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# Postural control in Menière's disease

## Controle postural na doença de Menière

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### ABSTRACT

**Purpose:** To evaluate postural control in Menière's disease. **Methods:** 34 patients with Menière's disease (experimental group) and 34 healthy individuals (control group) were submitted to Tetrax Interactive Balance System posturography under eight sensory conditions. Stability, weight distribution, synchronization, risk of falling and postural oscillation frequency were analyzed. **Results:** Stability index was higher in the experimental group with significant difference between the groups in all sensory conditions. Risk of falling was higher in the experimental group than in the control. Postural oscillation was higher in the experimental group in all frequency ranges, with significant difference in some of them. There was no significant difference between the groups in the weight distribution and synchronization indexes. **Conclusion:** In this study, Menière's disease patients presented impaired postural control, characterized by postural instability and oscillation and risk of falling.

**Keywords:** Menière's disease; Postural control; Vestibular function tests; Dizziness; Vertigo

### RESUMO

**Objetivo:** Avaliar o controle postural na doença de Menière. **Métodos:** 34 pacientes com doença de Menière definida (grupo experimental) e 34 indivíduos hígidos (grupo controle), homogêneos quanto à idade e ao gênero, foram submetidos à posturografia do *Tetrax Interactive Balance System* (*Tetrax IBS*™) em oito condições sensoriais. Índice de estabilidade, índice de distribuição de peso, índice de sincronização da oscilação postural direita/esquerda e dedos/calcanhar, frequência de oscilação postural e índice de risco de queda foram analisados. **Resultados:** O índice de estabilidade foi maior no grupo experimental, com diferença significativa entre os grupos, em todas as condições sensoriais testadas. O risco de queda foi maior no grupo experimental do que no grupo controle. A oscilação postural foi maior no grupo experimental em todas as faixas de frequência, com diferença significativa em algumas delas. Não houve diferença significativa entre os grupos nos índices de distribuição de peso e de sincronização, nas oito condições sensoriais avaliadas. **Conclusão:** Pacientes com doença de Menière apresentam comprometimento do controle postural, caracterizado por alterações do índice de estabilidade, em frequências de oscilação postural e no índice de risco de queda.

**Palavras-chave:** Doença de Menière; Controle postural; Testes de função vestibular; Tontura; Vertigem

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## INTRODUCTION

Menière's disease was first described in 1861 by Prosper Menière and is among the most common causes of vestibulopathy. The disease is characterized by an association between recurrent episodes of vertigo, followed by aural fullness, tinnitus, and episodic hearing loss. Postural instability, sudden falls, nausea, and vomiting may also occur[1]. Information on the prevalence of Menière's disease depends on diagnostic criteria, databases, country, and patient ethnicity. In the United States, less than 0.2% of the population has the disorder and its prevalence increases linearly with age until 60 years, at a proportion of three women for every two men[2].

Menière's disease does not have a well-defined etiology, however, it has been associated with a larger endolymph volume[3]. Theories suggest varying size or position of the endolymphatic sac and duct, viral inflammation, or autoimmune involvement, in addition to a genetic abnormality in endolymph control or obstruction of the ductus reuniens, saccular duct, and endolymphatic sac by saccular otoliths[4].

Despite the diagnosis for Menière's disease being clinical, based on the verification of symptoms, some tests favor a differential diagnosis by quantifying the vestibulopathy and monitoring the functional status of the vestibular system[5].

Conventional vestibular tests, like nystagmography, assess the vestibulo-ocular reflex by investigating vertigo and positional nystagmus, and visual, rotary, and thermal stimuli. However, these are insufficient to analyze the vestibular function more generally. Posturography complements the vestibular assessment of the clinical routine and can identify the risk of falling[6] by measuring postural stability through a force-sensitive pressure platform. This platform provides data on the patient's body sway by determining how the individual uses the vestibular, visual, and somatosensory cues and integrates them in the brainstem to maintain body balance[7].

The static posturography of the Tetrax Interactive Balance System (Tetrax IBS™) measures balance and postural sway through a platform constituted of four independent sensor plates that capture variations in weight distribution and compare the values for the toes and heel of each foot and each heel with the toes of the contralateral foot. The tension gauge in each plate transforms the variations in vertical force into analog wave electrical signals[8].

Interest in this research arose from observing the occurrence of postural instability and falling in patients with Menière's disease. Characterizing the role of vestibular, visual and/or proprioceptive systems in postural control is fundamental to developing individual therapeutic planning.

This research aimed to assess postural control in Menière's disease.

## METHODS

This is a cross-sectional, descriptive, and analytical study approved by the Ethics Committee for Research with Human Beings of the Escola Paulista de Medicina - Universidade Federal de São Paulo (EPM-UNIFESP), protocol number 46696415.2.0000.5505.

All participants were assessed between 2015 and 2017 and sequentially selected at the Otorhinolaryngology and Neurotology Outpatient Clinic of the Department of Otorhinolaryngology and Head & Neck Surgery of the EPM-UNIFESP.

The experimental group included patients with a defined clinical diagnosis of Menière's disease[1] during the intercritical period of the disorder, assessed between eight and 60 days after the last vertigo attack[9-11]. The intercritical period was established as the time starting after an acute attack until the following attack, characterized by partial or total improvement of the disorder's symptoms, including vertigo, nausea, vomiting, spontaneous nystagmus, hearing loss, aural fullness and/or tinnitus.

The sample included 34 female and male patients, aged between 30 and 65 years, with independent movement without need of assistive devices, who agreed to participate in the research by signing the Informed Consent Form (TCLE). We excluded patients with neurological or psychiatric disorders, those unable to understand and respond to simple verbal commands, those with severely reduced visual acuity not compensated with the use of corrective lenses, those unable to remain in the orthostatic position unassisted, or with lower limb orthopedic disorders that restrict movement, and amputee patients or those using lower limb prosthetics. All patients underwent tonal threshold audiometry, speech discrimination, and immittance testing as part of the clinical diagnosis to try to minimize the influence of severe hearing loss. Individual sound amplification devices were prescribed and fitted when necessary.

The control group included 34 healthy volunteers from the university where the research was conducted, both female and male, aged between 30 and 65 years, without a history of vestibular and/or hearing symptoms. All participants signed the TCLE.

All individuals in the control and experimental groups underwent body balance assessment through the Tetrax IBS™ posturography, by Sunlight Medical Ltd., in a silent and semi-lit room. The equipment includes a computer with the program installed, foam mats, and a force platform with handrails (Figure 1). The platform constituted by four independent and integrated plates (A-B-C-D) was placed on a level surface without carpet. A target consisting of a circular dot was positioned on the wall at eye level one meter in front of the participant being assessed.

The posturography of the Tetrax IBS™ assessed the vertical force variation generated by the heels and tips of the feet, characterizing body sway, according to the displacement of the pressure center. The following indices were assessed: risk of falling, stability, weight distribution, synchronization of the right/left postural sway and toes/heel, and variations in sway postural frequency[8].

Data were collected with the individual standing barefoot in an upright position and arms extended along the body, looking at the target for 32 seconds, in the following eight conditions: NO – stable surface, neutral head position, eyes open; NC – stable surface, neutral head position, eyes closed; PO – unstable surface, neutral head position, eyes open; PC – unstable surface, neutral head position, eyes closed; HR – stable surface, head with 45 degree rotation to the right, eyes closed; HL – stable surface, head with 45 degree rotation to the left, eyes closed; HB – stable surface, head extension, eyes closed, and HF – stable surface, head flexion, eyes closed. The examiner remained close to the participant throughout the assessment.

The stability index assessed the ability to compensate for postural changes and the number of sways on the four sensor plates, by body weight. Since it is the mean of the swaying recorded per plate, the greater the score, the lower the stability[8].

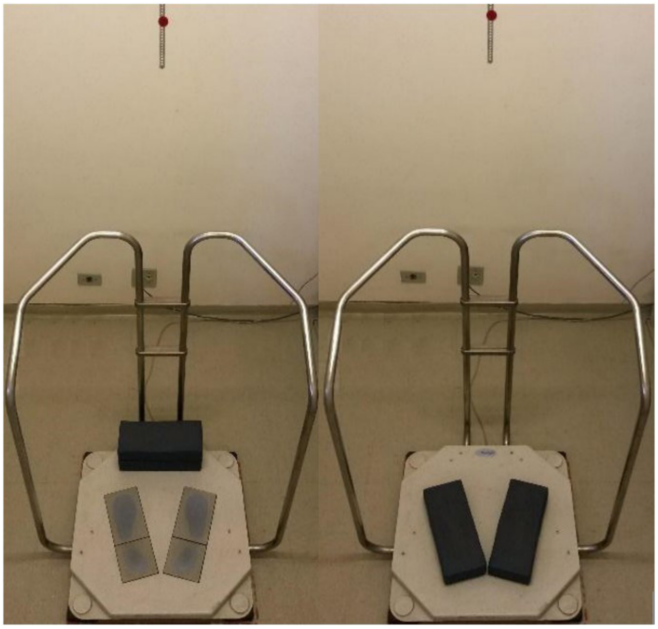

**Figure 1.** Tetrax Interactive Balance System (Tetrax IBS™)
**Source:** Elaborated by the author (2019)

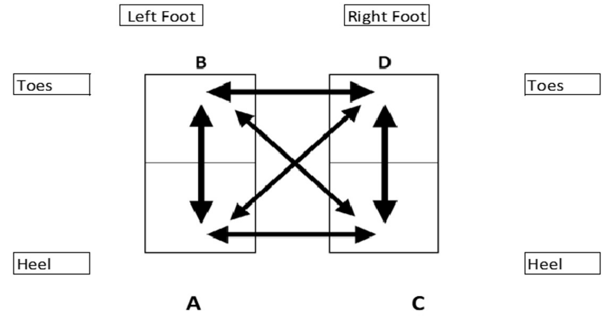


**Figure 2.** Indication of the postural sway synchronizations for the sensor plates of the Tetrax Interactive Balance System (Tetrax IBS™)

The weight distribution index compared the deviations of weight distribution for each sensor plate assuming an expected mean value of 25.0%. The higher the value, the greater the abnormal weight distribution per plate[8].

The synchronization indices of the right/left postural sway and heels/toes measured the coordination between the lower limbs and the weight distribution symmetry. The following six synchronizations were assessed per condition (Figure 2): between the heels and the toes of each foot (AB, CD); between the two heels and the toes of the two feet (AC, BD), and the two diagonals, between the heel of a foot with the toes of the contralateral foot (AD, BC)[8].

The frequencies of postural sway vary within a range from 0.01 to 3.0 Hz and were assessed using Fourier transform, a mathematical treatment of the wave signals of the individual's body sway in relation to the horizontal plane while maintaining an upright position. The Tetrax IBS™ subdivided the spectrum of postural sway into the following four frequency bands: low (F1), below 0.1 Hz; medium-low (F2-F4), between 0.1 – 0.5 Hz; medium-high (F5-F6), between 0.5 – 1.0 Hz, and high (F7-F8), above 1.0 Hz[8].

The risk of falling index expressed the results of the Tetrax IBS™ parameters for the eight sensory conditions, varying between 0.0 and 100.0%. Values between 0.0 and 36.0% were defined as "low risk", from 37.0 to 58.0% as "moderate risk", and 59.0 to 100.0% as "high risk"[8].

All data underwent statistical descriptive analysis for sample characterization with relative and absolute frequencies, mean, standard deviation, median, and minimum and maximum values. The Shapiro-Wilk test verified data normality and the parametric student's t-test, and non-parametric Mann-Whitney test analyzed the numerical variables. All categorical variables were analyzed through Chi-square non-parametric test. All analyses adopted a 5.0% significance level (p-value below or equal to 0.05) and all calculations were performed on the Estatística R and Excel Office 2016 software.

## RESULTS

The sample included 34 patients in the experimental group and 34 in the control group. Of the 34 patients from the experimental group with Menière's disease, 24 (70.59%) were female, and 10 (29.41%) were male. The control group had 28 female (82.35%) and 6 (17.65%) male individuals. The individuals with Menière's disease were aged between 30 and 60 years (mean age of 50.26 years; standard deviation of 8.37 years), while those in the control group were aged between 32 and 64 years (mean of 46.88 years; standard deviation of 8.64 years). Both groups presented the same gender (p=0.253) and age (p=0.067) profiles.

Table 1 presents the descriptive values and comparative analysis of the stability index for the experimental group and the control group in the Tetrax IBS™. The group with Menière's disease had a higher value in the stability index than the control group for all sensory conditions, with statistically significant differences between the groups.

Table 2 presents the descriptive values and comparative analysis between the experimental group and the control group in the Tetrax IBS™ for the weight distribution index. The Menière disease's group had a higher value for the weight distribution index than the control group for all sensory conditions, with no statistically significant difference observed between the groups.

Table 3 shows the descriptive values and comparative analysis of the synchronization index for the right/left postural sway and toes/heels for the experimental group and the control group in the Tetrax IBS™, in all eight sensory conditions. No statistically significant difference was found between the groups in the synchronizations assessed for all eight sensory conditions.

Table 4 presents the descriptive values and comparative analysis of the frequency variations for postural sway for the experimental and control groups, in all eight sensory conditions in the Tetrax IBS™. The Menière's disease group showed higher values than the control group, with a significant difference in the following frequency variations: low (F1), for eyes open and closed and firm ground, with eyes open and unstable surface and head inclined to the right and stable surface; medium-low

**Table 1.** Descriptive values and comparative analysis of the stability index in the sensory conditions of the Tetrax Interactive Balance System (Tetrax IBS™) for experimental and control groups

| Sensory conditions | Groups | Median | Standard Deviation | Minimum value | Median | Maximum value | p-value |
|---|---|---|---|---|---|---|---|
| Eyes open/Stable surface | MD | 17.27 | 8.77 | 6.98 | 14.71 | 50.99 | 0.001* |
| | C | 11.79 | 3.03 | 7.11 | 11.42 | 18.97 | |
| Eyes closed/Stable surface | MD | 27.48 | 18.86 | 9.11 | 20.72 | 100.85 | 0.007* |
| | C | 16.81 | 5.30 | 8.73 | 16.61 | 26.56 | |
| Eyes open/Unstable surface | MD | 25.49 | 11.18 | 13.89 | 22.67 | 67.25 | 0.000* |
| | C | 17.62 | 5.49 | 10.14 | 16.25 | 31.57 | |
| Eyes closed/Unstable surface | MD | 36.24 | 18.03 | 19.40 | 30.81 | 107.08 | 0.032* |
| | C | 27.37 | 7.50 | 14.59 | 26.88 | 39.36 | |
| Eyes closed/Head to the right/Stable surface | MD | 25.72 | 16.47 | 11.78 | 19.98 | 91.82 | 0.000* |
| | C | 15.31 | 4.36 | 6.50 | 15.73 | 21.04 | |
| Eyes closed/Head to the left/Stable surface | MD | 26.43 | 16.88 | 9.99 | 22.56 | 93.98 | 0.000* |
| | C | 15.80 | 5.44 | 6.82 | 14.56 | 29.80 | |
| Eyes closed/Head backwards/Stable surface | MD | 25.77 | 17.79 | 10.51 | 20.82 | 108.60 | 0.002* |
| | C | 16.25 | 4.51 | 8.03 | 15.89 | 28.73 | |
| Eyes closed/Head forwards/Stable surface | MD | 26.33 | 17.87 | 10.29 | 21.13 | 100.88 | 0.001* |
| | C | 16.17 | 5.72 | 7.65 | 14.79 | 30.20 | |

Mann-Whitney Test; *Statistically significant difference between the groups (p-value ≤0.05)
**Subtitle:** MD = Menière's disease; C = control

**Table 2.** Descriptive values and comparative analysis of the weight distribution index (%) in the sensory conditions of the Tetrax Interactive Balance System (Tetrax IBS™) for the experimental and control groups

| Conditions | Groups | Median | Standard Deviation | Minimum Value | Median | Maximum Value | p-value |
|---|---|---|---|---|---|---|---|
| Eyes open/Stable surface | MD | 5.61 | 3.02 | 1.14 | 5.55 | 13.64 | 0.589 [a] |
| | C | 5.23 | 2.76 | 1.29 | 4.76 | 12.32 | |
| Eyes closed/Stable surface | MD | 5.67 | 3.15 | 0.87 | 5.33 | 15.28 | 0.199 [b] |
| | C | 4.79 | 2.39 | 0.72 | 4.63 | 11.23 | |
| Eyes open/Unstable surface | MD | 4.85 | 2.30 | 0.97 | 4.11 | 11.16 | 0.589 [a] |
| | C | 4.73 | 2.62 | 1.26 | 4.38 | 10.88 | |
| Eyes closed/Unstable surface | MD | 4.67 | 3.02 | 0.68 | 3.80 | 13.83 | 0.922 [a] |
| | C | 4.19 | 2.15 | 0.55 | 3.89 | 10.06 | |
| Eyes closed/Head to the right/Stable surface | MD | 5.53 | 2.84 | 1.21 | 5.04 | 11.99 | 0.281 [b] |
| | C | 4.81 | 2.61 | 0.91 | 4.25 | 11.20 | |
| Eyes closed/Head to the left/Stable surface | MD | 5.78 | 2.70 | 1.30 | 5.29 | 12.91 | 0.269 [b] |
| | C | 5.13 | 2.04 | 1.58 | 5.36 | 10.27 | |
| Eyes closed/Head backwards/Stable surface | MD | 5.60 | 2.67 | 1.75 | 5.17 | 12.20 | 0.251 [b] |
| | C | 4.85 | 2.64 | 1.31 | 4.32 | 12.19 | |
| Eyes closed/Head forwards/Stable surface | MD | 5.97 | 2.74 | 1.18 | 5.23 | 12.47 | 0.382 [b] |
| | C | 5.40 | 2.61 | 1.15 | 5.34 | 13.17 | |

[a]Mann-Whitney Test; [b]t student Test
**Subtitle:** MD = Menière's disease; C = control

(F2-F4) in all sensory conditions tested; medium-high (F5-F6), for seven sensory conditions; high (F7-F8), for eyes open and closed and stable surface, and eyes open and unstable surface.

Table 5 presents the descriptive values and comparative analysis for the index and degree of falling risk in the control group and the experimental group in the Tetrax IBS™. The Menière's disease group showed a greater risk of falling than the control group, presenting a significant difference. All individuals in the control group presented a low risk of falling. The patients in the experimental group showed low risk in 47.06% of the cases, moderate risk in 23.53%, and high risk in 29.41% of cases.

**Table 3.** Descriptive values and comparative analysis of the synchronization indices in the eight conditions of the Tetrax Interactive Balance System (Tetrax IBS™) in the experimental and control groups

| Synchronizations | | AB | | | CD | | | AC | | | BD | | | AD | | | BC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | C | p-value | MD | C | p-value | MD | C | p-value | MD | C | p-value | MD | C | p-value | MD | C | p-value |
| Conditions | | (n=34) | (n=34) | | (n=34) | (n=34) | | (n=34) | (n=34) | | (n=34) | (n=34) | | (n=34) | (n=34) | | (n=34) | (n=34) | |
| NO | mean | -831.05 | -801.68 | 0.556 | -797.56 | -806.31 | 0.759 | 587.84 | 577.51 | 0.990 | 818.10 | 769.41 | 0.158 | -863.86 | -859.11 | 0.731 | -862.77 | -838.87 | 0.668 |
| | minimum | -981.71 | -980.37 | | -986.84 | -978.90 | | 33.55 | -102.29 | | 471.60 | 380.04 | | -986.80 | -978.36 | | -988.77 | -984.55 | |
| | maximum | -494.90 | -140.71 | | -335.85 | -413.18 | | 960.24 | 913.40 | | 985.10 | 949.31 | | -587.46 | -610.41 | | -514.41 | -430.22 | |
| NC | mean | -807.87 | -820.15 | 0.864 | -792.38 | -867.31 | 0.315 | 590.28 | 667.24 | 0.516 | 783.75 | 869.83 | 0.151 | -860.87 | -885.51 | 0.548 | -871.93 | -919.34 | 0.093 |
| | minimum | -990.99 | -986.57 | | -977.87 | -979.44 | | -586.53 | -428.74 | | 178.01 | 510.42 | | -987.76 | -982.87 | | -988.38 | -975.70 | |
| | maximum | -130.66 | 296.50 | | 162.47 | -482.09 | | 951.94 | 941.51 | | 976.40 | 980.81 | | 48.80 | -141.83 | | -340.41 | -656.38 | |
| HR | mean | -789.08 | -835.00 | 0.432 | -778.47 | -872.69 | 0.508 | 593.61 | 658.66 | 0.816 | 827.83 | 866.22 | 0.750 | -897.52 | -877.59 | 0.492 | -907.90 | -902.73 | 0.741 |
| | minimum | -986.94 | -989.37 | | -969.83 | -985.42 | | -428.00 | -379.18 | | 444.02 | 592.50 | | -974.14 | -985.92 | | -970.22 | -981.92 | |
| | maximum | 192.99 | 196.79 | | -198.72 | -640.71 | | 932.78 | 952.65 | | 978.98 | 989.21 | | -562.23 | -308.59 | | -667.59 | -685.94 | |
| HL | mean | -755.62 | -832.99 | 0.650 | -778.58 | -843.85 | 0.198 | 567.18 | 644.93 | 0.606 | 802.23 | 813.47 | 0.951 | -882.28 | -875.86 | 0.659 | -901.99 | -878.86 | 0.384 |
| | minimum | -976.93 | -966.10 | | -975.19 | -984.35 | | -492.94 | 88.43 | | 263.63 | 500.76 | | -984.53 | -983.22 | | -975.76 | -983.85 | |
| | maximum | 4.89 | -467.66 | | -70.41 | -434.82 | | 892.10 | 905.32 | | 980.18 | 978.90 | | -372.18 | -423.19 | | -673.26 | -615.18 | |
| HB | mean | -822.76 | -865.64 | 0.686 | -831.12 | -874.98 | 0.371 | 586.93 | 680.33 | 0.411 | 822.50 | 892.29 | 0.244 | -851.28 | -892.51 | 0.315 | -855.03 | -897.12 | 0.234 |
| | minimum | -989.12 | -986.31 | | -985.38 | -989.76 | | -700.42 | -116.18 | | 191.91 | 598.19 | | -985.57 | -988.52 | | -985.65 | -988.75 | |
| | maximum | 341.26 | -279.70 | | 130.42 | -257.07 | | 961.94 | 942.67 | | 988.27 | 987.48 | | -422.47 | -345.52 | | -3.17 | -572.06 | |
| HF | mean | -820.11 | -883.07 | 0.556 | -809.70 | -898.78 | 0.189 | 590.65 | 703.18 | 0.477 | 845.91 | 887.14 | 0.704 | -875.76 | -888.76 | 0.893 | -885.69 | -898.83 | 0.371 |
| | minimum | -994.47 | -983.81 | | -987.79 | -992.88 | | -339.06 | 234.48 | | 265.50 | 635.69 | | -982.55 | -976.88 | | -973.86 | -984.24 | |
| | maximum | 89.24 | -616.59 | | -270.41 | -698.63 | | 955.19 | 942.09 | | 973.96 | 973.07 | | -489.14 | -728.27 | | -519.20 | -476.33 | |
| PO | mean | -751.33 | -719.77 | 0.358 | -801.08 | -715.60 | 0.484 | 673.55 | 633.05 | 0.768 | 755.69 | 670.83 | 0.309 | -907.59 | -893.24 | 0.581 | -922.43 | -927.43 | 0.371 |
| | minimum | -981.07 | -967.69 | | -980.91 | -981.76 | | -199.75 | -197.04 | | 19.86 | 87.70 | | -989.24 | -991.86 | | -989.52 | -992.88 | |
| | maximum | -1.49 | -172.16 | | -428.76 | 72.42 | | 955.62 | 980.10 | | 980.47 | 967.42 | | -524.31 | -484.03 | | -706.27 | -671.19 | |
| PC | mean | -794.64 | -836.13 | 0.440 | -803.61 | -852.77 | 0.211 | 720.91 | 758.35 | 0.556 | 782.09 | 822.95 | 0.309 | -933.35 | -932.86 | 0.883 | -945.27 | -943.59 | 0.980 |
| | minimum | -981.14 | -981.15 | | -968.22 | -985.32 | | 213.06 | 464.14 | | 172.68 | -55.00 | | -989.00 | -990.06 | | -987.98 | -993.51 | |
| | maximum | -224.02 | -533.26 | | -166.30 | -428.64 | | 962.96 | 964.21 | | 961.60 | 984.79 | | -727.42 | -702.74 | | -831.28 | -770.34 | |

Mann-Whitney Test

**Subtitle:** MD = Menière's disease; C = control; NO = eyes open, stable surface; NC = eyes closed, stable surface; PO = eyes open, unstable surface; PC = eyes closed, unstable surface; HR = eyes closed, stable surface, and head to the right; HL = eyes closed, stable surface, and head to the left; HB = eyes closed, stable surface, and head backward; HF = eyes closed, stable surface, and head forward; AB = synchronization index between the platforms referring to the toes and heel of the left foot; CD = synchronization index between toes and heel of the right foot; AC = synchronization index between the two heels; BD = synchronization index for the toes of the two feet; AD: synchronization index between the left heel and the toes of the right foot; BC: synchronization index between the toes of the left foot and the heel of the right foot

**Table 4.** Comparative analysis of the frequency variations for postural sway in the eight conditions of the Tetrax Interactive Balance System (Tetrax IBS™) for the experimental and control groups

| Conditions | F1 | | | F2-F4 | | | F5-F6 | | | F7-F8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MD | C | p-value | MD | C | p-value | MD | C | p-value | MD | C | p-value |
| NO | 17.10 ± 8.60 | 10.86 ± 4.57 | 0.000[a*] | 8.83 ± 4.10 | 5.66 ± 1.42 | 0.000[a*] | 3.69 ± 2.45 | 2.39 ± 0.73 | .002[a*] | 0.54 ± 0.30 | 0.38 ± 0.12 | 0.005[a*] |
| NC | 16.25 ± 10.63 | 12.05 ± 5.95 | 0.000[a*] | 14.02 ± 6.98 | 8.33 ± 2.42 | 0.000[a*] | 5.64 ± 4.33 | 3.14 ± 1.08 | 0.000[a*] | 0.86 ± 0.71 | 0.53 ± 0.22 | 0.000[a*] |
| PO | 26.07 ± 14.99 | 18.36 ± 7.65 | 0.020[a*] | 10.61 ± 4.03 | 6.71 ± 1.61 | 0.000[b*] | 5.29 ± 2.51 | 3.46 ± 1.05 | 0.000[a*] | 0.89 ± 0.43 | 0.61 ± 0.21 | 0.001[a*] |
| PC | 24.61 ± 17.95 | 21.22 ± 14.42 | 0.225[a] | 16.30 ± 7.03 | 11.53 ± 3.34 | 0.003[a*] | 6.46 ± 3.73 | 5.02 ± 1.60 | 0.166[a] | 1.11 ± 0.56 | 0.91 ± 0.31 | 0.155[a] |
| HR | 15.91 ± 10.37 | 10.89 ± 4.97 | 0.004[a*] | 13.25 ± 8.49 | 7.39 ± 1.77 | 0.000[a*] | 4.70 ± 2.93 | 2.85 ± 0.93 | 0.001[a*] | 0.70 ± 0.56 | 0.49 ± 0.18 | 0.206[a] |
| HL | 14.66 ± 9.05 | 11.38 ± 6.25 | 0.249[a] | 11.82 ± 6.02 | 7.08 ± 1.94 | 0.000[a*] | 5.05 ± 3.58 | 2.93 ± 1.15 | 0.001[a*] | 0.72 ± 0.56 | 0.55 ± 0.22 | 0.234[a] |
| HB | 16.28 ± 9.79 | 14.37 ± 7.50 | 0.581[a] | 12.29 ± 5.89 | 7.75 ± 1.66 | 0.000[a*] | 4.72 ± 3.38 | 2.84 ± 0.82 | 0.000[a*] | 0.75 ± 0.67 | 0.55 ± 0.20 | 0.397[a] |
| HF | 14.15 ± 7.38 | 13.24 ± 6.39 | 0.704[a] | 12.36 ± 7.32 | 7.70 ± 2.37 | 0.000[a*] | 5.15 ± 3.85 | 2.90 ± 1.27 | 0.000[a*] | 0.72 ± 0.53 | 0.56 ± 0.26 | 0.194[a] |

[a]Mann-Whitney Test; [b]t student Test; *Statistically significant difference between the groups (p-value ≤0.05)

**Subtitle:** MD = Menière's disease; C = control; NO = eyes open, stable surface; NC = eyes closed, stable surface; PO = eyes open, unstable surface; PC = eyes closed, unstable surface; HR = eyes closed, stable surface, and head to the right; HL = eyes closed, stable surface, and head to the left; HB = eyes closed, stable surface, and head backward; HF = eyes closed, stable surface, and head forward

**Table 5.** Descriptive values and comparative analysis of the risk of falling index in the sensory conditions of the Tetrax Interactive Balance System (Tetrax IBS™) for the experimental and control groups

| Groups | Risk of falling | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Minimum Value | Median | Maximum Value | p-value | Low nº (%) | Moderate nº (%) | High nº (%) | p-value |
| MD | 44.24 | 30.37 | 4 | 38 | 100 | 0.000[a*] | 16 (47.06%) | 8 (23.53%) | 10 (29.41%) | 0.000[b*] |
| C | 16.35 | 9.14 | 0 | 16 | 36 | | 34 (100%) | 0 | 0 | |

[a]Mann-Whitney Test; [b]Chi-square Test; *Statistically significant difference between the groups (p-value <0.05)

**Subtitle:** MD = Menière's disease; C = control; nº = number of patients; % = percentage

## DISCUSSION

The postural control of patients with Menière's disease without symptoms or signs of acute phase compared with the control group was assessed through the static balance platform in the Tetrax IBS™. No study for Menière's disease applying a postural control assessment with this specific type of static posturography was encountered, suggesting the originality of our research.

In Brazil, the parameters of the Tetrax IBS™ posturography changed for patients with vestibular hypofunction[(12)], type-2 diabetes mellitus[(13)], or vestibular migraine[(14)], similar to our research, suggesting postural control disorders from vestibular, visual, somatosensory dysfunction, and/or in the interaction of these systems in the central nervous system.

The instability measured by the stability index in the Tetrax IBS™ was greater in patients with Menière's disease for all sensory conditions assessed, showing an inability to compensate for postural changes in situations where visual, somatosensory, vestibular assessments and/or their interactions in the central nervous system were altered or canceled. Similar findings were found when applying the Tetrax IBS™ in patients with vestibular hypofunction[(12)], type-2 diabetes mellitus[(13)], and vestibular migraine[(14)], indicating that these conditions may also interfere with the patient's overall stability.

The weight distribution index in the Tetrax IBS™ behaved similarly between the Menière's disease and control groups for all sensory conditions. This indicates that patients with Menière's disease can distribute their weight adequately over the support base during the period between vertigo attacks. Patients with vestibular hypofunction[(12)] presented significant differences in relation to the control group only for the eyes closed on a cushion, which is understood to involve vestibular stress. Patients with vestibular migraine[(14)] presented significant differences in relation to control group for a stable surface with eyes open and closed, and with the head forward or backward, suggesting central nervous system and vestibulo-cervical disorders by suppressing the visual system and stimulating the vestibular system and the cervical segment.

In the Menière's disease group, the synchronization index of postural sway in the Tetrax IBS™, similar to that of the control group, found adequate lower limb coordination, with a symmetrical pattern in the different sensory conditions for the six synchronizations: between the heels and the toes of each foot, between the two heels and the toes of the two feet, and the two diagonals, between the heel of a foot with the toes of the contralateral foot[(8)]. Patients with vestibular hypofunction[(12)] and type-2 diabetes mellitus[(13)] showed significant differences in relation to the control group for some synchronization indices of postural sway, indicating changes in the quality and efficiency of the compensation and coordination mechanisms between the heels and toes of each foot, in the simultaneous activation of the parallel plates in the Tetrax IBS™ platform. In addition, it indicates the influence of these conditions on these structures and on the mechanism of fine postural control[(8)].

In our study, patients with Menière's disease showed significantly greater postural sway in the Tetrax IBS™ at medium-low frequency variations in all eight sensory conditions; at medium-high frequency variations in seven conditions; at low-frequency variations in four conditions, and high-frequency variations in three conditions. The sway increase within a specific frequency variation suggests visual dysfunction (low frequency); vestibular dysfunction, especially peripheral (medium-low frequencies); somatosensory dysfunction (medium-high frequencies), and central vestibular dysfunction (high frequencies)(8). The postural sway increase demonstrated vestibular, visual, and somatosensory dysfunctions or in the interaction of these systems in patients with Menière's disease. Similar findings were found in the Tetrax IBS™ in patients with vestibular hypofunction(12) and type 2 diabetes mellitus(13), showing that these disorders may also present changes in the vestibular, visual, and somatosensory systems. Vestibular migraine(14) presented more significant results for the medium-low and medium-high frequency variations, specifically vestibular abnormalities, fatigue, and/or somatosensory reactions measured by the motor system of the lower extremities and backbone(8).

The risk of falling index in the Tetrax IBS™ was considered moderate for the Menière's disease group and mild for the control group. The risk of falling index also differed within the groups, since all individuals in the control group presented a low risk of falling, while in addition to a mild risk in almost half of the casuistic in the Menière's disease group, moderate and high risks were also found in just over half the cases. This indicates that patients with Menière's disease are more prone to falling than healthy individuals. Excessive visual stimulation in Menière's disease contributes to unstable posture due to vestibular dysfunction, leading to falling(15). In severe and long-term cases, falling is frequent(16) and may occur even at the late period of the disorder, after the acute attacks of vertigo end(17). Identifying the risk of falling with the Tetrax IBS™ allows for proposing preventive therapeutic strategies. Patients with vestibular hypofunction(12) and type 2 diabetes mellitus(13) also presented a moderate risk of falling, while those with vestibular migraine(14) presented a mild risk of falling in the Tetrax IBS™, thus highlighting the importance of such an assessment for these patients.

It is difficult to establish a quantitative comparison of our findings using the Tetrax IBS™ in patients with Menière's disease with other posturography procedures using other types of assessment protocols and parameters, that characterize sensory information differently or that use static, mobile, or virtual reality platforms. Other types of posturography have shown regular results, non-specific changes, or response patterns compatible with peripheral vestibular dysfunction, neurological, visual, or mixed changes, as well as visual or somatosensory dependence in Menière's disease(9,10,15,16,18-28). One explanation argues that poor postural performance in Menière's disease may be related to inadequate integration of vestibular, visual, and somatosensory information and incomplete central compensation(29).

Research with different static posturographies has identified that patients with Menière's disease have higher sway speed and displacement of the pressure center than healthy individuals for the eyes open and closed conditions, both on stable and unstable ground(15-18,20,22,23), thus suggesting strategies for the maintenance of body balance and vestibular rehabilitation guidance(23).

The association of visual stimuli with virtual reality in posturography with mobile platforms revealed values with significant changes in sway speed with eyes closed and under visual stimuli, expressing visual dependence and increased diagnostic sensitivity(24). The static posturography with virtual reality provided significant findings of change in sway speed and the ellipse area in sensory conditions of visual deprivation and visual conflict under optokinetic and vestibulo-visual stimuli(25).

Dynamic posturography provides typical data of vestibular dysfunction in Menière's disease(9,10,26), correlated with the time since the last vertigo attack(10). Excessive visual stimuli seem to contribute to postural instability and falling in patients with severe vestibular disorders(15). Dynamic posturography can be more useful to monitor the treatment of patients than for disease diagnosis(30).

Posturographies assess postural control differently; static posturography assesses the capacity of maintaining balance on a stable platform with eyes open or closed, through sensors that transform the mechanical sways from the friction force of the feet on the platform into electrical signals. Static posturography using virtual reality recreates environments and situations that measure the individual's postural responses under different visual stimuli. Conversely, static posturography in the Tetrax IBS™ measures variations in the vertical force exerted by the heels and tips of the feet, characterizing body sway through the displacement of the individual's pressure center. In contrast, dynamic posturography measures postural adjustment in response to translations and rotations of the support surface, visual environment, or both, establishing patterns of vestibular, somatosensory, and/or visual dysfunction, visual dependence or preference, dysfunction severe, and aphysiological.

Static and/or dynamic posturography, with or without virtual reality, are clinically useful to functionally assess balance by evaluating the contributions of vestibular, visual, and somatosensory cues for the maintenance of postural control in different sensory conditions. Although the posturography results tend not to locate or lateralize injuries or determine their causes, they are useful for the functional measurement of postural control by assessing the patient's ability to adequately use vestibular information to plan the vestibular rehabilitation and favor the detection of simulators, upon inconsistent results.

The sample size was a potential limitation of this study. Many patients could not be included due to the exclusion criteria. Despite this, we could identify significant changes in postural control by comparing the control group with the Menière's disease group using the Tetrax IBS™ posturography. Further studies with other instruments for assessing vestibular function and body balance are necessary to assess the evolution of vestibular damage and its influence on postural control in patients with Menière's disease.

In the posturography of the Tetrax IBS™, changes in postural control related to the stability index, frequency of postural sway, and risk of falling index, in situations with or without visual deprivation and somatosensory or vestibular alterations, may be useful to suggest, planning, and monitoring the treatment of labyrinthine disorders, including Menière's disease, seeking the functional restoration of body balance. A more comprehensive diagnosis of vestibular disorders may help prevent falls in patients suffering from dizziness and imbalance, thereby reducing public expenses in social assistance tertiary care.

## CONCLUSION

Patients with Menière's disease present impaired postural control characterized by changes in the stability index, frequency of postural sway, and risk of falling index.

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