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Research Article

How To Study the Effect of Vestibular Activation on Vestibulo-Spinal Pathway using Portable Posturography

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Abstract

Background: Clinical tests performed in posturography are a useful element in evaluation of balance and postural control. It usually demands, however, large and expensive equipment and for this reason this examination is not performed by many neurotologists.

Aims/Objectives: This study was conducted with a recently developed posturography system - Balance Angular Posturography (BAP) - in order to evaluate into clinical practice.

Materials and Methods: Fifteen healthy volunteer patients without vestibular disease or complaint of loss of balance were studied prospectively using BAP to establish the reference values of the variables, standardizing its use. They were tested standing over the floor or over a foam platform and were stimulated with right and left Head Tilt, Head-Shaking and right and left Fast Head-Turning tests. The stimuli were presented both with eyes open and closed.

Results: Six male and nine female patients (25,7 average) were enrolled in this study, which the results varied, but allowed for the establishment of reference values.

Conclusion: The validated BAP protocol may become useful to study patients with imbalance complaint and document their improvement after vestibular rehabilitation, since the vestibulo-spinal pathway is also evaluated.

Significance: This equipment may contribute to increase the interest in posturography, particularly with patients that need vestibular rehabilitation.

Keywords: *Portable Posturography; Reference Values; Balance; Postural Control; vestibulo-spinal Pathway*

Introduction

Posture control is defined as the ability to balance the body in space to perform a task. It is influenced by three individual factors: sensory, motor and cognitive elements. The sensory contribution occurs from visual, somatosensorial and vestibular stimuli that are capable to modulate the motor response and necessary corrections for maintain posture [1].

Dynamic Posturography is the reference method to evaluate the human balance and thus to study the disorders of posture control. However, it usually demands large and expensive equipment [2]. D'Albora developed a portable posturography (BAP - Balance Angular

Posturography), in 2017, in order to facilitate balance assessment [3]. Carmona., *et al*. defined the reference values of the variables, standardizing its use [3]. The device assesses five different conditions according to the angular Sway in the X and Y axes and the area based on the measures, that indicate the possible variables found in a person with a balance disturbance: vestibular dysfunction, visual preference, visual dependence, somatosensory dependence and aphysiological pattern. In vestibular dysfunction, vestibular information is used in an altered way and this is able to correspond to peripheral or central lesions. Visual preference appears when there is instability in situations of great visual conflict and this does not identify a disease. Visual dependence reveals limited use of vestibular and somatosensory informations, through better action with visual information. In somatosensory dependence, an optimal balance is maintained on a firm and regular floor, since there is difficulty in the management of visual and vestibular informations. Aphysiological pattern refers to obtain better results in simpler tests than in the more complex ones, suggesting self-simulation or exaggeration about the complaints due to an anxious personality [3].

Study vestibulo-spinal pathway is a fast, reproducible and a simple way to test the vestibular system, since it is a direct pathway and it was proven to provide less bias in comparison with ocular movements, which is a more complex system, sharing circuits in the brainstem and brain [4, 5], moreover this approach looks like very useful in telemedicine [6].

Vestibular stimulations, such with Head Tilt test and passive Head-Shaking maneuver, increase significantly the differences observed performing posturography [7,8]. Adopting another vestibular activations in the BAP, as also active lateral Fast Head-Turning test, a new protocol could be a better indicator of peripheral vestibular asymmetry and its central compensation process by vestibular rehabilitation. Including these three new situations in the exam, this paper analyzes the normative data of the Sway per minute (X and Y) presented by patients with no vestibulopathy, in order to establish the limits of normality of its variables.

Materials and Methods

Fifteen healthy volunteer patients without vestibular disease or complaint of loss of balance were evaluated prospectively using BAP (Figure 1).

Figure 1: *BAP (Balance Angular Posturography) equipment.*

The portable posturography equipment is usually composed of an accelerometer and a 3-axes gyroscope connected to an 8-bit micro-controller, that processes the sensors information input. A combination of acceleration and angular velocity measurement provides the position of the sensors in angular values, which are transmitted to a computer through a USB port (or a BlueTooth connection, although not available yet). These values, that represent the position of the body in a certain time and condition, are converted graphically by the software, representing the maximum and minimum angular movements in the X and Y axes and an area based on the measures. Therefore, it calculates the patient Sway per second or per minute (Sway/s or Sway/m, respectively) [3].

After being asked to remove the shoes, the equipment was placed immediately above the internal malleolus of the patient's left ankle (Figure 2) and he was requested to assume the orthostatic position, leaving an intermalleolar separation of 8 cm [3]. The exam was performed in a room with walls of a single color and without horizontal or vertical visual reference.

Figure 2: *Proper placement of BAP: immediately above the internal malleolus of the patient's left ankle.*

In addition to the five conditions standardized by Carmona: Limit of Stability (LOS), Firm Platform Open Eyes (FPOE), Firm Platform Closed Eyes (FPCO), Open Eyes Foam Pillow (OEFP) and Foam Pillow Closed Eyes (FPCE) [3], three new situations that stimulate the vestibular system were added. The patients were evaluated during a Head Tilt test, after a passive Head-Shaking maneuver and while performing an active Fast Head-Turning test in lateral (Yaw) plane. All of the conditions were tested on a firm surface and then on the foam pillow, following the test blocks (Figure 3).

1° TEST (STANDARD)
L.Limit of Stability (LOS)
A.Firm Platform Open Eyes (FPOE)
B.Firm Platform Closed Eyes (FPCO)
C.Open Eyes Foam Pillow (OEFP)
D.Foam Pillow Closed Eyes (FPCE)

2° TEST (HEAD TILT)
L.Limit of Stability (LOS)
A.Right Head Tilt Open Eyes
B.Left Head Tilt Open Eyes
C.Foam Right Head Tilt Open Eyes
D.Foam Left Head Tilt Open Eyes

3° TEST (HEAD TILT)
L.Limit of Stability (LOS)
A.Right Head Tilt Closed Eyes
B.Left Head Tilt Closed Eyes
C.Foam Right Head Tilt Closed Eyes
D.Foam Left Head Tilt Closed Eyes

4° TEST (HEAD-SHAKING)
L.Limit of Stability (LOS)
A.Head-Shaking Open Eyes
B.Head-Shaking Closed Eyes
C.Foam Head-Shaking Open Eyes
D.Foam Head-Shaking Closed Eyes

5° TEST (LATERAL FAST HEAD-TURNING)
L.Limit of Stability (LOS)
A.Right Head Rotation Open Eyes
B.Left Head Rotation Open Eyes
C.Foam Right Head Rotation Open Eyes
D.Foam Left Head Rotation Open Eyes

Figure 3: *Test blocks performed using BAP.*

In the Head Tilt situation, the patient was tested performing a cervical lateral flexion of about 15 - 20o, while keeping the look at a fixed target 1 m ahead (when tested with eyes open) [9], first to one and then to the other side of the head (Figure 4).

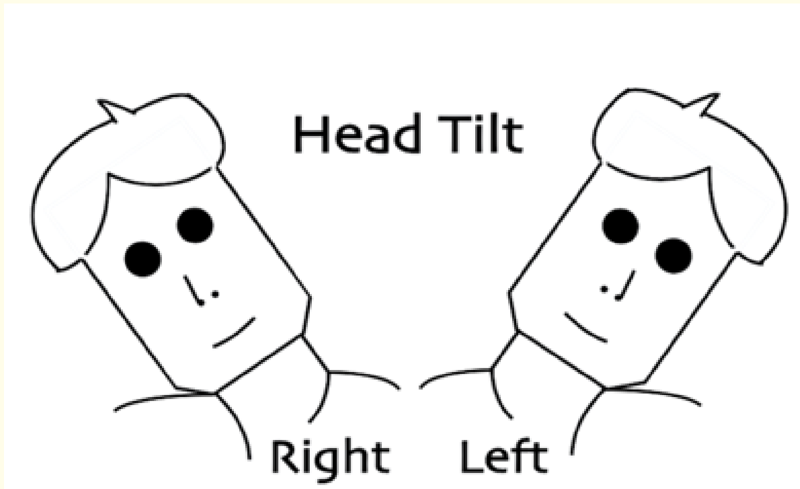

Figure 4: *Head Tilt test.*

The Head-Shaking maneuver was done flexing the patient's head 30o (to horizontalize the lateral semicircular canals) and shaking it about 2 Hz for approximately twenty seconds in the horizontal plane [9]. As soon as the maneuver ended, the patient was tested with the head straight looking at a fixed target 1 m ahead (when tested with eyes open) (Figure 5).

Figure 5: *Passive Head-Shaking maneuver.*

The lateral Fast Head-Turning was tested by asking the patient to rotate the head suddenly to the right side, until reached the look over the right shoulder, to better assesses the right lateral semicircular canal. The same was done to the left side, in order to separately rate the two lateral semicircular canals, one at a time (Figure 6). As exposed in the respective test block, this was the only test performed only with eyes open, so the patient would not fall from the foam pillow.

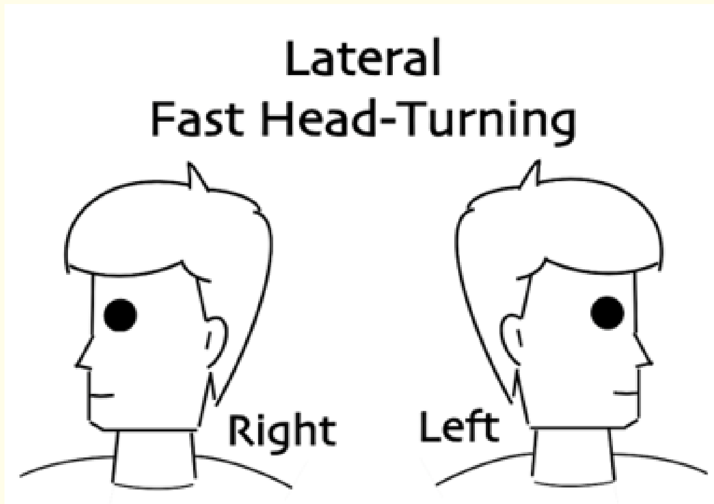

Figure 6: *Active Fast Head-Turning test in lateral (Yaw) plane.*

Each test block was composed by four positions (A, B, C, D) (Figure 7), configured in the graphic interface with a double letter (AA, BB, CC, DD). Before the patient accomplished a test block, the Limit of Stability (LOS) was customized with a double "L" (LL) and the same command was repeated in the beginning of each test block. LOS is defined by the extreme positions that the patient can oscillate all your body in block without losing balance or taking a step [3].

TEST BLOCK
L. Limit of Stability (LOS)
Position 1 -------- A. Ex.:Firm Platform Open Eyes (FPOE)
Position 2 -------- B. Ex.:Firm Platform Closed Eyes (FPCO)
Position 3 -------- C. Ex.:Open Eyes Foam Pillow (OEFP)
Position 4 -------- D. Ex.:Foam Pillow Closed Eyes (FPCE)

Figure 7: *Four positions tested in each test block.*

Each position lasted thirty seconds and, in every position change, the intermalleolar distance of 8 cm needed to be verified.

The data computed were the values of Sway/m obtained in the X and Y axes registered on the firm platform with open eyes, foam pillow with open eyes, firm platform with closed eyes and foam pillow with closed eyes. According to the BAP protocol, these values were used to determinate the individual patient variables in each test done: vestibular dysfunction, visual preference, visual dependence, somatosensory dependence and aphysiological pattern. For all variables there is a mean value, standard deviation, minimum and maximum values established that could be calculated [3].

Statistical analysis was performed with the IBM SPSS software, using the GLM test (General Linear Model Repeated Measures, Post Hoc LSD) and the value p < 0,05.

Results

Of the 15 patients enrolled in this study, 6 was male and 9 were female, age range 19 - 33 (25,7 average). The results of Sway/m in the X and Y axes are in the table 1.

		Open Eyes (Firm Platform)	Open Eyes (Foam Pillow)	Closed Eyes (Firm Platform)	Closed Eyes (Foam Pillow)
Standard	Sway X	104.33 ± 32.32	172.27 ± 55.29	110.47 ± 50.95	193.60 ± 90.87
	Sway Y	116.87 ± 22.75	190.93 ± 53.83	105.47 ± 33.86	213.07 ± 77.76
Head Tilt (Right)	Sway X	110.27 ± 40.83	164.67 ± 40.22	135.20 ± 37.25	234.33 ± 71.31
	Sway Y	129.33 ± 32.03	195.80 ± 49.59	151.33 ± 39.39	261.47 ± 59.41
Head Tilt (Left)	Sway X	119.67 ± 30.65	160.53 ± 44.28	139.87 ± 36.84	227.07 ± 62.88
	Sway Y	127.53 ± 25.80	205.87 ± 54.26	146.60 ± 41.00	242.67 ± 60.42
Head-Shaking	Sway X	107.00 ± 31.64	168.40 ± 45.22	112.60 ± 39.63	203.40 ± 65.89
	Sway Y	125.40 ± 30.62	200.20 ± 55.61	125.80 ± 29.90	225.20 ± 74.07
Lateral Fast Head-Turning (Right)	Sway X	149,80 ± 60.63	193.53 ± 42.84	-	-
	Sway Y	158.40 ± 53.48	242.40 ± 32.05	-	-
Lateral Fast Head-Turning (Left)	Sway X	149.40 ± 45.42	197.80 ± 44.77	-	-
	Sway Y	160.80 ± 47.97	224.00 ± 38.91	-	-

Table 1: *Values of Sway per minute (Sway/m) obtained in the X and Y axis.*

Significant results in relation to the standard test block were found: on the firm platform with open eyes, in the X axis with the lateral Fast Head-Turning to the right (p 0,02) and to the left (p 0,01) and in the Y axis also both to the right (p 0,009) and to the left (p 0,003); on the foam pillow with open eyes, just in the Y axis with the lateral Fast Head-Turning test to the right (p 0,003) and to the left (p 0,02); on the firm platform with closed eyes, in the X axis only during the Head Tilt to the left (p 0,039) and in the Y axis during the Head Tilt to the right (p 0,002), to the left (p 0,013) and after the Head-Shaking maneuver (p 0,018); finally on the foam pillow with closed eyes, in the X axis during the Head Tilt to the right (p 0,023) and in the Y axis during the Head Tilt both to the right (p 0,004) and to the left (p 0,011).

Discussion

Clinical tests performed in posturography are able to quantify functional capacity related to balance and postural control [10]. This paper aims to define reference values for the new tests added to BAP and to standardize its use for future studies.

During the Head Tilt test, statistically significant differences were obtained with closed eyes, on the firm platform as well as on the foam pillow condition. It shows the utility of stimulating the macular labyrinthine receptor of the utricle to detect subtle changes in the postural pattern that would not be detected. This instability observed when tilting the head may be increased in patients with vestibular disease, since they might have a greater visual dependence due to impaired vestibular inputs [7]. Moreover, the vestibulo-spinal reflexes are coordinated with other spinal reflexes. It is essential to perform daily activities and the Head Tilt can test it. Tilting the head while keeping the trunk motionless stimulates vestibular apparatus and neck proprioceptors simultaneously, canceling the reflex responses. In patients with vestibular disease, a similar tilt may cause the body falls immediately to the same side of the movement, since the cervico-spinal reflex is activated alone [11].

The passive Head-Shaking maneuver shows a statistically significant difference only in the Y axis on the firm platform with closed eyes, but not in the other conditions tested, probably because the patients submitted to BAP did not present vestibulopathy. The Head-Shaking increases the neural activity in the velocity storage integrator, disrupting individual posture by providing additional sensory cues that need to be integrated into the task of standing.

Statistically significant differences were obtained with open eyes performing the active lateral Fast Head-Turning test in the X axis on the firm platform and in the Y axis on the firm platform as well as on the foam pillow condition. As the exam was performed in a room with walls of a single color and without horizontal or vertical visual reference, rotating the head suddenly to one side requires the patient to stipulate a new fix target without following any referential plane and it facilitates this instability observed. Plus, the efficacy of vestibulo-spinal pathway is not constant but depends on the behavioral context. Specifically, vestibulo-spinal reflexes generated by the vestibular system are attenuated in 70% when the goal is to make voluntary head movements. It is advantageous, since these vestibulo-spinal reflexes that are needed to compensate an unexpected motion would be counterproductive in self-generated movements as it would oppose the predicted motion [11].

The patients were tested in the orthostatic position, in order to provide informations about the vestibular-spinal function or disfunction and the compensation process at this level for any damage to the vestibular system. It is not possible to analyze these informations by doing these tests with the patient in the sitting position. From the central vestibular nuclei in the brainstem, the integration of vestibular, visual and proprioceptive systems information related to stabilization of the body and spatial orientation functions autonomously, without the need of our conscious intervention. Only in the situations where there is a disorder in the sensory information through mismatch or disease do we become aware of the tendency to fall to one side, for example. In the case of a sensory conflict in the area of the central vestibular nuclei, hierarchical structures of the brain come into play: visual system dominates over vestibular and, within the vestibular system, the evolutionary older otolith organs dominate over the semicircular canals, determining the spatial perception. As know, the perception emerges from the vestibulo-spinal tract and the reticulospinal projections to the motoneurons on the extensor muscles along our body and that is why BAP is also able to evaluate the vestibular-spinal pathway [13,14].

The present study establishes the normative data of Sway per minute (X and Y) presented by healthy patients evaluated with a portable and compact examination equipment (BAP), under new situations capable of stimulating the vestibular system and then sensitizing the exam.

Conclusion

Once validated, this BAP protocol may become useful to study patients with imbalance complaint and their improvement after vestibulo rehabilitation, since the vestibular-spinal pathway is evaluated.

Contributions

The authors contributed equally.

Conflict of Interests

RC is a paid speaker of Grunenthal, Abbot and UCB Pharmaceutical. He received free devices for testing from Natus and Interacoustics. The other authors declare no potential conflict of interests.

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