ORIGINAL ARTICLE

Head Shake Posturography in Peripheral Vestibular Disorders

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Submitted: 06 September 2007
Revised: 12 February 2008
Accepted: 19 February 2008

Mediterr J Otol 2008; 4: 9-18

OBJECTIVE: The Sensory Organization Test is specifically designed to measure the functional integration between different senses responsible for balance. Alterations in test protocol using changes in head position have been attempted in order to increase its sensitivity. The aim of this research was to study the value of Head Shake-Sensory Organization Test in pitch, yaw and roll axes in patients with peripheral vestibular disorders, and to measure its sensitivity and specificity.

MATERIALS AND METHOD: Twenty patients with confirmed unilateral peripheral disorders constituted the study group. They were age- and sex-matched to 20 normal subjects.

RESULTS: The study group differed significantly from the control group in head shake posturography condition 5 in all 3 axes and in condition 2 in both pitch and roll axes. There were significant differences between patients with negative and positive Sharpened Fukuda test, and between Benign Paroxysmal Positional Vertigo patients and those with caloric weakness, in condition 5 in the three tested axes. The most sensitive conditions were 5 in the pitch axis followed by 5 in the roll axis, with relatively poor specificity.

CONCLUSION: Based on results of the present study, head shake posturography test can be considered a good enhancement to the standard Sensory Organization Test, being appropriate for patients who perform within the normal range on the standard test, yet remain symptomatic. It can objectively measure an individual's impairments with head movements and postural control, thereby providing evidence and guidelines for designing a more deficit-oriented rehabilitation for some dizzy patients.

Balance is maintained by the integration of orientation information from visual, vestibular and somatosensory inputs. Under normal fixed surface and visual surround conditions, these three senses provide redundant information about the orientation of the body relative to gravity and the support surface. Because of the multiplicity and redundancy of this orientation information, assessing the balance function of patients with complaints of dizziness and/or unsteadiness requires exposing them to altered visual and support surface conditions. This is because under fixed surface and visual surround conditions, if any one sensory system is functioning normally, it can mask abnormalities in the other two sensory systems [1].

Although numerous clinical studies have demonstrated that the sensory organization test (SOT), the gold standard test of computerized dynamic posturography (CDP), enhances the ability to differentiate among normal, abnormal and exaggerated symptoms of imbalance in a variety of patient populations [2, 3, 4, 5, 6]; other studies have documented that the SOT is relatively insensitive in detecting abnormality in patients with vestibular disorders that are physiologically compensated. For example, patients with compensated unilateral vestibular weaknesses can perform within the normal range on the SOT despite the fact that they may still complain of subtle imbalance [7, 8, 9, 10].

To increase the sensitivity of the SOT in identifying peripheral vestibular system lesions, alterations in the test protocol, using static changes in head position, have been attempted [11, 12, 13]. The general result of these changes has not demonstrated significant increases in sensitivity of the SOT, suggesting that, not static, but dynamic, movements of the head will be needed [14]. A dynamic task, like head shaking, can help disrupt the central compensation resulting in a temporary disruption in balance [15]. Head movements challenge the system by generating a vestibular stimulus in addition to that generated by the patient’s sway. To maintain balance in the absence of alternative visual and somatosensory inputs while moving the head, the brain must differentiate the sway and head-shake stimuli. Degradations in the sensitivity and accuracy of the vestibular receptors, however, can interfere with the process of signal differentiation and reduce stability during head shaking. Because the vestibular system is composed of multiple, direction specific sense organs, these degradations may also be axis specific, creating instability only when head movements occur about the involved axis [5].

Shepard et al. (15) found that controlled horizontal head movements during the SOT lead to highly significant reductions in the equilibrium scores in condition 5, but not in condition 2, in their unilateral peripheral vestibular patients. The present research is directed to further investigate the effect of dynamic head movements on SOT in the other axes of head movements, namely pitch and roll axes in peripheral vestibular disorders. The second aim is to evaluate the importance of adding head shake sensory organization test (HS-SOT) in the diagnostic battery for better identification of functional deficit in patients with positional vertigo. Hopefully, implementation of HS-SOT test may provide more accurate guidelines for individually-based customized rehabilitation.

MATERIALS AND METHOD

According to the previously outlined aims, the present research was divided into two main sections:

I - HS-SOT Test in Peripheral Vestibular Disorders:

The study group consisted of 20 dizzy patients, aged between 20 and 60 years, selected from the outpatient clinics of Audiology Units. All patients had unilateral peripheral vestibular disorders as confirmed by video-nystagmography (VNG), either unilateral caloric weakness or +ve Dix-Hallpike maneuver. Assessment of postural stability was done using the modified Clinical Test for Sensory Interaction of Balance (CTSIB). In order to be included in this study, subjects had to show negative CTSIB results in all four conditions denoting normal SOT (15 & 16). Patient having bilateral severe or profound hearing loss were excluded. The control group consisted of 20 age- and sex-matched normal healthy subjects with no dizziness or hearing complaints. All subjects, study and control, should have negative history for neuro-otological disorders and orthopedic abnormalities sufficient to reduce mobility and to cause cervical motion restriction not allowing head movements up to 15 degrees on either side of the primary position. An informal consent was obtained from all participants in this research.

All subjects in this study were submitted to the following:

1 Detailed history

2- Neuro-otological examination and office tests for vestibular evaluation:

a- CTSIB test [14, 15, 16]: The patients' ability to maintain quiet volitional stance was evaluated as they sequentially stood on: 1) a flat firm surface with eyes open, 2) a flat firm surface with eyes closed, 3) a compressible surface with eyes open, and 4) a compressible surface with eyes closed.

b- Fukuda Stepping test: The patients were asked to march in place fifty steps with their eyes closed. The test was considered positive if the patient rotates 45_ or more indicating an asymmetrical labyrinthine function [16]. The test was repeated after active head shaking for 30 seconds (Sharpened Fukuda Stepping Test) and was considered positive if the rotation was 60_ or more [14].

3- Basic audiological evaluation which included pure tone and speech audiometry using a computerized two channel audiometer Madsen model 922 in sound treated room IAC model 1602, and acoustic immittance testing (tympanometry and acoustic reflex threshold measurement) using Immittancemeter Amplaid model 775.

4- VNG battery using computerized videonystagmography ICS Chartr equipped with a light bar and an infrared camera, and connected to a water caloric irrigator model NCI-480. Following calibration, the testing protocol comprised random saccade, gaze, smooth pursuit at 0.1, 0.2 and 0.4 Hz, OPK, positional, positioning, and bithermal caloric tests. Online analysis of results and measurement of nystagmus velocity was done through the ICS software program. For caloric test, unilateral weakness was diagnosed when an inter-aural 20% difference was encountered, and directional preponderance was considered positive if 25 % or more according to normative data established in our lab.

5- CDP-SOT test using Neurocom Smart Equi-test system. This was done on the same day of the VNG evaluation. After patient's preparation, he/she is allowed to properly stand on the platform and the following tests were done:

a- Standard SOT test: Three trials were done for conditions 2 and 5. In both conditions, the subject stood with eyes closed on the dual force plate platform. The platform was stationary in condition 2, and moved about an axis parallel to the ankle joint in response to sagittal (anterior/posterior) plane movements of the subject in condition 5.

b- HS-SOT test: Conditions 2 and 5 were then repeated, three times each, with the patient performing reciprocal head movements, from one side to the other, in 3 different planes at a rate of 1 Hz with an excursion of 30_ peak to peak. The three axes of HS-SOT were yaw (horizontal axis), pitch (vertical axis), and roll (side to side axis). The subject was cued for head movement by listening to a metronome set at 1 Hz recorded from the VORTEQ equipment on a cassette tape. During practice, the degree of excursion was cued for the patient by holding their hands 15_ to each side of the face, such that with each head turn their cheek would contact their hand.

For both standard SOT and HS-SOT tests, equilibrium scores were analyzed for each trial and each condition (SOT2, SOT5, HS-SOT2, HS-SOT5). Analysis of data was done using the statistical analysis system (SAS) [17]. Descriptive data were calculated for all test scores, and Student's "t" test was used to compare between group scores. The effect of different variables on test scores was measured using the Analysis of Variance (ANOVA) model. Duncan Multiple Range test was used to compare the least square means (estimates) of the CDP test conditions between different groups, variables, and subcategories.

II– Sensitivity and Specificity of HS-SOT Test in Positional Vertigo:

In order to study the sensitivity and specificity of the newly applied HS-SOT test, a group of dizzy patients complaining of positional vertigo were included in this section. Subgroup "A" consisted of 20 patients with positive VNG findings suggesting a peripheral vestibular disorder (the same group of subjects included in Section I). Subgroup "B" patients were selected to match Subgroup "A" in every aspect except that they had negative VNG test results (n=20). All inclusion and exclusion criteria were similar to Section I. Data for SOT and HS-SOT tests were collected for both study subgroups .

According to Journal of Statistics Education (18), the sensitivity and specificity of SOT and HS-SOT test conditions were estimated by constructing the binary table for positive and negative test results, considering VNG findings as the gold standard test:

$$\text{Sensitivity} = \frac{\text{True positive}}{\text{True positive + False negative}} - 100$$

$$\text{Specificity} = \frac{\text{True negative}}{\text{True negative + False positive}} - 100$$

RESULTS

I-HS-SOT Test in Peripheral Vestibular Disorders:

The study group consisted of 20 patients (12 males and 8 females) with a mean age of 41.5 years (SD = 12.8). The control group (n = 20) was age- and gender-matched to the study group (mean age = 38.2 years, SD = 12.6). The most common presenting character in the study group was rotatory vertigo (75%), followed by imbalance and lightheadedness. The mean duration of the complaint was 19.0 months (SD=7.8 months). Sixty percent of patients showed variable degrees of hearing loss (SNHL in 10 patients and CHL in 2 patients; unilateral in 9 pat results in the control and study groups. As shown, the study group differed significantly from the control group in the HS-SOT 2 scores in both pitch and roll axes (p <0.05), and in the HS-SOT 5 scores in all 3 axes (p <0.001). Table (2) shows that there was no significant effect of age, gender, or duration of symptoms on test scores in all conditions. The presence of history of positional vertigo showed a significant effect (p<0.05) on HS-SOT scores in the yaw axis only.

A comparison was held between the SOT / HS-SOT tests and other vestibular tests. Table (3) shows that there was a significant difference between patients with negative and positive Sharpened Fukuda test in HS-SOT 5 in the three tested axes (p <0.05). As regards caloric test (table 4), there was a significant difference between patients within the normal range of UCW (<20% - diagnosed as BPPV) and the other subcategories in HS-SOT 5 in the three tested axes (p <0.05).

II- Sensitivity and Specificity of HS-SOT Test in Positional Vertigo:

Table (5) showed the sensitivity and specificity of CDP test conditions. The most sensitive sensory organization test conditions were HS-SOT 5 (pitch) (100%), HS-SOT 5 (roll) (95%), then HS-SOT 5 (yaw) (80%). All HS-SOT test conditions showed a relatively poor specificity (10% - 30%) compared to the SOT test conditions.

DISCUSSION

For standardization of the head shake sensory organization test (HS-SOT) of CDP, 20 normal subjects were evaluated using both SOT and HS-SOT tests. Normal subjects showed a tendency to increased sway with head shaking (decreased equilibrium scores) in HS-SOT 5 compared to HS-SOT 2 in the three axes of the test (table 1). This could be attributed to the increased challenge to maintain stance during condition 5. Clark et al. (5) and Shepard et al. (1) found that postural stability was significantly reduced in normal subjects attempting to execute such controlled head movements while simultaneously maintaining balance in the absence of functionally useful information from vision and somatosensory inputs. This emphasizes the importance of obtaining age-related norms in each condition of SOT and HS-SOT tests.

Comparison between the control and study groups:

In the present study, the results of the standard SOT conditions [2, 5] were not significantly different between the control and study groups (Table I & Figure 1). Similar results were obtained by several researchers [1, 7, 8, 10, 15]. They reported that the SOT is relatively insensitive in detecting abnormality in patients with physiologically compensated unilateral vestibular weaknesses despite the fact that they may still complain of subtle imbalance. Thus, modifying the SOT to identify these patients would clearly enhance its clinical value [1, 5, 15].

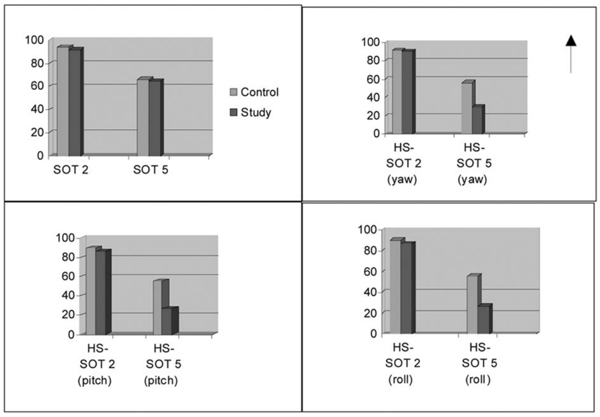

Figure 1: Least Square Means (Estimates) of SOT 2 & 5 and HS-SOT 2 & 5 in the three test axes (yaw, pitch and roll) in the control and study groups.

Table-I: Least Square Means (Estimates) and Standard Errors (S.E.) of SOT 2 & 5 and HS-SOT 2 & 5 in the control and study groups & results of Duncan Multiple Range and Student's "t" tests:

	Group	Control	Study	
Test	**Estimate**	**S.E.**	**Estimate**	**S.E.**
SOT 2	93.9 a	2.1	92.0 a	2.6
SOT 5	66.0 a	3.3	64.6 a	2.5
HS-SOT 2 (yaw)	91.9 a	2.8	90.3 a	2.7
HS-SOT 5 (yaw)	56.4 a	3.4	29.6 b***	3.7
HS-SOT 2 (pitch)	89.7 a	3.5	85.9 b*	1.9
HS-SOT 5 (pitch)	55.7 a	3.6	27.4 b***	3.1
HS-SOT 2 (roll)	90.1 a	3.3	86.6 b*	2.4
HS-SOT 5 (roll)	55.4 a	3.1	26.8 b***	3.1

- Duncan Multiple Range test: Means within a row with the same superscript are not significantly different, while means with a different superscript differ significantly.
- Student "t" test: * = $p < 0.05$ (statistically significant)
  *** = $p < 0.001$ (very highly significant)

In contrast to standard SOT, HS-SOT2 scores were significantly reduced in the study group in comparison to the control group in the pitch and roll axes, but not in the yaw axis. This agrees with Shepard et al. [1, 15] who found that controlled horizontal head movements (in the yaw axis) had no significant effects on balance with normal somatosensory inputs. It seems that the other two maneuvers, i.e. moving the head in planes other than the horizontal one, increased the sensitivity of the test in condition 2. Clark et al. [5] and Shepard et al. [1] reported that the sequence of pitch and roll motions used in HS-SOT were more disruptive to vestibular balance function than the horizontal head movements. Thus, Naval Aerospace Medical Research Laboratory (NAMRL) researchers suggested their use to detect more subtle reductions of vestibular function in individuals whose high performance flight duties require exceptional balance system capabilities.

The difference between control and study groups was still more significant in HS-SOT5 test in the three head axes (Table 1 & Figure 1). Similarly, Shepard et al. [1, 15] found that their vestibular patients showed highly significant reductions in HS-SOT condition 5 relative to the normal baseline.

Variables affecting test results:

The present study showed no significant effect of age or gender on SOT and HS-SOT test results (Table II). Though the pattern of degradation with age was previously investigated in normal subjects[15], further study is recommended to explore the pattern of abnormality in patients exceeding 60 years of age. The duration of symptoms also showed insignificant effect on the results; a finding that may be related to the selection criteria of dizzy patients. Stated differently, regardless the disease duration, all selected subjects showed a negative CTSIB test which is generally considered to be a crude sign of vestibular compensation.

As regards the effect of presence of positional vertigo on the equilibrium scores, there was a significant effect in both conditions of the head shake test in the yaw axis only (HS-SOT2 and HS-SOT5) (Table II). Since head movements in this axis presumably provoke more stimulation to the horizontal semicircular canals, pathology in these canals might be more prevalent in those patients with positive positional vertigo. Indeed, Shepard et al. [15] stated that SOT head shake modification in the yaw axis increased the sensitivity for identification and quantification of head movement provoked vertigo; thus could serve as a measure of success after vestibular rehabilitation therapy.

The present study showed a significant reduction in the equilibrium scores of HS-SOT5 condition in cases with positive Sharpened Fukuda test in comparison to negative cases (Table III). This reduction was statistically significant in the three tested axes; a finding which reflects the higher sensitivity of HS-SOT5 compared to HS-SOT2 and SOT in the diagnosis of peripheral vestibular disorders.

A comparison was held between results of SOT and HS-SOT in different subcategories of unilateral caloric weakness in cases of peripheral vestibular disorders. Results showed significant reduction in the equilibrium scores of HS-SOT5 in the three tested axes in patients with less than 20% caloric weakness (table 4). These patients were diagnosed as BPPV cases by the Dix-Hallpike maneuver, and these results suggest

Table-II: Analysis of Variance (ANOVA) table to study effect of variables on SOT 2 & 5 and HS-SOT 2 & 5 in the study group:

	ANOVA Mean Squares							
	Standard		HS-Yaw		HS-Pitch		HS-Roll	
	SOT 2	SOT 5	HS-SOT 2	HS-SOT 5	HS-SOT 2	HS-SOT 5	HS-SOT 2	HS-SOT 5
Age	25.69	16.03	57.05	41.01	30.54	22.45	46.85	24.28
Gender	61.35	52.41	69.16	30.69	26.15	24.79	57.33	36.74
Duration of symptoms	31.74	9.98	21.59	17.78	21.97	6.55	22.16	15.41
Positional vertigo	58.45	26.09	88.78*	68.51*	34.79	24.64	39.13	27.95

* = $p < 0.05$

Table-III: Duncan Multiple Range test to compare between SOT and HS-SOT and Sharpened Fukuda test results in the study group:

	Standard		HS-Yaw		HS-Pitch		HS-Roll	
Sharpened Fukuda	SOT 2	SOT 5	HS-SOT 2	HS-SOT 5	HS-SOT 2	HS-SOT 5	HS-SOT 2	HS-SOT 5
Negative (n=17)	92.6[a]	65.7[a]	89.8[a]	38.7[a]	87.4[a]	32.4[a]	87.7[a]	29.2[a]
Positive (n=23)	91.3a	61.8a	88.2a	26.5b*	85.1a	22.6b*	86.0a	23.3b*

* = $p < 0.05$

that they may be more sensitive to the head shake test. Such finding could be attributed to the unique additional information provided by the head shake test regarding higher frequency VOR function. Another physiologically-based speculation could be that HS-SOT test can evaluate vertical semicircular canals which are not otherwise tested by the caloric test.

On the other hand, there were no significant differences in the equilibrium scores of the other subcategories of unilateral caloric weakness between standard and head shake conditions (Table IV). Similarly, Goebel and Rowdon [21] found that more than 95 percent of patients with unilateral deficits on caloric testing yielded normal rotational VOR gains. Though calorics are considered the gold standard, in fact they measure very low frequency range of the vestibular system compared to other VOR tests including head shaking. Therefore, insignificant results do not necessarily mean that HS-SOT is a limited tool for diagnosis of compensated unilateral peripheral vestibular loss.

Results of the present study disagree with Shepard et al. [15] who found a gradual increase in the sensitivity of HS-SOT variables with the increase of the caloric asymmetry. Yet, their values of good sensitivity were accompanied by low values of specificity. Thus, they reported that the ability to identify a possible peripheral vestibular function asymmetry with the HS-SOT protocol would be only fair at best.

Sensitivity and Specificity of SOT and HS-SOT tests:

When all dizzy patients included in Section II were grouped together, and taking the VNG test results as the gold standard, the most sensitive SOT condition was HS-SOT5 in the pitch axis (100%) followed by HS-SOT5 in the roll axis (95%) then HS-SOT5 in the yaw axis (80%) (Table V). The sensitivity of HS-

Table-IV: Duncan Multiple Range test to compare SOT and HS-SOT test results and unilateral caloric weakness in the study group

Unilateral caloric weakness	Standard		HS-Yaw		HS-Pitch		HS-Roll	
	SOT 2	SOT 5	HS-SOT 2	HS-SOT 5	HS-SOT 2	HS-SOT 5	HS-SOT 2	HS-SOT 5
<20% (n=4)	92.8a	58.5a	90.3a	5.8b*	83.5a	14.0b*	84.8a	16.5b*
>20-40% (n=9)	92.4a	63.9a	90.7a	36.2a	87.1a	30.7a	87.7a	26.8a
>40% (n=7)	90.9a	61.7a	89.9a	38.8a	85.8a	30.7a	86.1a	30.6a

* = p <0.05

Table-V: Comparison of the sensitivity and specificity of SOT/HS-SOT test results according to the distribution of patients in the study group:

Test conditions	True +ve	True -ve	False +ve	False -ve	Sensitivity	Specificity
SOT 2	6	14	6	14	30%	70%
SOT 5	9	12	8	11	45%	60%
HS-SOT 2 (yaw)	11	5	15	9	55%	25%
HS-SOT 5 (yaw)	16	4	16	4	80%	20%
HS-SOT 2 (pitch)	12	6	14	8	60%	30%
HS-SOT 5 (pitch)	20	3	17	0	100%	15%
HS-SOT 2 (roll)	15	5	15	5	75%	25%
HS-SOT 5 (roll)	19	2	18	1	95%	10%

SOT2 was less than HS-SOT5 in the three axes of the test. This agreed with Shepard et al. (15) who found low sensitivity values for HS-SOT2 condition and higher sensitivity values for HS-SOT5 condition. They suggested that the head-shake protocol is not challenging enough when used with condition 2.

A marked reduction in the sensitivity was found in standard SOT conditions (30% for condition 2 and 45% for condition 5). This was reported by many researchers who concluded that the standard SOT is relatively insensitive in detecting abnormality in patients with vestibular disorders that are physiologically, but not functionally, compensated [7, 8, 1, 10, 15].

The previous results confirm the hypothesis posed in this study; that is detection of balance disorders is a function of the challenging nature of the investigation task. As the compensation process proceeds, the ability to detect abnormalities related to asymmetrical peripheral functioning on balance ability becomes more difficult. A dynamic task like head shaking can help disrupt the central compensation, resulting in a temporary balance dysfunction, especially during challenging tasks similar to those used in the SOT test.

CONCLUSION

In summary, results of this study indicate that the HS-SOT test can be considered a good enhancement and supplement to the standard SOT, being appropriate for patients who perform within the normal range on the standard test, yet remain symptomatic. It also provides useful objective information regarding the patient's ability to perform tasks of daily living e.g. head motion while maintaining postural control. When applied in the three fore-mentioned axes, it provides better evaluation of the VOR function in a frequency range which is higher than that tested in calorics, and also corresponds to 3 dimensional head movements. Such information may form the basis for a deficit-oriented individualized rehabilitation of some dizzy patients, which is expected to yield better and faster outcome compared to generic rehabilitation programs.

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EDITORIAL COMMENT

Evaluating and even more, interpreting postural control has been a problem for decades. Although an astonishing development of sophisticated methods, the ability to decide normality or pathology has remained a problem. Partly this may be said to depend on the redundancy of the control of human stance. This ability is not singularly dependent on one sensory input but utilizes vestibular, somatosensory and visual input and may change its preferences in case of a lesion or when one input is unavailable or less reliable.

Postural control in vestibular problems seems to be especially elusive to study. Although patients report unsteadiness and falls, the effects of a vestibular impairment on quiet stance and posturography are less obvious. Generally one needs some type of provocation to stand out. The present approach of headshaking during the tests, is yet another and interesting method. Shaking the head at higher frequencies will cause a charging of the central nervous so called 'velocity storage mechanism' that prolongs the response to vestibular or for that matter optokinetic stimulation. In case of a vestibular asymmetry this charging will be asymmetric according to Alexanders second law. This in turn will induce a vestibular asymmetry previously not obvious. In turn this will affect orientation and vestibular-dependent reflexes. It should be pointed out that headshake and charging of the velocity storage does not cause de-compensation as suggested, but causes asymmetric responses in its own right (1, 2).

An argument against the headshake procedure would be that it would affect any cervical problem as well. This might of cause be true in those cases the patients would have such problems, unfortunately, this was not reported. Indeed, cervical provocation may cause postural responses (3,4). However, inducing a vestibular asymmetry with headshake may be effective by itself. Panosian and Paige (5) demonstrated that performing headshake in advance of the posturographic measurement, which was then performed with the head in neutral position, and thus without immediate cervical stimulation, reduced postural performance if the headshake had caused nystagmus. But even low level vestibular stimulation can by itself cause postural reactions without causing nystagmus (6). This problem could be somewhat better understood if the vestibular lesion could have been correlated or at least plotted against the headshake-SOT5 results in the present study. Unfortunately we do not have a closer record of the patients and therefore have to await extended reports. Such data may in turn provide information on the usefulness of the test as a diagnostic procedure. At present, the low specificity reported, advices against giving it too extensive diagnostic importance.

Anyhow, the present study may corroborate another recent finding, that even low level or compensated vestibular lesions may impact functionality. Brandt et al (7,8) recently showed that compensated unilateral vestibular lesions has an effect on cognitive function and Kristinsdottir et al (9,10) could correlate subclinical vestibular asymmetry, revealed by headshake, to falls and fractures and reduced postural control in elderly.

Thus, inducing or enhancing a vestibular asymmetry by fast head movements may reveal deficits in postural control not evident in normal testing but perhaps noted by patients when performing such movements in everyday life.

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AUTHOR'S RESPONSES TO EDITORIAL COMMENTS

1. The authors agree to the speculation of "vestibular asymmetry secondary to charging of the velocity storage mechanism" as a physiological basis for transient decrease in postural control indices. Anyway, there is a general agreement for the role of the central vestibular system in compensation in cases of peripheral vestibular cases. Whether this be through the "velocity storage mechanism" or through any other mechanism is not yet clear.
2. All subjects, study and control, had negative history for neuro-otological disorders and orthopedic abnormalities sufficient to reduce mobility and to cause cervical motion restriction not allowing head movements up to 15 degrees on either side of the primary position. This was one of our selection criteria mentioned in the "Methodology Section". Therefore, we do not have to worry about postural instability provoked by cervical disorders in our group of patients.
3. As regards the need for correlation studies between the extent of vestibular lesion and HS-SOT5, we also believe that this point needs to be studied extensively in the future in a more quantitative manner.