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Evaluation of Uncompensated Unilateral Vestibulopathy Using the Modified Clinical Test for Sensory Interaction and Balance

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Objective: To compare the results of the Modified Clinical Test for Sensory Interaction and Balance (mCTSIB) and the Sensory Organization Test (SOT) of computerized dynamic posturography (CDP) to better understand the role and limitations of the mCTSIB in the diagnosis and rehabilitation of patients with uncompensated unilateral vestibulopathy.
Study Design: Prospective blind study.
Setting: Tertiary referral center.
Interventions: Ninety-eight patients with uncompensated unilateral vestibulopathy were enrolled. After diagnosis was established through ocular motor studies, head roll and Dix–Hallpike tests, caloric testing, and pure tone audiometry, the mCTSIB and SOT were administered simultaneously.
Main Outcome Measure: Composite or comprehensive scores and equilibrium scores.
Results: When composite or comprehensive scores were used to classify subjects as normal or abnormal, the mCTSIB and SOT showed significant agreement ($p > 0.256$). SOT condition 2 (eyes closed on a firm surface) showed a greater degree of correlation than did other conditions; the foam-surface or eyes-open conditions yielded poor correlation coefficients.
Conclusion: The mCTSIB can be used instead of the SOT in screening to distinguish normality from abnormality in dizzy patients with unilateral vestibulopathy. However, the degree of dizziness assessed by SOT condition was poorly correlated with mCTSIB results, especially in conditions with the eyes open and those using a foam surface. **Key Words:** Modified clinical test for sensory interaction and balance—Sensory organization test—Unilateral vestibulopathy.
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The Sensory Organization Test (SOT) of computerized dynamic posturography (CDP) is useful for the evaluation of patients with postural instability. However, its clinical use is limited by the cost, time required for testing, and space requirements of CDP (1,2). The clinical test for sensory interaction and balance (CTSIB) was designed as a less expensive and more rapidly performed method, yielding results similar to those of the SOT. It is now widely used by physicians and physical therapists to evaluate vestibular dysfunction and to monitor the progress of vestibular rehabilitation (1–5).

The Modified Clinical Test for Sensory Interaction and Balance (mCTSIB) is a form of computerized static platform posturography. The original CTSIB included 6 conditions similar to those used in the SOT: condition 1, standing on a firm surface with the eyes open; condition 2, standing on a firm surface with the eyes closed; condition 3, standing on a firm surface with a visual conflict dome; condition 4, standing on a compliant surface with the eyes open; condition 5, standing on a compliant surface with the eyes closed; and condition 6, standing on a compliant surface with a visual conflict dome (6). However, the CTSIB was modified because the conditions using the visual conflict dome (Conditions 3 and 6) yielded scores that did not differ significantly from those obtained under conditions without the dome (7). The mCTSIB includes only 4 conditions: firm EO, standing on a firm surface with the eyes open; firm EC, standing on a firm

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surface with the eyes closed; foam EO, standing on a compliant surface with the eyes open; and foam EC, standing on a compliant surface with the eyes closed (6).

The original CTSIB and the SOT showed good correlation in identifying vestibular disorders (8,9) The mCTSIB is now widely used in practice, but few studies have assessed the correspondence between mCTSIB and SOT scores in patients with uncompensated unilateral vestibulopathy.

In the current study, we sought to determine whether mCTSIB findings were correlated with results obtained from the SOT of CDP in patients with unilateral vestibulopathy.

METHODS

Subject Recruitment and Selection

This prospective study was conducted between January 2011 and January 2012. Consecutive uncompensated unilateral vestibular hypofunction patients who visited the Department of Otorhinolaryngology–Head and Neck Surgery at Korea University Guro Hospital, Seoul, Korea, during this period were enrolled in the study. We defined uncompensated unilateral vestibular hypofunction patients as those who had unilateral vestibulopathy (>25% canal paresis by a bithermal caloric test) and who complained of dizziness, which was defined as a total score higher than 30 on the Korean version of the Dizziness Handicap Inventory (DHI) (10).

Subjects meeting any of the following criteria were excluded: had spontaneous nystagmus by videonystagmography or could not stand for 30 seconds; had additional neurologic signs or symptoms suggesting a central lesion; had a history of neuro-otologic disease; were younger than 18 years or older than 65 years; had a history of orthopedic problems, trauma, hypertension, or diabetes mellitus; or were diagnosed with any other severe underlying disease.

We diagnosed patients with vestibular neuritis or Ménière's disease who matched the following criteria during the active state. However, no active state Ménière's disease or vestibular neuritis was identified during this study. The criteria for vestibular neuritis were acute vertigo with spontaneous horizontal-torsional nystagmus, a canal paresis of 25% or more on a bithermal caloric test, no hearing loss, no additional neurologic signs or symptoms suggesting a central lesion, and no history of neuro-otologic diseases. The criteria for Ménière's disease, according to the American Academy of Otolaryngology– Head and Neck Surgery guidelines, were 2 or more episodes of rotatory vertigo lasting longer than 20 minutes, neurosensory hypoacusia reported on at least one occasion, tinnitus or a sensation of otic fullness in the affected ear, and exclusion of other causes.

Informed consent was obtained from all subjects before study participation, and the study was approved by the institutional review board of the Korea University Medical Center.

Balance Testing

The mCTSIB and SOT were administered to each subject in random order on the same day, using the Smart Balance Master (NeuroCom International, Portland, OR, USA) according to the manufacturer's instructions. Before testing, subjects were provided with safety information about the 2 tests. The system uses a force plate consisting of two 9 × 3 × 18–inch foot plates, each of which rests on 2 force transducers with the sensitive axis oriented vertically. For the foam EO and foam EC conditions, high-density viscoelastic foam was placed on the stationary force platform. The foam dimensions matched those of the force plate, and sway pressures were transmitted through the foam.

For the mCTSIB, subjects underwent 3 test repetitions under each of the 4 conditions described above, and scores were calculated as the average of 3 trials. The examiner asked each subject to stand for 30 seconds to assess his/her center of gravity. Each subject's height was entered into the computer, which then calculated the amount of sway during each test in degrees. A composite score was calculated by averaging scores obtained under the 4 test conditions. Subjects also completed the 6 conditions of the SOT according to the manufacturer's protocol. For both the mCTSIB and SOT, equilibrium scores and normal or abnormal findings were determined according to the manufacturer's criteria for each subject, taking into account height and age (11). The equilibrium score was determined according to each subject's amount of sway under each sensory condition; a small amount of sway yielded a score close to 100. When the amount of sway exceeded the limits of stability, requiring the subject to take a step or the examiner to provide support, an equilibrium score of 0 was assigned. Examiners administering the mCTSIB and SOT were blinded to the results of the other test.

Data Analysis

To calculate the sample size, we used a study power of 80% with a type I error of 5% ($\alpha = 0.05$). Assuming that a 10% difference in the ratio of abnormal findings between tests is significant, we needed 97 patients. Assuming a loss of 10%, 108 patients were needed for this study. Previous studies showed that the sensitivity of the SOT was approximately 50%, and we assumed a sensitivity of less than 40% for the mCTSIB (12–14). Using these values, it was determined that the inclusion of 97 patients was necessary. Assuming a loss of 10%, 108 patients were needed for this study.

All data are expressed as means ± standard deviations. McNemar's test was used to compare mCTSIB and SOT results. The relationship between the 2 tests was evaluated using Spearman's rank correlation coefficients. Correlation coefficients less than 0.25 were designated as ''weak,'' 0.26 to 0.5 as ''fair,'' 0.51 to 0.75 as ''moderate,'' and greater than 0.76 as ''strong''(15,16). All statistical analyses were performed using the SPSS software (ver. 13.0; SPSS Inc., Chicago, IL, USA).

TABLE 1. *Characteristics of patients with uncompensated unilateral vestibulopathy*

Characteristic	Finding
Age (yr)	51.5 ± 14.3
Range	20–65
Sex, n (%)	
Male	43 (43.9)
Female	55 (56.1)
Follow-up (mo)	2.5 ± 1.4
DHI	56.4 ± 11.8
Cause	
Vestibular neuronitis	64
Ménière's disease	34

DHI indicates Dizziness Handicap Inventory.

RESULTS

A total of 169 patients with dizziness and unilateral vestibulopathy were screened, and 106 patients satisfied the inclusion criteria. Eight patients did not complete the study. Thus, the analysis included 98 patients. Patient characteristics are presented in Table 1. According to the manufacturers' criteria, 64 patients had abnormal mCTSIB results, and 72 had abnormal SOT results. The level of agreement between the results of the 2 tests is presented in Table 2. Predictive values were 65.3% (64/98) and 73.5% (72/98) for the mCTSIB and SOT, respectively. The 2 tests showed the same positive detection rate for uncompensated unilateral vestibulopathy, as determined by McNemar's test ($p > 0.256$). The sensitivity of the mCTSIB versus SOT was 68.1% (49/72), and the specificity of the mCTSIB versus SOT was 44% (11/25).

The comparison between mCTSIB and SOT results in patients with uncompensated unilateral vestibulopathy is shown in Table 3. The sensitivities of the mCTSIB and SOT were 65.3% and 73.5%, respectively. The SOT seemed to be more sensitive than the mCTSIB ($p < 0.01$). The mCTSIB and SOT showed a fair degree of correlation (–0.273). The only correlation identified as being of moderate strength was that for EC on a firm surface; all others were poor to fair. The strongest correlation (–0.650) was observed between the firm EC and SOT 2 conditions, and the weakest correlation was observed between the foam EO and SOT 4 correlations. Correlations were weaker for foam-surface conditions than for firm-surface conditions and for eyes-open conditions than for eyes-closed conditions. Foam EO and SOT4 or Foam EC and SOT 5 showed a weaker correlation than Firm EO and SOT1 or Firm EC and SOT 2. Firm EO and SOT1 or Foam EO and SOT4 showed a weaker correlation than Firm EC and SOT2 or Foam EC and SOT5.

TABLE 2. *Agreement between Modified Clinical Test for Sensory Interaction and Balance and Sensory Organization Test scores in patients with uncompensated unilateral vestibulopathy*

		SOT		
		Abnormal	Normal	Total
mCTSIB	Abnormal	49	15	64
	Normal	23	11	34
Total		72	26	98

mCTSIB indicates Modified Clinical Test for Sensory Interaction and Balance; SOT, Sensory Organization Test.

DISCUSSION

The results of this study showed that the mCTSIB can be used instead of the SOT to evaluate patients with uncompensated vestibulopathy. However, the use of the mCTSIB as a follow-up tool to the SOT is limited, as indicated by weak correlations between the 2 tests under each condition.

The SOT is a type of CDP. Whereas other tests of dizziness and balance, such as electronystagmography, the caloric test, and the rotatory chair test, evaluate only the vestibulo-ocular reflex, the SOT provides more integrated measures for balance (12,17,18). Although the SOT is not a very sensitive or specific test for uncompensated unilateral vestibulopathy, it is widely used for monitoring changes in postural stability and vestibular rehabilitation (11,13,14,18,19). However, this technology is expensive and is likely to be available only in neuro-otologic centers serving a large volume of patients with equilibrium disorders.

Because of these limitations, modifications of the standard SOT have been developed. In 1986, Shumway-Cook and Horak (6) described one such measure for the clinical assessment of postural control, the CTSIB. The CTSIB has since been modified; the mCTSIB includes only 4 conditions correlating with conditions 1, 2, 4, and 5 of the SOT. The mCTSIB is less expensive and easier to administer because it requires less equipment and time than the SOT (3). The mCTSIB was computerized and is now widely used in various clinics and rehabilitation centers. Test-retest and interrater reliability of the mCTSIB are high in normal young adults (7).

TABLE 3. *Comparison of results obtained for the Modified Clinical Test for Sensory Interaction and Balance and Sensory Organization Test in patients with uncompensated unilateral vestibulopathy*

	mCTSIB		**SOT**	**Correlation coefficient**[a]	***p***
Sensitivity	65.3% (64/98)		73.5% (72/98)		0.013[a]
Comprehensive score	1.30 ± 0.04	Composite score	69.76 ± 1.02	–0.273	0.007[b]
Sway velocity score		**Equilibrium score**			
Firm EO	0.46 ± 0.02	SOT 1	92.95 ± 0.25	–0.406	0.001[b]
Firm EC	0.53 ± 0.02	SOT 2	89.63 ± 0.41	–0.650	0.001[b]
Foam EO	1.37 ± 0.07	SOT 4	72.69 ± 1.57	–0.226	0.025[b]
Foam EC	2.79 ± 0.11	SOT 5	53.70 ± 1.78	–0.266	0.008[b]

Positive ratios were determined by composite scores of the SOT and mCTSIB, according to the manufacturer's protocol.
EC indicates eyes closed; EO, eyes open.
[a]Chi-squared test.
[b]Spearman's rank correlation test.

Although several studies have compared the use of the mCTSIB and SOT, they have included patients with various vestibular diseases and/or have failed to fully describe compensation states. In the current study, we selectively included prospective subjects, and examiners administering each test were blinded to the results of the other test.

mCTSIB and SOT scores are moderately correlated (8,9). Low correlations between mCTSIB and SOT results were found in a group of patients with vestibular disorders and undergoing vestibular rehabilitation (9). In that study, mCTSIB and dynamic posturography were comparable in distinguishing vestibular disorder patients from healthy subjects. In addition, the authors compared the value of these measures for monitoring in chronic vestibular dysfunction patients. The investigators reported significant results of regression analyses between firm EO and SOT 1 conditions, firm EC and SOT 2 conditions, and comprehensive mCTSIB and composite SOT scores. However, no significant relationship was found between foam EO and SOT 4 conditions or foam EC and SOT 5 conditions. The authors suggested that the lack of relationship between the 2 tests under foam-surface conditions was due to the difficulty of performing tests reliably on the foam surface without the use of a support harness that subjects could grasp. Furthermore, the foam thickness was insufficient to provide reliable somatosensory cues, especially in obese patients (9).

Another study (1) found that mCTSIB results showed low degrees of correlation with DHI findings. They reported poorer correlations under firm surface than under foam-surface conditions. In our study, mCTSIB results under foam-surface conditions showed stronger correlations with SOT results. This discordance may be due to differences in the measurement of health status between the mCTSIB and the SOT or DHI (1) The mCTSIB and SOT assess the ability to maintain balance, whereas the DHI evaluates patients' subjective perceptions of symptoms.

Weber and Cass (8) demonstrated a significant correlation ($p < 0.005$) between the mCTSIB and SOT, with 95% sensitivity and 90% specificity, in adults with vestibular disorders. However, they found no significant correlation between the caloric and rotational chair function tests and the mCTSIB (8). They compared foam EC and SOT 5 conditions and mCTSIB results with any abnormal SOT result. They did not directly compare all mCTSIB and SOT conditions. Similar to our results, the authors report that eyes-closed conditions were more sensitive than eyes-open conditions.

Differences in sensitivity and specificity between the mCTSIB and SOT may be due to the type of foam surface used (3) We believe foam thickness is an important factor for somatosensory cues. High-density viscoelastic foam is used to remove somatosensory cues from the foam condition. With more rigid foam or insufficient foam, the mCTSIB cannot differentiate normal from abnormal. Studies showing less sensitivity and specificity of the mCTSIB, including our study, have tended to use more rigid foam surfaces than that used by Wrisley and Whitney (3), Weber and Cass (8), and El-Kashlan et al. (9). Modification of the foam surface tests of the mCTSIB may increase the sensitivity and/or specificity of this method. In addition, we compared the results of a sway measurement during the mCTSIB as it was performed on a force platform. Thus, the results of this study cannot apply to the mCTSIB when it is performed on a floor and quantified sway information is unavailable.

In conclusion, the mCTSIB achieved moderate detection of uncompensated unilateral vestibulopathy, and mCTSIB results reflected SOT results. However, the mCTSIB cannot be used as a follow-up test to the SOT. In particular, the analysis of mCTSIB results under eyes-open and foam-surface conditions must be performed with caution for patients with vertigo because of the lack of a significant correlation with SOT results. When interpreting the results of the mCTSIB, clinicians should understand the roles and limitations of this test in patients with uncompensated unilateral vestibulopathy.

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