Evaluation of postural stability in patients with unilateral vestibular hypofunction: effect of feet orientation

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Abstract Objective To investigate effect of feet orientation on the evaluation of the postural stability in patients with unilateral vestibular hypofunction (UVH) by timed standing tests and static posturography (SPG). Methods 65 subjects with UVH and 92 healthy subjects regarded as control group took the postural stability tests in four different stances including (1) standard Romberg test, (2) feet–apart stance test, (3) tandem and (4) unilateral standing tests. In each stance, the postural stability was measured in both eyes open (EO) and eyes closed (EC) conditions. The average time that subjects kept balance before falling in each test conditions was recorded by stopwatch as the timed result. In addition, the sway velocity (SV) of center of foot pressure in the upright stance during standard Romberg test and feet apart stance, regarded as postural stability, was also recorded as SPG. Results (1) The balance-maintaining time of the UVH group in tandem and unilateral standing with EO and EC was decreased ($P<0.001$) compared with the control group. (2) The SVs during standard Romberg test and foot–apart stance with EO were not different between the UVH group and control group ($P = 0.118$ and $0.110$ respectively), but significant with EC condition ($P < 0.001$). (3) For both groups, the SV during foot–apart standing was shorter than standard Romberg test both with EO and EC ($P < 0.05$ and $P < 0.001$). (4) There was no correlation between the balance time and SV for either groups ($P > 0.05$). Conclusions The results suggest that the tandem and unilateral stance tests may provide additional information about the upright stance to the SPG measurement in patients with UVH. The effect of feet orientation on SPG measurements should be considered.

Key words Musculoskeletal equilibrium; Vertigo; Vestibular disease

Introduction

Equilibrium functions can be limited in patients with unilateral vestibular hypofunction (UVH), including inability to stand and walk in dark, cross streets rapidly or stand in a moving vehicle. Valid and responsive performance tests are needed to assess improvements in equilibrium functions and to evaluate the efficacy of clinical intervention. Because there is no “gold standard” in balance assessment, clinicians apply multiple approaches to evaluate balance impairment and to determine whether a patient’s balance has improved over time¹³. Of the two main approaches, posturography can be used to qualify postural sway, while the timed standing test (also called semi–quantitative balance measure) records the duration of one’s ability to maintain posture with different feet orientations, including standard Romberg stance, tan-
den and unilateral stance. Although these methods are used widely\textsuperscript{4-6}, the effects of feet orientation on evaluating postural stability in patients with UVH are not fully understood. In addition, the relationship between these two main measures is largely unknown.

The purpose of this study was to investigate the effect of feet orientation on the postural stability in patients with UVH by static posturography (SPG) and clinical timed standing tests.

Material and Methods

Subjects

A total of 157 subjects were included in this investigation. The control group consisted of 92 healthy volunteers with no history of orthopedic, musculoskeletal or neurological disorders that could potentially affect balance or orientation. They also had negative history of impairment of somatosensory, hearing, vestibular or uncorrectable visual functions. In addition, they had no history of vertigo or ear surgery and were not taking any medications. They were instructed to withhold tobacco or alcohol consumption within 48 hours of testing.

The UVH group was consisted of 65 patients with UVH diagnosed at the Department of Otorhinolaryngology, Union hospital of Tongji Medical College, Huazhong University of Science and Technology between May 2003 and March 2004. Etiologies in this group included Meniere’\textquoteright s disease, sudden deafness, vestibular neuritis and acoustic neuroma (Table 1). All patients in this study received routine videonystagmography (CHARTR , ICS, Schaumburg, IL, US) examination that included spontaneous nystagmus recording, gaze test, saccades test, smooth pursuit test, optokinetic test, positional test and caloric test. Patients who showed a canal paresis of \(\geq30\%\) in caloric test were included in the study. Subjects were excluded if they had received surgical treatment or vestibular rehabilitation therapy, or presented with a history of visual or musculoskeletal impairment. Patients with central nerve system (CNS) diseases were also excluded from this study.

Instrument

SPG was performed using an Active Balancer EAB–100 Version of 2.15 (Sakai Medical Co., Tokyo, Japan). Signals from the force platform were interfaced through an A/D converter to a personal computer (ThinkPad 390X, IBM, US) at a sampling rate of 20 Hz. During SPG measurements, shifts of center of pressure (COP) of feet during upright stance were regarded as representative of postural stability. The postural stability parameters were quantified using a dedicated. In this study, the sway velocity (SV, mm/s) of was used in analyzing postural stability.

Procedures

Subjects were asked to stand on the force platform barefooted as still as possible. The test was repeated in 4 different foot orientations, i.e., (1) standard Romberg test with foot together; (2) foot–apart stance; (3) tandem stance; and (4) unilateral stance. In each orientation, the subject attempted to stand still with eyes open (EO) firstly and then with eyes closed (EC). The test duration for foot orientations 1 to 3 was 60 seconds and 30s for foot orientation 4. A 3 minute break was allowed between consecutive foot orientation tests. This also helped minimize the learning effect. The subject was instructed to keep his/her feet, arm and head still during testing. There was no interaction between the investigator and subject during the test. Testing was conducted in a quite and bright room to minimize interference.

For each foot orientation, a stopwatch was used to record the time between the start of the test and any of the following events: subject took step, opened eyes, touched the boundary or fell, which was regarded as falling. The average standing time before falling (STBF) was used as timed results.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>N</th>
<th>Duration</th>
<th>Affected side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meniere’\textquoteright s disease</td>
<td>20</td>
<td>9m–13y</td>
<td>Left 16, Right 13</td>
</tr>
<tr>
<td>Sudden deafness with vertigo</td>
<td>20</td>
<td>1–7d</td>
<td>Left 12, Right 14</td>
</tr>
<tr>
<td>Vestibular neuritis</td>
<td>8</td>
<td>7d–1m</td>
<td>Left 3, Right 5</td>
</tr>
<tr>
<td>Acoustic Neuromas</td>
<td>2</td>
<td>2y &amp; 5y</td>
<td>Right 2</td>
</tr>
</tbody>
</table>

Table 1 Descriptive Information of Patients with UVH (n=65)
For subjects who did not fall, parameters of body sway were recorded on SPG as quantitative result. For each trial, the quantitative result was recorded if the subject can keep balance in the test period and the subject continued the next foot orientation. Otherwise, the subject was tested for the second or third trial of this foot orientation until he/she cannot fall, and STBF of these two or three trials was recorded as timed result. In one kind of foot orientations, those who failed all three trials would yield no SPG result.

**Date analysis**

The statistical analysis was performed with the SPSS software, version 12.0. In all tests, p-values < 0.05 were considered to be statistically significant.

**Results**

**Timed standing test**

Subjects in both groups were able to maintain standing balance for 60 seconds while taking the standard Romberg and foot-apart stance. However, compared to the control group, the STBFs of the UVH group were decreased in tandem and unilateral stance under both EO and EC conditions (Table 2).

**SPG**

The SVs between the UVH and control groups were not different in the standard Romberg and foot-apart stance with EO \((P > 0.05)\). With EC, UVH group showed decreased SVs compared to the control group in both standard Romberg and foot-apart stances \((P < 0.001)\). In addition, the SV in standard Romberg stance was greater than that of foot–apart stance (Table 3).

**Correlation between timed standing test and SPG**

No comparison was made for the standard Romberg and foot–apart stances because subjects of both groups were able to maintain balance in these two stances for 60 seconds. When comparing for the tandem and unilateral stances, no correlations were found between STBFs and SVs in neither groups.

**Discussion**

Studies of the vestibule-ocular reflex (VOR) and postural control following unilateral loss of peripheral vestibular function provide an important means to investigate how the central nervous system compensates for loss of peripheral sensory informations.
nformation. The postural stability shows the function of vestibulospinal reflex (VSR) while the caloric test reflectes VOR. Many previous studies have demonstrated that the caloric test measures low–frequency stimuli of the lateral semicircular canals whereas the postural sway test may measure function of the vertical semicircular canal, high–frequency stimuli of the lateral semicircular canals and otolith\(^1\). These two kind tests provide different types of information, both helpful in the diagnosis and management of patients with vertigo. Through the study of postural stability in patients with UVH, it was possible to investigate the VSR in patients with abnormal VOR.

Our results indicate decreased postural stability in patients with UVH. However, 14 UVH subjects (21.54%) showed normal results on both timed balance test and SPG, indicating vestibular compensation in these patients. A possible explanation for the disagreement between the VOR and VSR may be that compensation processes of these two reflexes in the CNS are independent and discrepant after unilateral peripheral vestibular lesion. The abnormal VOR can persist for a long time while the postural stability in these patients improves over time. Then, the abnormality of postural stability may only represent active vestibular disorders\(^8\). Furthermore, dysfunction due to the bilateral vestibular loss (BVL) is more serious and lasts longer. The incidence of falls from BVL is significantly greater than from UVL under conditions when visual and somatosensory feedbacks are altered \(^9\). Patients with BVL have much higher risks of disequilibrium and the mechanism of CNS compensation may be complex. However, compensation in UVH can take place very soon, which is useful in analyzing the relationship between VOR and VSR as well as the influence of CNS compensation on these reflexes. In agreement with other previous investigations\(^8\), our study also showed the discrepancy between VOR and postural stability in patients complaining of vertigo. It is therefore necessary to examine both VOR and VSR function in these patients, which will provide us with information on the severity of vestibular disorder, the vestibular function and compensational status. This is helpful for generating customized management strategies for each patient.

In this study, foot orientation influenced postural stability in both groups. Maintaining balance involves controlling the center of body gravity (COG) over the base of support. If the COG sways out of the base of support, falling will happen or the subject will have to take a step to avoid falling \(^10\). Results from both timed balance and SPG indicate the feet position can affect postural stability in normal subjects and in patients with UVH. The decreased SVs in feet–apart stance when compared with standard Romberg stance with both EO and EC agree with results of Unimonen et al\(^11\). A possible explanation is increased base of support resulting in larger area of COG swaying in feet–apart stance, leading to improved postural stability and balance maintenance compared to foot together stance. Therefore, standard Romberg test may be an ideal foot position for SPG test both for the convenience for recording SPG parameters and the appropriate level of stance difficulties. In the standard test procedures recommended by the Japan Society for Equilibrium Research (JSER)\(^12\), closed legs are required. In this study, although none of the subjects in this study fell during the test period in either standard Romberg or foot–apart stance, some subjects in both UVH and control group failed to maintain balance in tandem and unilateral standing tests. This may be due to the fact that COG tends to sway beyond the limits of stability with narrowed supporting surface. Meanwhile, the control of COG becomes increasingly difficult from sensory–conflicts due to altered somatosensory clues in both tandem and unilateral standing. In unilateral standing, the supporting surface is decreased dramatically and maintenance of balance becomes the most difficult. Our study suggests that tandem stance and unilateral standing are excessively difficult in quantitative postural stability assessment even for healthy controls, although timed balance test may still be of use \(^1\).

The lack of relationship between the SVs and
timed balance results in this study may be due to the difference between the precise SPG and robust measurement in timed balance test. The transducers in the forceplate used for SPG are able to record instantaneous shifts in the COP and the computer system can determine minimal body sway. In contrast, the balance–maintaining time measured in timed balance test is a coarse measurement. The timed balance test is considered normal as long as the subject does not fall, while SPG may be abnormal when increased body sway is recorded without subject falling. Gill–Body et al., concluded that the timed balance test in tandem stance or unilateral standing was a complement of quantitative postural stability measurement.

Our study demonstrates that foot position affects postural stability both in patients with UVH and in normal subjects. The mean SV was different between UVH and control groups only in EC condition, whereas balancing times in tandem and unilateral standing stances under both EO and EC conditions were shorter in the UVH group than the control group. This is in agreement with study of Fregly and Graybiel, and confirms that tandem and unilateral standing as more sensitive than standard Romberg test in evaluating balance function in UVH. It is well known that balance maintenance relies on the information from visual, somatosensory and vestibular inputs and their integration in the CNS. The somatosensory clue is altered in tandem and unilateral standing stances in which postural stability is decreased. Balance control is difficult for patients with UVH, especially those without central compensation due to the intrinsic asymmetry of bilateral vestibular signal inputs when somatosensory inputs is altered in various stances. Thus, tandem and unilateral standing have a different clinical value from SPG test, and the combination of these two tests may help enhance evaluation of the balance function in UVH. In addition, tandem walk is employed in a variety of gait assessment test, while unilateral standing is one of vestibular rehabilitation techniques. Patients with asymmetric COG positioning can benefit from unilateral standing training programs. At present, tandem and unilateral standing are used to assess the efficacy of vestibular rehabilitation. Additional clinical applications of these tests in patients with vertigo need to be further explored.

Conclusions

When used in clinical assessment of balance function in patients with UVH, the tandem and unilateral stance test can provide supplementary information regarding the upright stance to the SPG tests. The effect of feet orientation on SPG results should be considered.

Acknowledgements

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References


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