http://dx.doi.org/10.1590/S2317-64312015000200001469

Computerized dynamic posturography in the assessment of body balance in individuals with vestibular dysfunction

Posturografia dinâmica computadorizada na avaliação do equilíbrio corporal de indivíduos com disfunção vestibular

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ABSTRACT

Purpose: To evaluate the body balance of patients with vestibular dysfunction with computerized dynamic posturography. **Methods:** Study of 116 individuals with peripheral vestibular dysfunction, aged 22 years and 6 months old to 94 years and 1 month old were subjected to a complete otoneurological assessment; computerized dynamic posturography with a sensory organization test, motor control test, and adaptation test; and an otolaryngological evaluation. **Results:** The sensory organization test detected balance changes with the most sensitivity. Condition 4, during which the patients stood with their feet apart with them placed on the sensors of the reference surface and with their eyes open; condition 5, during which the patients remained in position with their eyes closed; condition 6, during which the patients kept their eyes open and their visual field underwent anterior-posterior displacement; and all three conditions when the reference surface moved in a see-saw manner were the conditions during which the participants had the greatest difficulties. The results showed patients with composite scores between 60 and 69, which indicated a higher occurrence of falls compared to the risk of falls, during condition 4 of the sensory organization test and among the elderly. Women had a higher number of falls during testing. **Conclusion:** Computerized dynamic posturography, which concisely detected body balance changes, can be used in the diagnosis of vestibular disorders to complement vestibular assessments.

Keywords: Postural balance; Proprioception; Dizziness; Vestibular function tests; Aging

RESUMO

Objetivo: Avaliar o equilíbrio corporal de pacientes portadores de disfunção vestibular, por meio da posturografia dinâmica computadorizada. **Métodos:** Estudo com 116 indivíduos com disfunção vestibular periférica, com idades entre 22 anos e 6 meses e 94 anos e 1 mês. Foram submetidos à avaliação otoneurológica completa, avaliação otorrinolaringológica, além da posturografia dinâmica computadorizada com os testes de organização sensorial, controle motor e de adaptação. **Resultados:** O teste de organização sensorial foi o mais sensível para detectar alterações do equilíbrio e a condição 4, em que os pacientes permanecem na posição ortostática, com os pés afastados e sobre os sensores da superfície de referência, com os olhos abertos; condição 5, na qual os pacientes continuam na posição com os olhos fechados e a condição 6, em que os pacientes mantém os olhos abertos e o campo visual sofre deslocamentos anteroposteriores. Nas três condições, a superfície de referência oscila com movimentos similares à gangorra e foram as que os participantes apresentaram maiores dificuldades. Houve maior ocorrência de quedas se compararmos ao risco de quedas, avaliado quando o paciente tem pontuação entre 60 e 69 no índice de equilíbrio, principalmente a partir da condição 4 do teste de organização sensorial e entre os idosos. As mulheres tiveram maior número de quedas durante os testes. **Conclusão:** A posturografia dinâmica computadorizada detectou as alterações relacionadas ao equilíbrio corporal, auxiliando no diagnóstico das disfunções e complementando a avaliação vestibular.

Descritores: Equilíbrio postural; Propriocepção; Tontura; Testes de função vestibular; Envelhecimento

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Conflict of interests: No
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Received on: 9/1/2014; **Accepted on:** 5/26/2015

INTRODUCTION

Vestibular dysfunction can affect people of all ages for numerous reasons. Some symptoms, such as imbalance, falls, nausea, vertigo, hearing loss, and tinnitus, occur because of acute or chronic impairment of the vestibular and auditory systems. In addition, vestibular dysfunction often affects communication skills, psychological behavior, and school performance, especially in children. In adults, balance disturbances can influence quality of life by affecting social and professional performance. Thus, it is important to assess the factors, such as comorbid conditions and drug use, which may result in dysfunction of the vestibular system in patient populations with intact physical and intellectual activity[1-3].

The complex integration of the sensory and motor systems is required for appropriate body balance, which allows the harmonic and precise maintenance of a stable posture (static balance) or motion (dynamic equilibrium). Postural impairments in individuals occur because of proprioceptive (perception of posture and body movement), vestibular (position and movement of the head), or visual (spatial relationships) alterations, which cause balance problems and interfere with quality of life[2,4]. Deterioration in balance, which can be a natural part of aging or a result of a disease, is found more often in the elderly than in young individuals[5].

The vestibular system, which consists of the peripheral sensory system, central processor, and motor response mechanism, detects peripheral stimulation and transmits it to the extra-ocular muscles and spinal cord through the vestibulo-ocular reflex (VOR) and vestibulospinal reflex (VSR), respectively. The VOR operates when the head is in motion to maintain clear vision. The purpose of the VSR is to maintain cephalic and postural stability, avoid falls, and generate compensatory movements. Both the VOR and VSR are monitored by the central nervous system and, when necessary, adjusted by an adaptive processor[6].

Electronystagmography, which is used to identify dysfunctions in the vestibular system and its central connections, analyzes the vestibular system and the neural structures involved in the maintenance of body balance through various vestibular and oculomotor signals and detects changes in these structures. However, electronystagmography and its variants only assess the VOR when evaluating the vestibular system[6,7].

The advent of computerized dynamic posturography (CDP) has made the classical vestibular system tests more complete. CDP can be used test patients who present with complaints that are related to body balance and who have not been diagnosed by conventional tests. Clinically, the importance of these findings lies in the possibility of diagnosing body balance disorders and, subsequently, identifying whether these disorders are a consequence of a problem in afferent or sensory integration, motor response inefficiency, or both. Therefore, the conventional vestibular tests cannot be replaced by CDP, but CDP can complement the results of these tests in specific situations, such as analyses of the VSR and sensory analyses of balance disorders[8-10].

CDP analyzes visual, proprioceptive, and vestibular information, their central interaction, and motor responses of the lower limbs and body to a sensor-based force platform in order to assess body movements in different situations[6,8,10-12]. Three tests that evaluate the body balance of individuals in the orthostatic position and the functional state of the vestibulospinal system are the sensory organization test (SOT), motor control test (MCT), and adaptation test (ADT), which estimate the functional abilities of the patient[12].

Several studies suggest that the use of CDP in vestibular diagnosis and research is effective as a supplementary test in evaluating body balance and providing information that conventional tests do not, such as information mainly on the spinal reflexes and sensory systems that are responsible for balance and posture[7,10,11,13-15].

Considering the current lack of research on the use of CDP and its use as a supplementary test of conventional vestibular assessments, this study was conducted to assess the effectiveness of CDP in evaluating the body balance of individuals with peripheral vestibular dysfunction.

METHODS

This was a cross-sectional retrospective study that was based on survey data that was collected from the medical records of patients who were treated from January 2011 to January 2012 and that was conducted under the supervision of the lecturers who are responsible for the Discipline of Otoneurology of the *Universidade Federal de São Paulo* (UNIFESP). This study was approved by the *Plataforma Brasil* under paragraph 04896812.9.0000.5505 of the CAAE and Research Ethics Committee, protocol no. 040325/2012.

The sample was composed of 116 patients of both genders between 22 years and 6 months old to 94 years and 1 month old. The participants were subjected to complete otoneurological assessments, which included anamnesis, otoscopy, tonal and vocal audiometry, acoustic immittance measures, and vestibular evaluations with vectonystagmography or computerized videonystagmography, in addition to CDP. The patients were diagnosed with a vestibular dysfunction by an otolaryngologist based on abnormal findings of the vestibular exam and complaints related to dizziness and/or imbalance.

The sample consisted of 22 adult women (18.97%) who were 34 and 59 years old, 41 elderly women (35.34%) who were between 60 and 90 years old, 23 adult men (19.83%) who were between 22 and 59 years old, and 30 elderly men (25.86%) who were between 60 and 94 years old. This stratification was performed in accordance with the Statute of the Elderly of the Ministry of Health[16].

It was hypothesized that all of the individuals who were

included in the study had a diagnosis of unilateral or bilateral peripheral vestibular dysfunction, which includes disorders of the inner ear (labyrinth) and/or the vestibular branch of the eighth cranial nerve. These disorders can be confirmed by vestibular exam and clinical history.

For the study, patients with the following conditions were excluded: central vestibular dysfunction or normal results on the vestibular exam, motor impairments, an inability to follow simple verbal commands, serious or uncompensated visual impairment, neurological disorders, major psychiatric disorders, alcohol ingestion 24 h prior to the tests, and/or the use of drugs that affect the labyrinth or central nervous system. In addition, patients who could not undergo body balance rehabilitation over the six months of the study were excluded.

Three basic tests were performed during the CDP: the SOT, which examines sensory organization; MCT, which evaluates the intensity and coordination of the motor response to stimuli while the subject is in an orthostatic posture; and the ADT, which examines the adaptation of the motor system. The equipment used consisted of the Equitest System® (Version 4.0, NeuroCom, Clackamas, OR, USA)[7,11].

The equipment has a reference surface where the patient stands. The platform has pressure sensors, which are activated as a function of the displacement of the weight of the patient on the sole of the foot in response to displacement of the body. The reference surface is surrounded by a movable visual field, which displays anterior/posterior displacement that alters visual information (Figure 1).

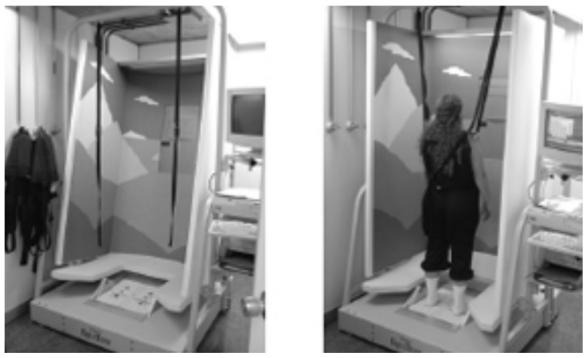
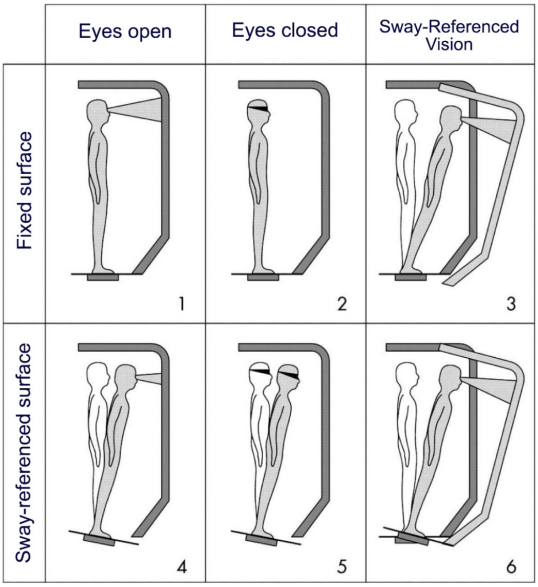


Figure 1. Computerized dynamic posturography

The paradigms that were used to evaluate the sensory and motor integration components included quantification of the following: visual, vestibular, and somatosensory information; the mechanisms of central integration, which determine the best way to use the input information; the response to various sensory stimuli; and the motor response resulting from the input stimulation.

The SOT is the only test available that provides quantitative data of the functionality of the three systems that influence balance. This test has six conditions that subject the individual to different types of sensory information and forces them to use different strategies to maintain body balance (Figure 2).



Source: NeuroCom (http://resourcesonbalance.com/program/role/cdp/protocols.aspx)

Figure 2. Different conditions were performed in the sensory organization test

Condition 1: The patient stands with their feet apart on the sensors of the reference surface with their eyes open,

Condition 2: The patient maintains the position in Condition 1 with their eyes closed,

Condition 3: The patient keeps their eyes open but the visual field undergoes anterior-posterior displacement,

Conditions 4, 5, and 6: The tasks in conditions 1, 2, and 3 are repeated, but the reference surface fluctuates with movements that are similar to those of a seesaw.

Each condition was repeated three times. During the examination, the letters NS, which means *no score*, appeared if the patient did not perform the test appropriately. The word *FALL* indicated that the patient stopped the test and that the equipment identified a fall because the patient was no longer standing on the reference sensors.

When the six conditions were completed, a *composite* was calculated, which was the balance index recorded during the exam when comparing the anteroposterior balance of the individual during each test and taking into account the stability limit of 12.5°, which was calculated regardless of the scores in conditions 1 and 2 by adding the scores of conditions 1 and 2 to the balance scores of each test in sensory conditions 3, 4, 5, and 6 and dividing this sum by the total number of tests. The individuals that oscillated within the limits of stability had very low scores. The score ranged from zero to 100. Scores from zero to 59 indicated a fall because the individual had to move his position on the reference surface, scores from 60 to 69 indicated a fall risk, and scores from 70 to 100 were considered normal.

The MCT consisted of a sequence of horizontal movements of the platform, which were called translation. The translations were from center back and center forward and lasted less than

a second. The amplitude of each translation was measured according to the patient's height, and the amplitudes were divided into three levels: small, medium, and large. The symmetry of the weight of the patient was determined before and after the translations of the force platform in order to assess if the patient maintained a uniform weight during the procedure. As in the SOT, the examination showed the letters NS when the patient was not scored.

The ADT involved a series of movements of the platform that automatically extracted postural responses. Two conditions were used in the ADT: toes up and toes down. These toe movements were caused by movements of the equipment, and the axis of motion was in the ankles. Their measurements showed the adaptation of the motor system. This test was performed five times with different movements of the platform each time. The oscillation and the center of force of the patient in both feet in each condition were displayed. When the patients was unable to perform on the test, the score on the test was listed as a *FALL*, indicating that there was a fall during the test.

The results of this study were analyzed with the Two Proportion Equality test. The level of significance was set at 0.05 (5%), and all of the confidence intervals were built with 95% statistical confidence.

RESULTS

In this study, we selected 116 individuals, including 64 females and 52 males of different ages, who had complaints of dizziness and who underwent CDP.

When the results of the three tests were compared according to gender, age, body balance alterations, and those who were classified as falls and fall risks, older women had a higher prevalence of imbalance and falls compared to adult women, adult men, and the elderly. The most sensitive test for detecting changes in balance was the SOT, and condition 4 showed a higher risk of falls as it had more abnormal cases compared to the other tests. Conditions 5 and 6 showed a greater number of people with falls during the tests. The MCT was the test with the lowest rate of falls in the sample, and condition 1 of the SOT showed the lowest risk of falls (Figure 3).

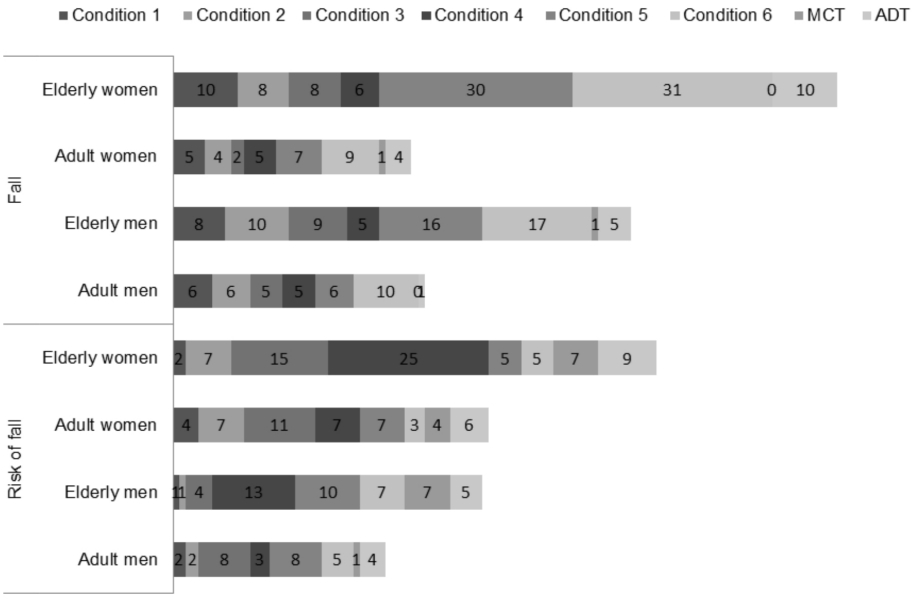
When comparing the conditions of the SOT, more individuals showed instability and a fall risk during condition 4. The highest rate of falls in the whole sample occurred in condition 6. Condition 1 at the beginning of the test showed the abilities of the individuals (Figure 4).

The balance index showed that 63.41% of the elderly women had scores below the normal range, which was consistent with changes in balance, resulting in falls during the procedure, in these women. There were fewer men and adult women in the "fall risk" group (Figure 5).

The groups were assessed separately with respect to the implementation of the tests and the falls. Subsequently, the whole population was compared.

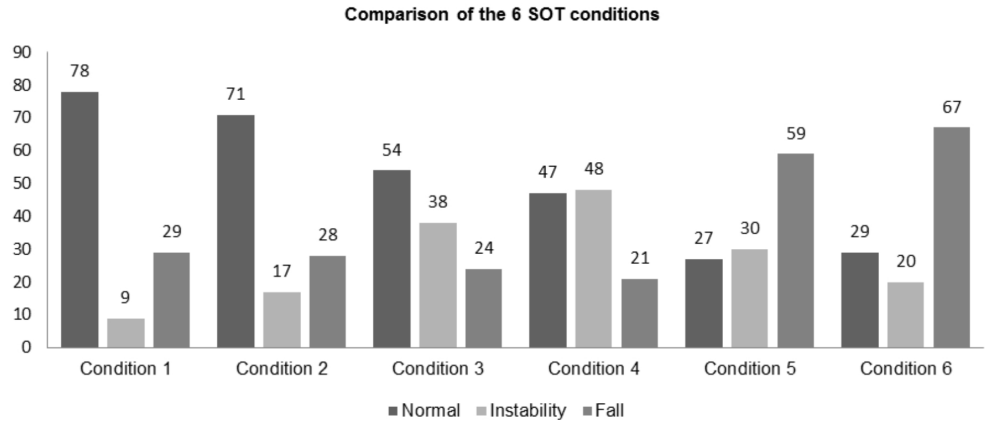
In the four groups, condition 6 of the SOT stood out because of the number of individuals that had falls during the test as a result of difficulties with moving around the reference platform, including 42.9% of the adult women, 77.8% of the elderly women, 41.4% of the adult men, and 65.2% of the elderly men.

In the total population (116 individuals), the number of individuals who did not complete the tests in conditions 5 and 6 did not significantly differ because the majority of the falls occurred in these conditions: 50.9% and 57.8%, respectively.



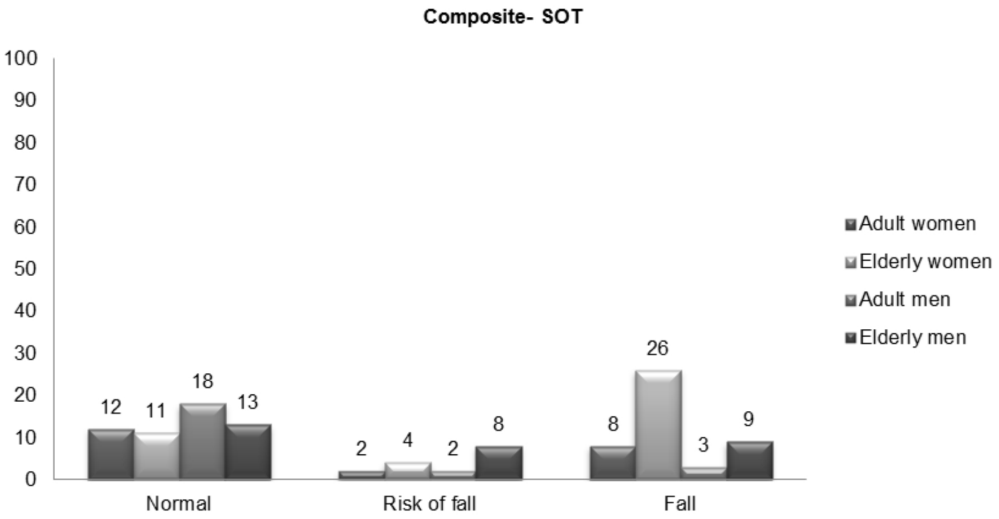
Note: Condition 1 = eyes open and fixed surface; Condition 2 = eyes closed and fixed surface; Condition 3 = eyes open, fixed surface, and sway visual surround; Condition 4 = eyes open and sway-referenced surface; Condition 5 = eyes closed and sway-referenced surface; Condition 6 = eyes open, sway-referenced surface, and sway visual surround; MCT = motor control test; ADT = adaptation test; CDP = computerized dynamic posturography

Figure 3. Comparison of the three CDP tests according to the gender and age group of the total sample for the presence of falls and risk of falls



Note: CDP = computerized dynamic posturography; SOT = sensory organization test; Condition 1 = eyes open and fixed surface; Condition 2 = eyes closed and fixed surface; Condition 3 = eyes open, fixed surface, and sway-referenced surface; Condition 4 = eyes open and sway-referenced surface; Condition 5 = eyes closed and sway-referenced surface; Condition 6 = eyes open, sway-referenced surface, and sway visual surround

Figure 4. Comparison of the CDP SOT results of the 116 individuals



Note: SOT = sensory organization test

Figure 5. Representation of the number of individuals according to the results obtained in the balance index in each group among the whole sample

In general, for all of the groups, the comparison between the MCT and ADT tests showed a significant difference because more individuals showed reductions in the ADT than in the MCT in all of the age groups and in both males and females.

DISCUSSION

CDP is an important tool that can complement conventional tests as it shows evidence of changes in body balance in the majority of cases and provides information to establish an otoneurological clinical picture. CDP was efficient in the present study, mainly in the evaluation of the elderly population, because imbalance and falls in this population result from the cumulative effects of diseases and degenerative phenomena that are typical of aging[9-11,17-21].

This study found that, in the SOT test, condition 4 showed that the elderly population was most affected with respect to falls[22,23], which probably indicated a difficulty in stabilizing the image on the retina in patients with vestibular disorders when facing an unstable supporting surface and which may explain the body oscillation in the condition mentioned. Similarly, body oscillation can be explained by other hypotheses, such as neurological impairment as a result of conflicting afferent stimuli[24]; dependence on proprioceptive afferents that are associated with the inability to compensate with visual support[25]; dependence of vision on postural control, especially when facing a rough surface[26,27]; inadequate motor response when proprioception is modified[28]; alteration in vestibular-visual integration, which is hampered by age[22]; or all of the above.

Conditions 5 and 6, which are more difficult to implement due to the decrease in the proprioceptive sensory afferents of the ankles, together with the absence of visual support, as was shown in the results of this study, require higher efficiency of the vestibular system in the maintenance of balance[28]. Condition 6 was the situation that best evaluated the vestibular system

because the patient was free on the platform and did not have any visual information[8,14].

The functional impact of peripheral and/or central vestibular abnormalities on patients' body balance can be categorized as the inability to use vestibular information, which was shown as abnormal results in conditions TOS5 and TOS6 or only TOS5. The inability to annul/cancel the influence of inaccurate visual information, which was shown as abnormal results in conditions TOS3 and TOS6 or only TOS6 and the combinations of that described above, elicited abnormal results in conditions TOS3, TOS5, and TOS6. Patients with peripheral vestibular disorders showed abnormal balance, especially in conditions TOS5 and TOS6, which require normal vestibular function for the maintenance of body stability, and this completed the analysis of the findings and agreed with the information collected from the patients in the SOT[18].

The MCT and the other tests that were performed in this study are complementary tests that are used to assist in the diagnosis of patients with postural changes, in addition to contributing to their treatment, as has been shown in a study on the SOT[29,30], which used the scores in conditions 5 and 6 and the MCT in patients with moderate to severe difficulties in postural control to accelerate the process of central compensation and recover functional balance. Another study that used the scores of the six SOT conditions and the balance index of young healthy adults correlated the repetition of the tests with the improvement in the composite score, which aided in the rehabilitation and which can be an additional method of postural assessment[20].

The results of this study were in agreement with those of previous studies[15,18,28,29] because some of the patient population, especially the elderly, had greater difficulty performing the same tasks on the SOT. An increase in age and in the complexity of the tests worsened performance and resulted in falls or instability on the reference platform.

The composite in the SOT showed lower scores in elderly women, which indicated that stability in this population was impaired compared to adults. This impairment might be associated with degeneration of the visual, motor, and proprioceptive systems that elderly individuals experience with increasing age[23]. It was not possible to compare this data with those of published studies because the authors who used CDP in their studies did not divulge the results of analyses of the composite.

There is still much to explore with the ADT because several authors have focused their studies on the SOT and somewhat on the MCT. Few studies report findings with ADT, which is considered part of CDP. Therefore, it was not possible to compare the analyses conducted in this study with others due to the lack of published data.

In general, CDP assists in the diagnosis of vestibular dysfunction. It should be studied further in different populations and vestibulopathies and applied on an individual basis to assist in otoneurological diagnosis and provide important information for therapy with vestibular rehabilitation.

CONCLUSION

Computerized dynamic posturography detected changes that were related to body balance in patients with peripheral vestibular dysfunction, and the main changes were found in the tests that required conflicting information. The computerized dynamic posturography aided in the diagnosis and complemented conventional vestibular evaluations.

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