Original Article

Artigo Original

Posturography with virtual reality stimuli in normal young adults with no balance complaints

Posturografia com estímulos de realidade virtual em adultos jovens sem alterações do equilíbrio corporal

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Keywords

Vestibular diseases
Posture
Dizziness
Postural balance
Evaluation

ABSTRACT

Purpose: To analyze the findings of posturography with virtual reality stimuli carried out in young healthy adults with no otoneurological complaints, based on the parameters center of pressure, limit of stability and sway speed for different visual stimuli, and regarding differences between female and male genders. **Methods:** Participants were 50 healthy individuals of both genders (50% female and 50% male) with ages ranging from 18 to 25 years (mean age 21.30 years), with no complaints regarding body balance, and with vestibular outcomes assessed through digital vectonistagmography within normal limits. Posturography was composed of 11 visual stimuli and determined the limit of stability area (LOS), the ellipse area, and the sway speed in ten sensorial conditions. Results were calculated for the studied age range and analyzed according to the values for each stimulus, with the aim to obtain normality parameters. **Results:** The average values obtained in posturography regarding limit of stability, ellipse area and sway speed for stimuli with viso-vestibular interaction presented significant differences between genders, and, in all cases, women obtained lower values than men. **Conclusion:** The findings of posturography with virtual reality stimuli in healthy young adults evidence that the parameters center of pressure, limit of stability and sway speed present differences between genders and, therefore, must be considered separately.

Descritores

Doenças vestibulares
Postura
Tontura
Equilíbrio postural
Avaliação

RESUMO

Objetivo: Analisar os achados à posturografia com estímulos de realidade virtual realizada em adultos jovens, hígidos e sem queixas otoneurológicas, de acordo com parâmetros de centro de pressão, limite de estabilidade e velocidade da oscilação para diferentes estímulos visuais e em relação aos gêneros masculino e feminino. **Métodos:** Participaram 50 indivíduos hígidos de ambos os gêneros (50% gênero feminino e 50% masculino), com idades entre 18 e 25 anos (média de idade 21,30 anos), sem queixas relacionadas ao equilíbrio corporal e avaliação vestibular com vectonistagmografia digital dentro dos padrões de normalidade. A posturografia foi composta por 11 estímulos visuais e determinou a área do limite de estabilidade (LOS), área de elipse, e velocidade de oscilação em dez condições sensoriais. Os resultados foram calculados para a faixa etária estudada e analisados quanto aos valores para cada estímulo, visando à obtenção de limites de normalidade dos parâmetros. **Resultados:** Os valores médios obtidos na posturografia, quanto ao limite de estabilidade, à área da elipse e à velocidade de oscilação para os estímulos com interação visuo-vestibular apresentaram diferenças entre os gêneros, sendo que em todos os casos as mulheres obtiveram valores inferiores aos dos homens. **Conclusão:** Os achados à posturografia com estímulos de realidade virtual em adultos jovens hígidos evidenciam que os parâmetros centro de pressão, limite de estabilidade e velocidade da oscilação apresentam diferenças entre os gêneros, e portanto, devem ser considerados separadamente.

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INTRODUCTION

Body balance is a complex interaction between the sensorial and motor systems allowing the body either to stand still stably or to move harmoniously and precisely. When there is an alteration in any of its components (proprioceptive – perception of both posture and body movement; vestibular – head position and movement, and visual – spacial relations), alterations appear characterizing the imbalance and possibly affecting the individual's quality of life[1].

Posturography allows us to evaluate and train patients with balance disorders, dizziness or instability. It completes the conventional tests of the otoneurologic evaluation, providing information not only from the vestibular system but also from the other systems that help to maintain balance[2].

Posturography is defined as any study or technique that assess the body sway or a variable associated with this sway[3]. The posturographic measure generally used in the postural control evaluation is the center of pressure (CoP), which is the applying point of the resultant vertical force acting on the support surface and represents the collective outcome of the postural control system and the gravity. The CoP is measured by a force platform that consists of a plate on which force sensors are placed in a way that they measure the force components and the force moment in the anteroposterior, mediolateral and vertical directions, acting on the platform[4].

Many authors have used the computerized dynamic posturography in the assessment of different diseases or vestibular symptoms related to body balance and have also reinforced its importance in the otoneurologic evaluation[2,5-9]. However researches about it are still scarce in Speech-Language Pathology and Audiology[10].

The posturography with virtual reality stimuli contributes to identify the signs related to imbalance by means of sensorial stimuli projected in goggles of virtual reality that simulate real life situation. It can also contribute to vestibular rehabilitation, inducing situations that cause dizziness or vertigo which would lead to adaptation of vestibular system[11].

Virtual reality allows us to recreate to the maximum the feeling of the individual's interaction with the computer. It makes the immersion in an illusory world possible, where the perception of the environment is changed by some artificial sensorial stimuli which can cause a vestibulocochlear conflict and the change of this reflex gain[12].

The use of the posturography platform with virtual reality stimuli is a new assessment method, the number of publications about it is scarce and there is no benchmark. Therefore it is necessary to determine such benchmarks in different age groups that will be the base to future researches and evaluations with different groups of patients.

Thus, this study aims to evaluate the findings of posturography with virtual reality stimuli performed in young, healthy adults, with no otoneurologic complaints, according to the center of pressure, limit of stability and sway speed to the different visual stimuli.

METHODS

This research was carried out between the years of 2008 and 2009 in the Equilibriometry and Vestibular Rehabilitation Clinics of the Otoneurology Discipline, Otorhinolaryngology Department of the Universidade Federal de São Paulo (UNIFESP), Brazil. It is a clinical prospective study approved by the Research Ethics Committee of UNIFESP (protocol number 1398/07).

Participants were 50 individuals with ages between 18 and 25 years, 25 male and 25 female, without any complaints related to body balance and to the ability of standing on biped position with no help. Mean age of the female group was 22 years (SD=1.96), and 20.6 years in the male group (SD=1.98). There was no significant difference between the groups regarding age. All patients should present normal results in the Otoneurologic Evaluation (anamnesis, tonal and vocal audiometry, imitanciometry and vestibular testing with the computerized vectonistagmography).

Individuals that used any type of ortheses or showed any recent signs or symptoms or previous disease related to vestibular system disorders were not included.

All participants underwent computerized posturography with virtual reality stimuli, based on 11 visual stimuli controlled by the computer. Stimuli were showed on virtual reality goggle lenses coupled to the individual's head.

The posturography was done on a balance platform unit (BRU™) that converts the pressure applied to a plain surface into electric signals to determine the area of the center of pressure (CoP) or center of mass, the patient's limit of stability (LOS) and the sway speed[10].

The pressure platform has an area of 1600 cm^2 (40 cm x 40 cm), including vertical and horizontal coordinates. Furthermore, it has a horizontal line of 8 cm (intermalleolar line) for the individual's foot placement and a vertical line of 12 cm to intercept the middle point of the intermalleolar line.

To perform the posturography, the participant should be on a force platform, barefoot, on bipodal support and with relaxed arms extended along the body. When necessary corrective lenses were used. During the procedure, everyone was advised to maintain upright and stable position, standing still.

Initially, in order to establish the limit of stability, the patient was instructed to shift the body in an antero-posterior and lateral directions using the ankle strategy, without moving the feet or using trunk strategies. The movement should happen slowly until the participant reached his body limit of stability, respecting the following: forward and back to initial position; to the right and back to initial position; to the left and back to initial position; backward and back to initial position. The individuals were instructed to perform the complete sequence of movements twice, with no need to complete it in the maximum time of 60 seconds. In case of either foot or trunk movement, the procedure was restarted.

The sensorial stimuli shown during the exam were visual (opened eyes, closed eyes, specific visual stimuli – mobile objects on the virtual reality goggles which recreated styled versions of real life situations), vestibular (objects on the virtual reality goggles moved according to the head movement of the patient) or somatosensory (use of a foam pillow) to change the support surface.

The posturography assessment had 11 visual stimuli (which happened during 60 s, with two-second delay between them, in which the patient should stay in an orthostatic position. The stimuli were: LOS (area of limit of stability) – open eyes; standing on firm floor – open eyes and after closed eyes; standing on a foam pillow – closed eyes; saccadic (firm floor) – many directions; optokinetic bars (firm floor) – horizontal directions (from left to right and from right to left) and vertical (from top to bottom and from bottom up); vestibulo-visual interaction (firm floor) – circle train – horizontal directions (from left to right) and vertical (from bottom up) (Chart 1).

During the assessment a foam pillow with medium density was used. The virtual reality goggles were employed in the evaluation with the foam pillow use.

Reports were created by the program holding information about the limit of stability area, the 95% trust ellipse area and the sway speed in the ten sensorial conditions. The 95% trust ellipse area is defined with the area of distribution of 95% of the pressure center samples. The medium sway speed is determined by the total distance divided by the time of the test, 60 seconds[11].

Posturography results were collected from the CoP information by means of the balance platform, for each stimulus, aiming to establish normal limits of the posturography parameters (LOS area, ellipse area and sway speed of each stimulus). Each parameter was analyzed singly and in group, in order to observe the development of young healthy adults in this test.

All results underwent descriptive statistical analysis to characterize the sample. The Mann-Whitney test was used to compare the results between gender and the LOS area limit variable, ellipse area and sway speed, under BRU™ conditions. The level of significance used was 5% (p=0.05). All the trust intervals built along the research were defined with 95% statistics trust**.**

RESULTS

Regarding the values related to the limit of stability area (LOS) and to the sway speed, we verified that the variations between genders were low (coefficient of variation near 50%). As to the value of ellipse area, these variations were considered high, characterizing the non-homogeneity of data**.** The obtained values were higher in male with difference related to female (Table 1).

The descriptive values and the comparative analysis of the LOS values, the ellipse area (cm^2) and the sway speed (cm/s) in the group of male and female, were obtained (Table 2). There was difference between the genders to the LOS, the female showed lower results than male. We verified that there was also difference between genders regarding the ellipse area, to the following BRU™ firm surface with visuo-vestiular interaction in the horizontal and vertical directions. In all cases of difference, female got lower values than male. To the sway speed, on firm surface with visuo-vestibular interaction in the horizontal and

Chart 1. Protocol to perform the posturography

1. LOS, open eyes: Delay = 2 Length = 180 s
2. Standing on firm floor, with open eyes: Delay = 2 Length= 60 s
3. Standing on firm floor, with closed eyes: Delay = 2 Length = 60 s
4. Standing on foam pillow, with open eyes: Delay = 2 Length = 60 s
5. Standing on firm floor , saccadic: Delay = 2 Length = 60 s Height = 7 Frequency = 1 Hz Direction = random
6. Standing on firm floor, optokinetic bars — direction: horizontal Delay = 2 Length = 60 s Height = 7 Speed = 60 Direction = from left to right
7. Standing on firm floor, optokinetic bars — direction: horizontal Delay = 2 Length = 60 s Height = 7 Speed = 60 Direction = from right to left
8. Standing on firm floor, optokinetic bars — direction: vertical Delay = 2 Length = 60 s Height = 7 Speed = 60 Direction = from top to bottom
9. Standing on firm floor, optokinetic bars — direction: vertical Delay = 2 Length = 60 s Height = 7 Speed = 60 Direction = from bottom up
10. Standing on firm floor, vestibular optokinetic – circle train – direction: horizontal Delay = 2 Length = 60 s Height = 7 Speed = 60 Direction = from left to right
11. Standing on firm floor, vestibular optokinetic – circle train – direction: vertical Delay = 2 Length = 60 s Height = 7 Speed = 60 Direction = from bottom to up

Source: BRU™, Medicaa®

vertical directions, difference between genders was observed, female values being lower than male values.

DISCUSSION

Posturography can be useful to detect vestibular disorders. Studies show that the information about changes of sway speed values and ellipse area in the posturography can be relevant to the programming and the treatment follow-up of the body balance[16,19-21].

In this study, the static posturography evaluation was used. However, in the literature more numbers of studies using the dynamic posturography are found. Such fact hindered the comparison among the results.

A study[22] using static posturography quantified and analyzed the postural sways of youths, adults and elderly, which task was to stay still on bipodal support during 60 s, initially with open eyes and after with closed eyes. The authors did not observe any differences regarding the sways between groups. However, there was difference among the visual sways, being the obtained values higher in the tasks with closed eyes.

This study tried to show reference values to the use of posturography with virtual reality stimuli in young, healthy adults related to female and male genders, facing the necessity of creating standards in different age, to base future researches with different groups of patients.

The posturography findings of this study are difficult to be quantitative compared with the other types of posturography, since different parameters and procedures of assessment are used. To the studies done[20,21] with BRU™ a control group was used to be compared with the obtained results in the research group in patients with Menière[21] disease and in patients with multiple sclerosis[20], with average age of 45.55 (SD=12.36 years, varying between 33 and 57 years) and 34.91 (SD=13.97 years, varying between 20 and 48 years), respectively. On the other hand, the recent study showed average age of 21.30 (SD=2.07 years, varying between 19 and 23 years, according to inclusion criteria), showing difference between the studies related to age[20,21].

Comparing the values of the study mentioned previously[20,21] with the recent study, we verified that the mean values of obtained LOS in the control group with the patients with Menière disease – MDCG were closed to the ones of control

Table 1. Descriptive values and comparative analyses of Limit of Stability area – LOS (cm²), ellipse area (cm²) and sway speed (cm/s) of balance rehabilitation unit (BRU™) conditions of male and female individuals

Descriptive		Mean	Median	SD	VC	Q1	Q3	Min	Max	CI
Stability area		236.2	233.0	62.4	26.4%	187.0	285.8	135.0	375.0	17.3
Ellipse area (cm²)	FSOE	2.18	1.87	1.30	59.7%	1.48	2.64	0.55	7.37	0.36
	FSCE	2.30	1.89	1.83	79.7%	1.13	2.68	0.20	9.88	0.51
	FPCE	8.83	7.40	5.52	62.6%	5.35	10.82	3.58	37.91	1.53
	FSS	1.77	1.25	1.46	82.5%	0.82	2.30	0.25	7.48	0.41
	FSOR	2.09	1.60	1.83	87.5%	1.11	2.14	0.30	10.90	0.51
	FSOL	1.68	1.04	1.51	90.2%	0.87	2.29	0.42	9.63	0.42
	FSOB	1.78	1.55	1.28	72.2%	0.81	2.41	0.47	6.49	0.36
	FSOU	1.96	1.59	1.45	74.0%	0.89	2.82	0.46	7.03	0.40
	FSVVIHD	3.46	2.43	3.51	102%	1.86	3.97	0.47	19.48	0.97
	FSVVIVD	3.93	2.71	3.28	83.3%	1.59	5.57	0.69	14.27	0.91
Sway speed (cm/s)	FSOE	0.75	0.66	0.43	57.8%	0.58	0.78	0.42	3.50	0.12
	FSCE	0.92	0.87	0.30	32.6%	0.67	1.13	0.45	1.82	0.08
	FPCE	2.41	2.26	0.56	23.4%	2.05	2.70	1.52	3.93	0.16
	FSS	0.89	0.85	0.29	32.5%	0.72	1.02	0.46	1.89	0.08
	FSOR	0.81	0.76	0.26	32.1%	0.64	0.92	0.44	1.65	0.07
	FSOL	0.82	0.75	0.28	34.3%	0.61	0.94	0.42	1.73	0.08
	FSOB	0.84	0.82	0.27	31.9%	0.63	0.98	0.45	1.64	0.07
	FSOU	0.87	0.78	0.35	39.6%	0.65	0.95	0.43	1.92	0.10
	FSVVIHD	1.24	1.11	0.53	42.6%	0.93	1.34	0.61	3.00	0.15
	FSVVIVD	1.52	1.39	0.58	38.1%	1.13	1.83	0.61	3.15	0.16

* Mann-Whitney Test ($p \leq 0.05$)

Note: SD = standard deviation; VC = variation coefficient; Q1 = distribution to 25% of the sample; Q3 = distribution to 75% of the sample; Min = minimum value of the sample; Max = maximum value of the sample; CI = confidence interval; FSOE = firm surface with open eyes; FSCE = firm surface with closed eyes; FPCE = foam pillow with closed eyes; FSS = firm surface saccadic movement; FSOR = firm surface optokinetic bars in the horizontal direction from left to right; FSOL = firm surface optokinetic bars in the horizontal direction from right to left; firm surface optokinetic bars; FSOB = firm surface optokinetic bars in the vertical direction from top to bottom; FSOU = firm surface optokinetic bars in the vertical direction from bottom up; FSVVIHD = firm surface vestibulovisual interaction in the horizontal direction from left to right; FSVVIVD= firm surface vestibulovisual interaction in the vertical direction from bottom up

Table 2. Descriptive values and comparative analyses of Limit of Stability area – LOS (cm^2), ellipse area (cm^2) and sway speed (cm/s) of balance rehabilitation unit (BRU™) conditions of male and female individuals

Descriptive		Gender	Mean	Median	SD	p-value
Limit of stability area (LOS)		F	207.1	200.0	44.4	0.001*
		M	265.2	272.0	64.9	
Ellipse area (cm^2)	FSOE	F	1.93	1.79	0.78	0.554
		M	2.43	2.05	1.65	
	FSCE	F	1.94	1.66	1.43	0.168
		M	2.65	2.08	2.13	
	FPCE	F	8.83	7.60	6.72	0.554
		M	8.82	6.96	4.14	
	FSS	F	1.47	1.14	1.09	0.187
		M	2.08	1.31	1.73	
	FSOR	F	1.98	1.55	2.00	0.655
		M	2.20	1.62	1.67	
	FSOL	F	1.42	0.98	1.04	0.236
		M	1.94	1.29	1.86	
	FSOB	F	1.51	1.09	1.17	0.086#
		M	2.05	1.59	1.36	
	FSOU	F	1.69	1.33	1.40	0.109
		M	2.24	2.05	1.48	
	FSVVIHD	F	2.25	2.05	1.23	0.007*
		M	4.66	2.82	4.54	
	FSVVIVD	F	2.37	1.81	1.69	<0.001*
		M	5.49	4.51	3.74	
Sway speed (cm/s)	FSOE	F	0.72	0.74	0.16	0.171
		M	0.77	0.62	0.60	
	FSCE	F	0.88	0.87	0.26	0.362
		M	0.97	0.88	0.34	
	FSOF	F	2.49	2.32	0.67	0.587
		M	2.32	2.25	0.43	
	FSS	F	0.87	0.85	0.31	0.587
		M	0.90	0.85	0.27	
	FSOR	F	0.78	0.76	0.24	0.357
		M	0.85	0.75	0.28	
	FSOL	F	0.78	0.75	0.26	0.420
		M	0.86	0.75	0.30	
	FSOB	F	0.81	0.82	0.22	0.662
		M	0.87	0.82	0.31	
	FSOU	F	0.81	0.73	0.30	0.286
		M	0.93	0.87	0.38	
	FSVVIHD	F	1.04	0.93	0.40	<0.001*
		M	1.45	1.29	0.57	
	FSVVIVD	F	1.21	1.15	0.46	<0.001*
		M	1.83	1.73	0.53	

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

As p values are close to the acceptability limit, they tend to be significant

Note: F = female group; M = male group; FSOE = firm surface with open eyes; FSCE = firm surface with closed eyes; FPCE = foam pillow with closed eyes; FSS = firm surface saccadic movement; FSOR = firm surface optokinetic bars in the horizontal direction from left to right; FSOL = firm surface optokinetic bars in the horizontal direction from right to left; firm surface optokinetic bars; FSOB = firm surface optokinetic bars in the vertical direction from top to bottom; FSOU = firm surface optokinetic bars in the vertical direction from bottom up; FSVVIHD = firm surface vestibulovisual interaction in the horizontal direction from left to right; FSVVIVD= firm surface vestibulovisual interaction in the vertical direction from bottom up group of patients with multiple sclerosis – MSCG. However, these values are distant from the ones obtained in this study. It can be explained because the control group of the this study presents the age group bellow the MDCG and the MSCG.

To the ellipse area, we observed that the same happened to the following sensorial stimuli: firm surface with open eyes, firm surface with closed eyes, with optokineticic bars to the right, with visuovestibular interaction in the horizontal and vertical directions. As to the stimuli of foam surface with closed eyes the MSCG is near this study, getting further from the mean value of MDCG. In the other stimuli (firm surface saccadic movement, with optokineticic bars to the left, to the bottom and up) the mean values in the three studies are close.

As for the sway speed the mean obtained values in this study were not very distant form the MSCG[20] and MDCG[21] values.

In our casuistic, posturography of BRU™ showed that the LOS area values (Table 2) of the female group were lower than the male group. This difference can be explained by the patients' stature of male gender which, in general, was higher than the female group, once the higher the individual is the bigger is the support base. References in the literature about LOS area in young adult patients to the posturography of BRU™ equipment were not found.

Study with dynamic posturography of "*Foam-Laser*"[16] type showed difference in the test that measure the body sway – Sensorial Organization Test (SOT), regarding the individual's gender and age group, women had better results in the different age group. Such findings and the results of this study show that there is the necessity of obtaining normal differentiated values regarding the gender.

The sway difference between women and men can be explained by the reduction of somatosensorial responses, associated with the lowering of the degree of muscular power. This is more significant in women, since they have more loss in the lean body mass and in the muscle strength than men at the same age[30].

Furthermore, the relation between the sensorial information and motor action is another fact that can influence on the less stable behavior with advancing age[22,30].

The value of ellipse area, for the sensorial stimuli test on firm surface with optokinetic bars to bottom, showed difference related to genders. References in the literature about ellipse area in young adult patients to the posturography of BRU™ were not found.

Our results indicated that the posturography with virtual reality stimuli is a method that provides relevant information about the body balance of young healthy adults. The findings regarding the LOS area values, the ellipse area and the sway speed in the posturography can be useful not only for diagnoses to characterize the body balance disorder but also to follow the disease progression under treatment.

CONCLUSION

The findings of posturography with virtual reality stimuli in young, healthy adults show that the parameters center of pressure , limit of stability and sway speed present differences between genders, therefore must be singly considered.

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