Posturography with virtual reality stimuli in different vestibular dysfunctions

Posturografia com estímulos de realidade virtual nas diferentes disfunções vestibulares

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ABSTRACT

Purpose: To assess body balance and to quantify possible alterations over the static posturography of the Balance Rehabilitation Unit (BRU™) in patients with vestibular dysfunction. **Methods:** Retrospective study, with files of 100 patients with topographic diagnosis of peripheral or central vestibular dysfunction and 100 healthy individuals that composed the Control Group, of both genders, with ages varying between 7 and 86 years. For the posturography, the Balance Rehabilitation Unit (BRU™), of Medicaa® was used. The following parameters were analyzed: stability limits, elliptical area, and speed of oscillation in ten sensory conditions. **Results:** Mean values of the stability limit, the elliptical area and the speed of oscillation in the Experimental Group was significant when compared to the Control Group in all conditions. The mean parameters of the female Experimental Group were significant when compared to the Control Group in all conditions. Patients with central vestibular dysfunction obtained higher values than patients with peripheral vestibular dysfunction in the variables elliptical area and speed of oscillation, however with lower value of the area of the stability limit. **Conclusion:** Posturography with virtual reality stimuli was an effective assessment method for detecting alterations related to the variables stability limits, elliptical area, and speed of oscillation, since the Control Group performed better, both between groups and between genders. Among the vestibular dysfunctions, individuals with peripheral condition performed better than those with central vestibular dysfunction in all the variables analyzed on posturography.

Keywords: Vestibular diseases; Postural balance; Dizziness; Vestibular function exam; Vestibule, labyrinth/pathology

INTRODUCTION

Body balance is the individual's ability to stay upright or to execute movements of acceleration and rotation without wobble or fall; it is based on the interaction between vestibular system, visual stimuli, and proprioceptive sensitivity. The imbalance of one or more of these systems leads the individual to present a set of symptoms, in which dizziness is usually preponderant[1,2].

Vestibulopathy is the generic designation for body balance disorders, based on the central and/or peripheral vestibular system. It is very usual, with or without involvement of the auditory system. Among the symptoms of the vestibular system, dizziness, vertigo (particular type of dizziness, of a spinning character), imbalance, nausea, falls, and tinnitus may be mentioned[3].

To study body balance, many otoneurological assessment methods were developed, and the most commonly used procedure is the electronystagmography (ENG) or vectoelectronystagmography (VENG). The vestibular examination is useful to confirm or deny the diagnostic hypothesis of vestibular impairment based on the clinical history, to localize the injury at peripheral, central or mixed level, to establish prognoses, to guide therapeutic procedures, and to allow monitoring of the evolution[4,5].

The ENG or VENG tests evaluate the vestibulo-ocular reflex, which has its main origin in the semicircular canals. Although the vestibulo-ocular reflex is essential for angular displacements of the body, the vestibulospinal reflex plays a key role in posture maintenance, because the evaluation of the vestibulo-ocular reflex alone is insufficient for the analysis of vestibular function as a whole. The visual and somatosensory information, as well as the proper sensory integration originated in the brainstem, actively participate on the maintenance of the body balance, thus evidencing the importance of a diagnostic method that evaluates individually those pieces of information.

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Posturography is an assessment method that seeks to find proprioceptive deficits in the balance of subjects in the standing posture, and evaluates their equilibrium by exposing the individual to different situations(7). It is divided into static, when the erect posture of the person is studied, and dynamic, when the response to a perturbation applied on the person is studied(8).

The computerized dynamic posturography researches dynamic posture and balance. It is a quantitative test of postural stability, which can provide a great amount of information that needs to be carefully studied(9). Dynamic posturography does not directly assess peripheral or central vestibular function, it is a technique for estimating the functional ability of the patient(10).

Posturography assesses the vestibulospinal pathway, which is not analyzed by conventional tests. However, individuals who present this test within normal limits might present electronystagmography alterations, therefore posturography complements the findings of conventional vestibular tests, and is indicated in situations in which is important to investigate the vestibulospinal reflex and the sensorial analysis of the balance disorder(6).

The computerized posturography carried out with the Balance Rehabilitation Unit (BRU™) evaluates the interaction between visual, somatosensory and vestibular systems. It is a computerized static posturography equipment which conducts an analysis of the body sway in different sensory conditions, held in a virtual environment(11).

The term "realidade virtual" was created to define the virtual worlds developed using high technology to convince the user that he is actually in another reality. It is a man-machine interface that simulates a real environment, an immersive and interactive experience based on three-dimensional graphic images, generated by a computer(12).

The virtual reality platform enables immersion in an illusory world, in which the perception of the environment is modified by an artificial sensory stimulus that may cause a vestibulo-ocular conflict and the change of gain of this same reflection(13).

Posturography with virtual reality provides information about the manifestations related to imbalance, based on sensory stimulations designed in virtual reality goggles which recreate versions of real life situations(14).

Some studies have evaluated patients using the Balance Rehabilitation Unit (BRU™) and demonstrated its effectiveness in detecting alterations in different otoneurological clinical reports(15-19).

The aim of this study was to assess body balance, and quantify possible alterations at static posturography conducted using the Balance Rehabilitation Unit (BRU™) in patients with vestibular dysfunction.

METHODS

This research was approved by the Research Ethics Committee of the Universidade Federal de São Paulo – UNIFESP (0457/09).

This retrospective study aimed to compare the computerized posturography parameters of individuals with diagnostic hypothesis of peripheral or central vestibular dysfunction (Experimental Group), to those of healthy individuals (Control Group).

We selected record files of 100 individuals from the Control Group and 100 individuals from the Experimental Group, with diagnosis of peripheral vestibular dysfunction or central vestibular dysfunction, who had been treated at the Balance and the Vestibular Rehabilitation Clinics of the Otoneurology Discipline of the Department of Otorhinolaryngology of the UNIFESP over the years of 2007 and 2009. The Control Group consisted of 31 male participants (31%) and 69 female participants (69%). The Experimental Group consisted of 22 male participants (22%) and 78 female participants (78%). Regarding age, the Control Group had mean age of 40.77 ± 3.70 years, and the Experimental Group had mean age of 40.77 ± 4.25 years.

Concerning the topographic diagnosis, it was verified that 91 individuals had peripheral vestibular dysfunction (91%) and nine had central vestibular dysfunction (9%).

For inclusion in the Control and Experimental groups, the record files were supposed to contain the neurotology evaluation, including anamnesis, pure tone and speech audiometry, acoustic immitance measures, final results of the computerized VENG and the posturography with virtual reality stimuli using the Balance Rehabilitation Unit (BRU™) equipment from Medicaa®.

The inclusion criterion for the Experimental Group was the diagnostic hypothesis of peripheral vestibular dysfunction or central vestibular dysfunction, confirmed by the vestibular examination. The inclusion criteria for the Control Group were absence of otoneurological complaints and of any uncompensated disease.

The record files that did not achieve the criteria mentioned were automatically excluded from the study.

The following tests were used on the computerized VENG: eye movement calibration, spontaneous nystagmus with opened and closed eyes, semi-spontaneous nystagmus, saccadic movements, pendular tracking, optokinetic nystagmus, decreasing pendular rotation test, and caloric air test.

The posturography module of the Balance Rehabilitation Unit (BRU™) provides information regarding the position of the patient's pressure center through quantitative indicators: stability limit area, elliptical area, and speed of oscillation in ten sensory conditions.

The posturography of the Balance Rehabilitation Unit (BRU™) was performed with the patient in upright static posture and arms spread along the body. The patient was standing on the platform, barefoot, with the right and left internal malleolus positioned at the intermalleolar sides. The Balance Rehabilitation Unit (BRU™) uses the midpoint of the intermalleolar line as the center of the standard limit of the stability circle. A mold helped marking the 10º-separation of the midline of the anterior part of each foot on the platform, forming an angle of 20° between the first two toes.

To determine the stability limit, the patient was told to carry out anteroposterior and lateral body dislocations using the ankle strategy, without moving the feet or using trunk strategies. The patient moved slowly until he could reach his body stability limit in the following sequence: a) forward; b) return to starting position; c) to the right; d) return to starting position; e) to the left; f) return to starting position; g) backwards; h) return to starting position. The patient was asked to perform this sequence of movements twice, without necessarily completing the 60 seconds reserved for this procedure. The procedure was restarted in cases where the patient moved his feet or trunk.

The ten sensory conditions assessed were: 1) orthostatic position on steady surface, eyes open; 2) orthostatic position on steady surface, eyes closed; 3) orthostatic position on foam surface, eyes closed; 4) orthostatic position on steady surface, saccadic stimulation; 5) orthostatic position on steady surface, optokinetic stimulation with horizontal direction from left to right; 6) orthostatic position on steady surface, optokinetic stimulation with horizontal direction from right to left; 7) orthostatic position on steady surface, optokinetic stimulation in vertical direction from top to bottom; 8) orthostatic position on steady surface, optokinetic stimulation with vertical direction from bottom to top; 9) orthostatic position on steady surface, optokinetic stimulation with horizontal direction associated to slow and uniform movements of head rotation; 10) orthostatic position on steady surface, optokinetic stimulation with vertical direction associated to slow and uniform flexion-extension movements of the head. A mat of medium density foam was used in the assessment of the third sense condition. Virtual reality goggles were used in the evaluations of the fourth to the tenth condition.

The program generates reports with data related to the area of the stability limit, the 95% confidence elliptical area, and the speed of oscillation on the ten sensory conditions. The 95% confidence elliptical area is defined as the distribution area of 95% of the pressure center samples; the mean speed of oscillation is determined by the total distance divided by the 60-second period of the task.

All results were submitted to descriptive statistical analysis for sample characterization. The Mann-Whitney test was used for comparative analysis of the Experimental and Control groups, and the peripheral and central vestibular dysfunctions, in all variables (area of the stability limit, elliptical area, and speed of oscillation). The nonparametric Mann-Whitney test was used due to the asymmetry and variability of the scores of these variables. Analyses used the computer program SPSS 16.0 for Windows (Statistical Package for Social Sciences, version 16.0, 2007), and the level of significance adopted for statistical tests was of 5% (a=0.05).

RESULTS

There was difference (p=0.001) between the values of stability limit area (cm^2) of the Control Group (mean=183.70, standard deviation (SD)=59.90, median=180.00, range=172.00-195.40) and the Experimental Group (mean=150.80, SD=67.50, median=149.00, range=137.60-164.00) on the posturography of the Balance Rehabilitation Unit (BRU™), with higher mean value for the Control Group.

The mean values of ellipse area in the Experimental Group were higher than those of the Control Group in all assessed conditions (p<0.05) (Table 1).

The mean values of oscillation speed in the Experimental Group were higher than those of the Control Group in all assessed conditions (p<0.05) (Table 2).

With regards to the values of stability limit area (cm^2) of the female genre, the Control Group (mean=176.40, SD=55.20,

Table 1. Descriptive values and comparative analysis of the ellipse area (cm^2) of Experimental and Control groups

Ellipse area (cm²)		Mean	Median	SD	CI	p-value
SS/eyes open/no stimulus	Experimental	3.83	2.66	4.26	0.83	<0.001*
	Control	2.14	1.79	1.52	0.30	
SS/eyes closed	Experimental	6.69	2.86	13.76	2.70	<0.001*
	Control	2.25	1.76	1.89	0.37	
Foam surface/eyes closed	Experimental	23.88	12.87	29.94	5.87	<0.001*
	Control	10.67	7.60	7.67	1.50	
SS/sacadic	Experimental	3.43	2.18	3.55	0.70	<0.001*
	Control	1.86	1.48	1.62	0.32	
SS/bars/optokinetic to right	Experimental	3.92	2.22	4.28	0.84	0.001*
	Control	2.11	1.66	1.91	0.37	
SS/bars/optokinetic to left	Experimental	4.42	2.38	5.04	0.99	<0.001*
	Control	1.94	1.36	1.85	0.36	
SS/bars/optokinetic to top	Experimental	4.19	2.33	4.67	0.91	<0.001*
	Control	2.10	1.63	1.78	0.35	
SS/bars/optokinetic to bottom	Experimental	4.63	2.70	5.22	1.02	<0.001*
	Control	2.24	1.55	2.02	0.40	
SS/visual-vestibular interaction/horizontal stimulation	Experimental	6.37	3.88	7.11	1.39	<0.001*
	Control	3.20	2.24	2.58	0.51	
SS/visual-vestibular interaction/vertical stimulation	Experimental	5.25	3.51	5.30	1.04	0.001*
	Control	3.43	2.33	3.22	0.63	

* Significant values (p≤0.05) – Mann-Whitney test

Note: SS = steady surface; CI = confidence interval; SD =standard-deviation

Table 2. Descriptive values and comparative analysis of the oscillation speed (cm/s) of the Experimental and Control groups

Oscillation speed (cm/s)		Mean	Median	SD	CI	p-value
SS/eyes open/no stimulus	Experimental	0.99	0.90	0.47	0.09	<0.001*
	Control	0.79	0.73	0.28	0.06	
SS/eyes closed	Experimental	1.48	1.19	1.04	0.20	<0.001*
	Control	1.00	0.93	0.36	0.07	
Foam surface/eyes closed	Experimental	3.73	3.15	2.25	0.44	0.001*
	Control	2.80	2.50	1.06	0.21	
SS/sacadic	Experimental	1.37	1.23	0.69	0.14	<0.001*
	Control	1.06	0.94	0.47	0.09	
SS/bars/optokinetic to right	Experimental	1.31	1.18	0.67	0.13	<0.001*
	Control	0.99	0.87	0.43	0.08	
SS/bars/optokinetic to left	Experimental	1.29	1.20	0.66	0.13	<0.001*
	Control	0.99	0.91	0.45	0.09	
SS/bars/optokinetic to top	Experimental	1.30	1.18	0.64	0.13	<0.001*
	Control	1.02	0.89	0.44	0.09	
SS/bars/optokinetic to bottom	Experimental	1.31	1.18	0.67	0.13	<0.001*
	Control	1.03	0.90	0.48	0.09	
SS/ visual-vestibular interaction/ horizontal stimulation	Experimental	1.67	1.42	0.88	0.17	<0.001*
	Control	1.33	1.16	0.63	0.12	
SS/ visual-vestibular interaction/ vertical stimulation	Experimental	1.74	1.49	0.87	0.17	0.008*
	Control	1.51	1.30	0.72	0.14	

* Significant values ($p \leq 0.05$) – Mann-Whitney test

Note: SS = steady surface; CI = confidence interval; SD =standard-deviation

median=176.00, range=163.40-189.40) had higher mean value when compared to the Experimental Group (mean=144.70, SD=65.50, median=146.50, range=130.20-159.20), which was statistically significant (p=0.002).

The mean values of ellipse area and oscillation speed in the Experimental Group were higher than those of the Control Group in all evaluated conditions (p<0.05).

Regarding the values of stability limit area (cm^2) of the male genre, the Control Group (mean=199.80, SD=67.30, median=187.00, range=176.10-223.50) had higher mean value when compared to the Experimental Group (mean=172.60, SD=71.60, median=158.50, range=142.70-202.50), but this difference was not significant (p=0.162).

The mean values of ellipse area and oscillation speed in the Experimental Group were higher than those of the Control Group in all assessed conditions. With regards to the ellipse area, differences were found between the conditions of steady surface and saccadic movement, steady surface and optokinetic stimulation to the left, and steady surface and horizontal visual--vestibular interaction. For the oscillation speed, differences between the conditions steady surface and saccadic movement, steady surface and optokinetic stimulation to the right, steady surface and optokinetic stimulation to the left, and steady surface and downward optokinetic stimulation.

The mean value of stability limit area (cm^2) in peripheral vestibular dysfunction (mean=152.10, SD=68.20, median=151.00, range=138.10-166.10) was higher than that in central vestibular dysfunction (mean=137.80, SD=62.30, median=139.00, range=97.10-178.50), but this difference was not significant (p=0.651).

The mean values of ellipse area in central vestibular dysfunction were higher than those in peripheral vestibular dysfunction in all conditions tested (Table 3). In the speed of oscillation, central vestibular dysfunction values were higher than those of peripheral vestibular dysfunction; differences were observed between the conditions steady surface and saccadic movement, steady surface and optokinetic stimulation to the left, steady surface and downward optokinetic stimulation, and steady surface and horizontal visual-vestibular interaction.

DISCUSSION

In this research we used the results of the computerized VENG with peripheral vestibular dysfunction and central vestibular dysfunction, in order to compare the balance performance between these two groups of patients through posturography with Balance Rehabilitation Unit (BRU™).

Regarding the findings of these groups, variables gender, area of the stability limit, elliptical area, and speed of oscillation were selected.

In this study there was a prevalence of female (78%) over male (22%) gender in patients with topographic diagnosis of peripheral vestibular dysfunction and central vestibular dysfunction. This finding agrees with several studies of patients with vestibular complaints[16,20,21].

The prevalence of vestibular disorders in women may be related to a higher organic predisposition to vestibular dysfunction due to intrinsic hormonal variation and metabolic disorders[22].

The mean age found in individuals with topographic diagnosis of vestibular dysfunction was 54.46 years. In several studies with vestibular dysfunction the mean age ranged between 40 and 59 years[16,20,23].

There was a prevalence of individuals with topodiagnosis of peripheral vestibular dysfunction in relation to the topo-

Table 3. Comparison between vestibular dysfunction for the variable ellipse area (cm²)

Ellipse area (cm²)		Mean	Median	SD	CI	p-value
SS/eyes open/no stimulus	Peripheral	3.39	2.49	3.31	0.68	0.005*
	Central	8.23	6.28	8.79	5.74	
SS/eyes closed	Peripheral	6.25	2.73	13.41	2.76	0.025*
	Central	11.08	5.89	17.24	11.27	
Foam surface/eyes closed	Peripheral	23.48	12.40	30.19	6.20	0.317
	Central	27.98	18.84	28.72	18.76	
SS/sacadic	Peripheral	3.03	2.11	3.27	0.67	0.001*
	Central	7.39	7.69	4.05	2.64	
SS/bars/optokinetic to right	Peripheral	3.60	2.14	4.14	0.85	0.017*
	Central	7.11	8.03	4.59	3.00	
SS/bars/optokinetic to left	Peripheral	3.79	2.14	4.02	0.83	0.002*
	Central	10.84	10.10	9.02	5.90	
SS/bars/optokinetic to top	Peripheral	3.61	2.01	3.94	0.81	<0.001*
	Central	10.07	6.78	7.22	4.72	
SS/bars/optokinetic to bottom	Peripheral	4.12	2.49	4.72	0.97	0.006*
	Central	9.73	6.31	7.38	4.82	
SS/ visual-vestibular interaction/ horizontal stimulation	Peripheral	5.70	3.64	6.19	1.27	0.003*
	Central	13.10	7.75	11.76	7.69	
SS/ visual-vestibular interaction/vertical stimulation	Peripheral	4.81	3.43	4.74	0.97	0.024*
	Central	9.77	6.92	8.37	5.47	

* Significant values ($p \leq 0.05$) – Mann-Whitney test

Note: SS = steady surface; CI = confidence interval; SD =standard-deviation

diagnosis of central vestibular dysfunction. The same was observed in similar studies[24-27].

VENG and posturography are part of the otoneurologic testing, and assess different types of reflexes: the vestibulo-ocular reflex and vestibulospinal reflex, respectively. Posturography differentiates itself from conventional vestibular tests because it quantifies the patient's standing functional stability through somatic, visual and vestibular stimuli[28].

Static posturography assesses the vestibulospinal reflex, analyses the oscillation of the body in stand-up position within the limits of the center of gravity, and contributes to the study of the balance of patients with positioning dizziness[29].

In this study we observed that the groups of patients with vestibular dysfunction had lower performance on the posturography, when compared to a Control Group regarding the stability limit area, the elliptical area, and the speed of oscillation.

Regarding the determination of the stability limit area (cm²), significant differences were found between Control and Experimental groups. No differences were found between the vestibular dysfunctions, neither in the comparison between Control and Experimental groups between male and female genders. The group with central vestibular dysfunction showed lower values, followed by the peripheral vestibular dysfunction group. The Control Group obtained higher values, which meant better performance on the balance assessment.

In their studies, some authors have observed better performance of the Control Group when compared to the Experimental Group[11,16,17,19].

Concerning the findings of elliptical area, the Control Group achieved the lowest mean values in all conditions, and, between vestibular dysfunctions, the lowest values were presented by the peripheral vestibular dysfunction group in all sensory conditions.

Taking into account that the smaller the ellipse area, the better the performance of the individual, the Control Group obtained better results when compared to the other groups, followed by the peripheral vestibular dysfunction group, which had a better performance over the central vestibular dysfunction group.

On previous studies, the mean values of ellipse area were higher in the Experimental Group when compared to the Control Group in all conditions assessed[16-19].

Regarding the results of the speed of oscillation, the Control Group obtained lower values in all sensory conditions; between vestibular dysfunctions, the central vestibular dysfunction group obtained the highest values, presenting a lower performance when compared to the Control and peripheral vestibular dysfunction groups.

These findings corroborate other studies, in which the mean values of speed of oscillation were higher on the Experimental Group when compared to the Control Group in all conditions evaluated[16-19].

In studies conducted with the static posturography Balance Rehabilitation Unit (BRU™), several authors have concluded that the body balance evaluation allows the identification of oscillation speed and elliptical area abnormalities in patients with vestibular dysfunction[15-18].

The Balance Rehabilitation Unit (BRU™) is a new procedure designed to assess and rehabilitate patients with balance disorders of vestibular origin[14]. The values found in the assessment may be useful both in diagnosis for the characterization of body balance disorders, and in monitoring the progress of the disease under treatment[30].

CONCLUSION

Posturography with virtual reality stimuli was an effective assessment method to detect alterations related to the variables stability limit area, ellipse area, and speed of oscillation, since the Control Group achieved better performance, both between groups and genders. Between the vestibular dysfunctions, individuals with peripheral condition obtained better performance than individuals with central vestibular dysfunction in all variables analyzed.

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RESUMO

Objetivo: Avaliar o equilíbrio corporal e quantificar possíveis alterações na posturografia estática do Balance Rehabilitation Unit (BRU™) em pacientes com disfunção vestibular. **Métodos:** Estudo retrospectivo, com prontuários de 100 pacientes com topodiagnóstico de disfunção vestibular periférica ou central e 100 indivíduos hígidos compondo o grupo controle, de ambos os gêneros, entre 7 a 86 anos. Para a posturografia foi utilizado o equipamento Balance Rehabilitation Unit (BRU™), da Medicaa[a]. Foram analisados os parâmetros limite de estabilidade, **área** de elipse e velocidade de oscilação em dez condições sensoriais. **Resultados:** A média dos valores do limite de estabilidade, da área de elipse e da velocidade de oscilação do grupo experimental foi significativa em relação ao grupo controle em todas as condições. A média dos parâmetros do gênero feminino do grupo experimental foi significativa em relação ao do grupo controle em todas as condições avaliadas. Os pacientes com disfunção vestibular central obtiveram maiores valores que os pacientes com disfunção vestibular periférica nas variáveis área de elipse e velocidade de oscilação, porém menor valor da área do limite de estabilidade. **Conclusão:** A posturografia com estímulos de realidade virtual foi um método de avaliação eficaz para detectar alterações relacionadas **às** variáveis limite de estabilidade, **área** de elipse e velocidade de oscilação, uma vez que o grupo controle obteve melhor desempenho, tanto entre os grupos quanto entre os gêneros. Entre as disfunções vestibulares, os indivíduos com acometimento periférico obtiveram melhor desempenho do que os indivíduos com disfunção vestibular central em todas as variáveis analisadas na posturografia.

Descritores: Doenças vestibulares; Equilíbrio postural; Tontura; Testes de função vestibular; Vestíbulo do labirinto/patologia

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