG; $n = 11$). The control group (CG; $n = 11$) consisted of elderly women with no vestibulopathy, light-headedness or dizziness.

The CG was recruited from the community and submitted to otoneurological examinations at the Department of Otorhinolaryngology, to confirm the absence of symptoms of dizziness and vestibulopathies.

The inclusion criteria for the MDG and SDG were complaints of light-headedness, having consulted the otorhinolaryngologist with symptoms of dizziness over the previous 6 months, and still be experiencing dizziness made worse by head movements (indication of vestibular pathology, according the Bárány Society[2]), with daily or weekly episodes of dizziness, even after having undergone VR. The CG could not show dizziness, light-headedness or any biomechanical alterations, after being examined by a general practitioner over the previous month. The exclusion criteria for patients with chronic peripheral vestibulopathy were use of medications affecting balance, such as benzodiazepines and anticonvulsants, calcium channel blockers (cinnarizine and flunarizine, for example); motor, visual or cognitive limitations that hindered the execution of the tests; and systemic diseases not controlled by drugs.[9] In addition, none of the volunteers could present any biomechanical alterations, such as, hip, knee or ankle hypomotility or muscle weakness that incapacitated them to perform the physical tests.

The Mini-Mental State Examination (MMSE) questionnaire was applied to rule out cognitive impairment and used as exclusion criteria for the volunteers who obtained scores $\leq$ 15 for illiteratcy, $\leq$22 for 1 to 11 years of schooling, and $\leq$27 for more than 11 years of schooling.[10]

The Ethics Committee approved the present study (protocol n. 3350/2013).

Measurements

The DHI was used to assess the self-perception of dizziness and to categorize the patients into the MDG and SDG; no participants reported mild dizziness. The DHI includes 25 questions that address physical (7 queries), emotional (9 queries) and functional (9 queries) aspects.[11] Each item has a four-point scale, with a total possible score of 100 points; higher scores indicate higher severity, regardless of the aspect concerned.[9] Scores ranging from 0 to 30 points suggest mild impact of the symptom on quality of life; 31 to 60 points means moderate impact; and 61 to 100 points correspond to severe impact.[11]

The cognitive aspects were assessed through the application of the Montreal Cognitive Assessment (MoCA),[12] the clock-drawing (CD) test, [13] the verbal fluency (VF)[14] test, and Trail Making Test Part B (TMB).[15]

The MoCA measures executive function, memory, language, visuoconstructive capacity and calculation skills, attention, conceptualization, and orientation. The highest score is 30 points, with a score $\geq$ 26 points indicating no need for other neuropsychological exams.[12]

The CD test estimates verbal understanding, praxis, visuospatial function, attention, memory and executive functions.[13] In this test, the patient is instructed to draw the clock numbers and hands indicating the time of 11h10.[13] The score varies

from 1 to 10, with scores < 6 associated with abnormality, scores between 6 and 8 classified as suspicious, and scores equal to 9 or 10 considered as normal performance.[16]

The VF test evaluates semantic memory related to general knowledge defined by the examiner. The participants were asked to list the maximum number of fruit names they could remember in one minute. The educational level was used as a criterion for scoring this test.[14]

The TMB assesses processing speed, working memory, visual attention, executive function and visuospatial skills.[15] It has a set of numbers from 1 to 13 and letters from A to M that must be paired up in sequence. The examiner times the task; the longer it takes, the worse the performance.[17]

Semi-static balance and functionality were assessed through the limits of stability (LoS) and walking tests (WTs) using the Balance Master (Neurocom International, Inc., Clackamas, OR). The participants performed 3 trials, each lasting 10 seconds, toward predetermined and random targets. The equipment provided the final values for each variable analyzed.

The LoS test quantifies the characteristics of the displacement of the center of pressure (CoP).[18] The participants were instructed to lean, using the ankle strategy for balance control.[19] They executed voluntary leaning movements toward targets randomly displayed on a computer monitor. Four displacements were required in the test: anterior direction, posterior direction, right lateral direction and left lateral direction. The variables analyzed were: movement response time (LSRT), which measures the time from the visual stimulus until a predetermined target is reached; movement speed (LSMV), which assesses the speed of oscillation of the CoP toward the predetermined target; movement endpoint excursion (LSEPE), which is defined as the longest distance covered by the displacement of the CoP in the first movement toward the predetermined target, measured as a percentage of the limit of stability predefined in the equipment according to the participant's height; and the maximum movement excursion (LSMXE), which corresponds to the longest distance covered by the CoP displacement during the test, expressed as a percentage of the maximum reach according to the height of the volunteer.[18,19]

The WT was used to measure the dynamic balance during a walk on a 1.52-m long platform. The parameters measured in this test were: step width (WTSW), progression speed (WTPS), and step length (WTSL).[20]

Calculation of Sample Power

Based on the study by Rahal et al[21], the calculation of the sample power was performed using the Gpower software, version 3.1.7. The primary outcome was the final score on the MoCA test, with an effect size = 1.4589, power = 0.95, and α error = 0.05. The output exhibited an actual power = 0.9518 for a sample size of 11 participants per group, for use in the Student *t*-test for independent samples. Finally, a correlation coefficient (r) = 0.74 was determined based on the MoCA score and gait speed, generating an effect size = 0.8602, taking into account a power = 0.95 and α error = 0.05. The output was an actual power = 0.9549, with a sample of 6 participants per group, for use in the Pearson correlation test.

Statistical Analysis

After collecting the data, the variables were submitted to a descriptive statistical analysis, with the calculation of central tendency measures and dispersion. The Shapiro-Wilk test was then used to determine whether the distribution was Gaussian. The Student *t*-test for independent samples was used to compare the cognitive, limit of stability, and walking variables for both groups (MDG × CG; SDG × CG; MDG × SDG).

Pearson correlation analyses between the cognitive variables (MoCA, VF, CD and TMB tests) and the LoS and walking variables were performed. The correlation was considered weak from 0.20 to 0.39, moderate from 0.40 to 0.59, and strong when > 0.59.[20]

In addition, for an effect size measurement (ESM) of the results obtained between intergroup comparisons, in association with the *p*-value, the Cohen d value, was calculated. According to the study by Hattie,[22] values between 0.5 and 1.0 may be preferred to demonstrate the desired effects. In the present study, large ESM values were considered significant for the reliability of the *p*-value obtained with the Student *t*-test.

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS, SPSS, Inc., Chicago, IL, US) software for Windows, version 11.0. The level of significance was set at 5% ($p \leq 0.05$).

Results

►**Table 1** presents the characteristics and anthropometric data of the sample. Most of the chronic peripheral vestibulopathy patients had symptoms for over five years. Furthermore, all groups were homogeneous regarding age, weight, height and body mass index (BMI).

►**Table 2** presents the means and standard deviation of the cognitive variables. The groups were similar regarding the results of the MMSE, CD, VF and TMB tests.

For the cognitive variables, there was a statistically significant difference ($p < 0.01$; ***large*** ESM [Cohen d > 1.0]) in the score of the MoCA test between both the MDG and SDG when compared with the CG (►**Table 2**). Both dizziness groups scored worse in the MoCA test than the CG.

The SDG presented a higher CoP speed of oscillation in the anterior (LSMV1) and posterior (LSMV5) directions than the CG ($p < 0.01$; ***large*** ESM [Cohen d > 1.0], ►**Table 3**). In the gait analysis, the SDG had a smaller step length ($p < 0.01$; ***large*** ESM [Cohen d > 1.0]) and a lower gait speed ($p < 0.01$) than the CG (►**Table 3**). The MDG exhibited a lower gait speed ($p < 0.01$; ***large*** ESM [Cohen d > 1.0]) than the CG.

The SDG developed a higher speed of oscillation of the CoP in the posterior direction ($p > 0.05$; ***large*** ESM [Cohen d > 1.0]), a lower gait speed ($p > 0.05$; ***large*** ESM [Cohen d > 1.0]) and a smaller step length ($p > 0.05$; ***large*** ESM [Cohen d > 1.0]) than the MDG.

►**Table 4** shows the data regarding the correlations between the cognitive and functional performance variables. Regarding the correlations between the cognitive and LoS variables for the MDG, there were significant ($p < 0.05$) and strong (r > 0.59) correlations between them. There was a

Table 1 Mean and standard deviation of the anthropometric data and characterization of the sample, including the *p*-values for the comparisons between groups

		Groups					
Variables		**MDG (n = 11) mean ± SD**	**SDG (n = 11) mean ± SD**	**CG (n = 11) mean ± SD**	**MDG x SDG *p*-value**	**MDG x CG *p*-value**	**SDG x CG *p*-value**
Age (years)		63.3 ± 7.3	63.4 ± 10.4	64.1 ± 7.2	**0.384** (0.01)	**0.382** (0.11)	**0.399** (0.07)
Body mass (Kg)		74.0 ± 9.4	76.5 ± 11.6	75.5 ± 8.3	**0.452** (0.23)	**0.533** (0.16)	**0.825** (0.09)
Height (m)		1.6 ± 0.1	1.6 ± 0.0	1.6 ± 0.1	**0.257** (0.00)	**0.770** (0.00)	**0.264** (0.00)
BMI (kg/m^2)		28.1 ± 3.7	30.5 ± 4.7	29.3 ± 2.9	**0.598** (0.56)	**0.282** (0.36)	**0.566** (0.30)
Schooling (years)	**1–4**	4	3	4	–	–	–
	5–8	2	3	4	–	–	–
	9 a 11	5	5	3	–	–	–
	> 11	–	–	–	–	–	–
Onset of dizziness (years)	**1–2** **3–4**	1 2	1 3	- -	- -	- -	- -
	> 5	8	7	–	–	–	–

Abbreviations: BMI, Body Mass Index; CG, control group; MDG, moderate dizziness group; SD, standard deviation; SDG, severe dizziness group.

Table 2 Mean and standard deviation values for the cognitive variables, including the *p*-values for the comparisons between groups

	Groups					
Cognitive variables	**MDG (n = 11) mean ± SD**	**SDG (n = 11) mean ± SD**	**CG (n = 11) mean ± SD**	**MDG x SDG *p*-value (Cohen d)**	**MDG x CG *p*-value (Cohen d)**	**SDG x CG *p*-value (Cohen d)**
MMSE (score)	26.1 ± 2.2	24.7 ± 3.9	27.4 ± 1.7	**0.343** (0.44)	**0.230** (0.66)	**0.142** (0.89)
Clock Drawing Test (score)	8.3 ± 2.0	7.1 ± 1.0	8.1 ± 1.3	**0.106** (0.75)	**0.705** (0.11)	**0.117** (0.86)
Verbal Fluency Test (score)	13.3 ± 3.3	12.6 ± 2.0	14.0 ± 3.0	**0.562** (0.25)	**0.952** (0.22)	**0.683** (0.54)
Trail Making B (s)	162.0 ± 37.1	168.5 ± 57.9	150.5 ± 92.8	**0.892** (0.13)	**0.810** (0.16)	**0.627** (0.23)
MoCA (score)	22.9 ± 1.9	22.0 ± 3.9	25.6 ± 1.8	**0.342** (0.29)	**0.004*** (1.45$^\#$)	**0.022*** (1.64$^\#$)

Note: $^*p < 0.05$; $^\#$***large*** effect size measurement (ESM) (Cohen d = 0.8–1.0).
Abbreviations: CG, control group; MDG, moderate dizziness group; MMSE, Mini Mental State Examination; MoCA, Montreal Cognitive Assesment; SD, standard deviation; SDG, severe dizziness group.

negative correlation with reaction time in the anterior direction (LSRTA), showing that the lower the MoCA score, the longer the reaction time for the anterior displacement. There was also a positive correlation for the movement endpoint excursion in the posterior direction (LSEPEP), revealing that the lower the MoCA score, the lower the final reach in the LSEPEP. The VF test results and the distance covered by the CoP in the anterior direction (LSMXEA) showed a positive correlation.

The SDG showed a higher number of significant ($p < 0.05$) and strong ($r > 0.59$) correlations between the cognitive aspect assessed by the TMB and the LoS variables. There were positive correlations with the movement speed of the anteroposterior movement (LSMVA and LSMVP), revealing that the poorer the executive function, the higher the movement speed in the anteroposterior displacement. Moreover, there was a significant ($p < 0.05$) and strong ($r > 0.59$) correlation between the MoCA score and the distance covered by the CoP in the anterior direction (LSMXEA).

Furthermore, the analysis showed a negative correlation between the TMB and the distance covered by the CoP in the posterior direction (LSMXEP), demonstrating that the worse the executive function, the shorter the distance covered by the CoP in that specific direction.

Table 3 Mean and standard deviation values for the limit of stability and walking variables for the sample groups, including the *p*-values for the comparisons between groups

	Groups					
Limit of stability variables	**MDG (n = 11) mean ± SD**	**SDG (n = 11) mean ± SD**	**CG (n = 11) mean ± SD**	**MDG x SDG**	**MDG x CG**	**SDG x CG**
				***p*-value**	***p*-value**	***p*-value**
	Anterior			(Cohen d)	(Cohen d)	(Cohen d)
LSRT (s)	1.5 ± 0.3	1.6 ± 1.4	1.4 ± 0.8	**0.562** (0.09)	**0.833** (0.16)	**0.516** (0.17)
LSMV (°/s)	2.4 ± 1.1	3.1 ± 1.1	1.9 ± 0.8	**0.175** (0.63)	**0.224** (0.51)	**0.006*** (1.24#)
LSEPE (%)	49.2 ± 19.1	48.5 ± 14.9	53.0 ± 15.8	**0.315** (0.04)	**0.572** (0.21)	**0.544** (0.29)
LSMXE (%)	67.5 ± 17.3	64.8 ± 11.3	66.7 ± 20.7	**0.687** (0.18)	**0.924** (0.04)	**0.839** (0.23)
	Left					
LSRT (s)	1.1 ± 0.4	1.5 ± 0.8	1.2 ± 0.6	**0.146** (0.63)	**0.583** (0.19)	**0.272** (0.42)
LSMV (°/s)	2.9 ± 1.5	3.6 ± 1.31	2.4 ± 1.1	**0.364** (0.07)	**0.345** (0.38)	**0.111** (0.12)
LSEPE (%)	62.4 ± 24.2	63.3 ± 21.9	62.7 ± 23.3	**0.934** (0.03)	**0.971** (0.01)	**0.963** (0.02)
LSMXE (%)	78.4 ± 13.4	71.1 ± 22.4	78.5 ± 10.2	**0.386** (0.39)	**0.987** (0.39)	**0.418** (0.42)
	Posterior					
LSRT (s)	0.8 ± 0.6	1.0 ± 0.4	0.8 ± 0.5	**0.502** (0.39)	**0.968** (0.00)	**0.439** (0.44)
LSMV (°/s)	1.7 ± 0.8	2.5 ± 0.6	1.4 ± 0.4	**0.025*** (1.31#)	**0.184** (0.47)	**0.000*** (2.15#)
LSEPE (%)	48.7 ± 20.6	46.1 ± 17.3	55.0 ± 19.9	**0.937** (0.13)	**0.505** (0.31)	**0.127** (0.47)
LSMXE (%)	59.0 ± 16.8	59.8 ± 21.2	63.5 ± 20.6	**0.764** (0.04)	**0.515** (0.04)	**0.681** (0.17)
	Right					
LSRT (s)	2.8 ± 1.2	2.8 ± 1.2	2.9 ± 1.0	**0.113** (0.00)	**0.903** (0.09)	**0.083** (0.09)
LSMV (°/s)	2.29 ± 1.20	2.80 ± 1.06	2.51 ± 1.08	**1.000** (0.34)	**0.659** (0.19)	**0.790** (0.28)
LSEPE (%)	58.1 ± 17.9	60.9 ± 22.2	62.8 ± 24.4	**0.758** (0.13)	**0.627** (0.13)	**0.893** (0.08)
LSMXE (%)	72.1 ± 13.9	70.3 ± 21.8	72.9 ± 17.5	**0.823** (0.09)	**0.912** (0.09)	**0.819** (0.13)
Walking variables	**MDG (n = 11) mean ± SD**	**SDG (n = 11) mean ± SD**	**CG (n = 11) mean ± SD**	**MDG x SDG *p*-value** (Cohen d)	**MDG x CG *p*-value** (Cohen d)	**SDG x CG *p*-value** (Cohen d)
Step width(m)	0.15 ± 0.003	0.17 ± 0.003	0.16 ± 0.003	**0.395** (0.66)	**0.963** (0.33)	**0.096** (0.33)
Step Length(m)	0.47 ± 0.011	0.36 ± 0.008	0.53 ± 0.006	**0.025*** (1.92#)	**0.108** (1.39#)	**0.000*** (2.40#)
Speed (m/s)	0.545 ± 0.110	0.453 ± 0.058	0.761 ± 0.124	**0.038*** (1.07#)	**0.002*** (2.45#)	**0.000*** (3.50#)

Abbreviations: LSEPE, Limits of Stability – movement endpoint excursion; LSMV, Limits of Stability – movement speed; LSMXE, Limits of Stability – maximum movement excursion; LSRT, Limits of Stability – reaction time; CG, control group; MDG, moderate dizziness group; SD, standard deviation; SDG, severe dizziness group.
Notes: *$p < 0.05$. #***large*** effect size measurement (ESM) (Cohen d = 0.8–1.0).

Table 4 Pearson correlation values between cognitive variables, limits of stability and walking variables for the sample groups

MDG (n = 11)					SDG (n = 11)				CG (n = 11)			
	MoCA	FVT	CDT	TMB	MoCA	FVT	CDT	TMB	MoCA	FVT	CDT	TMB
WTSW	−0.21	−0.27	0.06	−0.14	−0.30	−0.01	−0.53	0.20	−0.29	−0.55	−0.31	0.15
WTSL	0.44	0.12	0.22	−0.02	0.49	0.15	0.61	**−0.69***	0.55	−0.11	0.09	−0.28
WTS	0.18	0.19	0.46	−0.35	**0.74***	−0.14	0.42	−0.63	0.49	−0.12	−0.03	−0.25
LSRTA	**−0.64***	0.15	−0.04	−0.12	0.19	−0.15	0.02	−0.30	−0.04	0.07	−0.02	−0.17
LSRTR	0.22	0.19	−0.14	−0.21	−0.09	0.39	−0.43	0.08	−0.35	0.42	−0.01	0.33
LSRTP	−0.08	0.33	0.27	0.01	−0.20	0.27	−0.23	0.12	−0.48	0.14	−0.26	0.43
LSRTL	0.50	−0.17	−0.05	−0.36	−0.37	0.13	−0.12	0.11	−0.11	−0.24	−0.20	0.39
LSMVA	0.48	−0.09	0.24	−0.32	0.22	−0.35	0.18	**0.64***	−0.27	−0.56	−0.27	0.43
LSMVR	−0.49	−0.24	−0.34	0.49	−0.23	−0.15	−0.29	0.46	0.30	−0.15	0.29	−0.31
LSMVP	0.19	0.26	−0.44	−0.44	0.39	−0.20	0.18	**0.67***	0.51	0.03	0.36	−0.18
LSMVL	−0.37	0.13	−0.07	0.24	−0.08	0.53	0.14	0.07	0.04	0.01	−0.38	0.15
LSEPEA	−0.15	0.07	0.09	0.09	0.46	0.26	0.17	−0.42	−0.23	0.57	−0.35	0.23
LSEPER	−0.35	0.42	0.15	0.10	0.14	0.26	0.44	−0.54	−0.50	−0.24	−0.10	0.48
LSEPEP	**0.67***	0.46	0.36	−0.43	0.30	−0.25	0.12	−0.12	−0.44	0.03	−0.13	0.39
LSEPEL	0.22	−0.09	−0.38	−0.49	0.12	0.49	0.22	−0.23	−0.51	−0.03	−0.41	0.49
LSMXEA	−0.09	**0.65***	0.01	0.04	**0.69***	−0.20	0.02	−0.30	−0.37	−0.08	−0.28	0.33
LSMXER	−0.40	0.34	0.08	0.12	0.31	0.15	0.54	−0.30	−0.55	−0.08	−0.04	0.27
LSMXEP	0.23	−0.11	0.37	−0.24	0.51	0.06	0.35	**−0.67***	−0.14	0.25	0.12	0.13
LSMXEL	−0.21	−0.12	0.48	−0.22	0.02	0.48	0.21	−0.16	−0.17	0.05	−0.41	0.31

Note: *$p < 0.05$.

Abbreviations: CG, control group; CDT, Clock Drawing Test; LSEPE A,R,P,L, Limits of Stability – Endpoint excursion outing in the A (anterior), R (right side), P (posterior), and L (left side) positions; LSMXE A,R,P,L, Limits of Stability – maximum movement excursion in the A (anterior), R (right side), P (posterior), and L (left side) positions; LSMV A,R,P,L, Limits of Stability – movement speed in the A (anterior), R (right side), P (posterior), and L (left side) positions; LSRT A,R,P,L, Limits of Stability – reaction time in the A (anterior) R (right side), P (posterior), and L (left side) positions; MDG, moderate dizziness group; MoCA, Montreal Cognitive Assesment; SDG, severe dizziness group;TMB, Trail Making Part B; VFT, Verbal Fluency Test; WTS, Walking Test – speed gait; WTSL, Walking Test – step length; WTSW, Walking Test – step width.

For the correlations involving walking, the SDG was the only group with significant ($p < 0.05$) and strong ($r > 0.59$) correlations. There was a positive correlation between the MoCA score and gait speed (WTS), revealing that the lower the MoCA score, the slower the gait; and a negative correlation between the performance on the TMB and step length (WTSL), showing that the longer the time to perform the trail task, the smaller the step length.

No significant correlation between cognitive performance and the LoS and walking variables were observed in the CG.

Discussion

The present study included only elderly patients with chronic peripheral vestibulopathy who did not respond to at least 3 months of VR treatment, and whose dizziness persisted. In addition, the studied sample consisted only of women, because they seek medical help more often than men, and are more affected by the symptom, at a rate of 2:1. Moreover, it is known that the prevalence of dizziness is preponderant in women because of a predisposition to vestibular disorders, probably related to an inherent hormonal variation and/or metabolic disorders, especially after menopause.[23]

Peripheral vestibulopathy can cause chronic dysfunction in which the interaction of the individuals with their environment can lead to conflicting sensory information, mainly when there is more demand for postural control.[24] Studies[25–27] have used computerized posturography, exemplified by the Balance Master equipment, to objectively measure postural tasks in patients with vestibular dysfunction. Ricci et al[26] reported that the objective evaluation of balance based on computerized posturography and the variables related to the LoS were the most common in studies with elderly patients, showing that the poorer the patients perform in the tests, the worse their balance.

According to previous studies,[26,27] individuals with chronic peripheral vestibulopathy present a lower LoS, longer movement excursion latency time, higher movement excursion speed of oscillation, and smaller reach in the maximum movement excursion toward a predetermined target. The present study corroborates the information available in the medical literature. The SDG showed a higher speed of oscillation of the CoP in the anteroposterior

direction (LSMVA and LSMVP) when compared with the CG, and a higher speed of oscillation of the CoP in the posterior direction (LSM) in comparison with the MDG. These alterations in the LoS can be attributed to impaired detection of linear deceleration due to input deficit, and can cause functional incapacity and increase the risk of falls.[20]

Moreover, the correlation analyses showed that in the SDG, the lower the MoCA score, the worse the performance in the limit of stability in the maximum movement excursion in the anterior direction (LSMXEA). And the poorer the executive function evaluated by the TMB, the worse the movement speed in the anteroposterior movement (LSMVA and LSMVP) and the maximum movement excursion in the posterior direction (LSMXEP). The more severe the dizziness, the larger the correlation between the cognitive variables, described by the MoCA score, and the executive function assessed by the TMB, with the variables referring to balance and gait.

Della-Justina et al[28] showed that the vestibular inputs directed to the frontal regions of the cortex could change the information originating in this area, which is associated with executive function. Vestibular inputs are also necessary to generate effective actions targeted to goals related to activities of daily living, such that individuals can perform daily activities independently. The current study showed that a worse performance of the executive function, by the group of patients with severe symptoms had a greater tendency to further body displacements, lower gait speed and smaller step length, which may be associated with impairment in the capacity to plan a motor strategy to ensure balance.

In a review, Bigelow et al[29] analyzed studies that tried to find connections between cognitive deficits and vestibular disorders. Although the neurophysiological mechanisms behind this phenomenon have not yet been properly described, evidence suggests that vestibular dysfunction may be especially related to a deficit in visuoconstructive skills, memory and executive function, causing a worse performance in these specific areas.

The findings described in the present study point to the existence of a relationship between cognitive performance, mainly the executive function, and balance in women with chronic peripheral vestibulopathy who underwent vestibular rehabilitation and continued to present severe dizziness. The medical literature has suggested that vestibular disorders can influence areas in the prefrontal cortex and hippocampus, and that the latter can even atrophy. It is important to stress that these structures play a role in the maintenance of spatial memory, which is crucial to the ability to move when any of the sensory inputs used in postural control are taken away.[30]

The results of the present study suggest that the severity of the dizziness in patients with chronic peripheral vestibulopathy leads to greater cognitive impairment, worse balance, and major gait alterations, which increase the risk of falls.[24] These findings corroborate the conclusions of Kim et al,[30] who assessed the gait of middle-aged and elderly patients with peripheral vestibulopathy and healthy individuals. They observed that the people suffering from the disorder showed lower gait speed and smaller step length when compared with the individuals with no vestibulopathy.

Some studies[30,31] have suggested that alterations in speed and step length, during the gait of vestibulapathy patients, may be related to the fact that otolith organs play an important role as an input source. The otolith organs feed a net of structures, as part of the vestibular system, which is directly responsible for tuning the antigravity muscles to mantain posture and proper regulation of the center of mass during body displacement.

These studies indicate that hippocampus impairment and the influence of vestibular inputs on superior cortical areas may be related to the effects of vestibular disorders on cognition, especially the executive function. Consequently, impairment of the executive function may worsen balance and functional performance. However, it is not possible to extend these results to the population with vestibulopathy who has experienced positive outcomes after VR, because these patients may have physical, functional and cognitive performances that differ from those of the studied sample.

A limitation of this study is that no cognitive tasks were combined with the posture and gait tests. Examples of these hybrid tests are the dual task and the use of cognitive assessment tools to measure spatial cognitive skills, such as the Corsi block-tapping test, the Hooper Visual Organization Test, and the Judgement of Line Orientation Test – Form V. In addition, there was no group of patients relating improvement in dizziness and light-headedness symptoms after treatment with classic VR.

Conclusion

The results of the present study revealed that elderly women with chronic peripheral vestibulopathy presenting severe dizziness show higher speed of oscillation of the CoP relative to the limit of stability, smaller step length, and slower gait in comparison with elderly women with moderate dizziness and those with no vestibulopathy. These outcomes suggest that lower performance in cognitive areas such as executive function, attention, language, abstraction, visuoconstructive skills and orientation may negatively impact gait and balance, mainly in the anteroposterior direction, depending on the level of severity of the dizziness caused by chronic peripheral vestibulopathy.

Confilcts of Interest
The authors have none to disclose.

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