Use of the Head Shake-Sensory Organization Test as an Outcome Measure in the Rehabilitation of an Individual with Head Movement Provoked Symptoms of Imbalance

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ABSTRACT

Background and Purpose: The purpose of this case report is to highlight the Head Shake (HS) Sensory Organization Test (SOT) (HS-SOT) as an outcome measure in the rehabilitation of a patient with head movement provoked symptoms of dysequilibrium. Despite complaints of imbalance and head movement provoked symptoms, there are individuals who are able to score within normal limits on measures such as the SOT and Berg Functional Balance Test. The HS modification to the SOT can objectively identify abnormal vestibular inputs associated with head motion and maintaining balance. **Methods:** This case report describes the examination, intervention, and outcomes for a 71-year-old female with a history of imbalance and decreased ambulatory endurance. During examination, the patient presented with SOT scores within functional limits. The HS-SOT was then implemented to assess vestibular function during head motion in standing, with eyes closed. The intervention included balance retraining, dynamic gait activities, lower extremity strengthening, and instruction in a home exercise program. **Results:** Improvements were noted for all measures. Initially, during the HS-SOT, the patient fell during all 6 trials of the HS modification to condition 5 and her equilibrium score was 12. Posttreatment, she was able to maintain her balance in 5 out of 6 trials and her score increased to 55. The patient reported increased ambulatory endurance and independence with functional activities (ie, walking and turning her head, and stair negotiation without use of a railing). **Conclusions:** The HS-SOT quantified the complaint of head movement provoked symptoms for this individual with dysequilibrium and was useful in measuring success of an intervention.

Key Words: imbalance, gait, vestibular, dysequilibrium, sensory organization

INTRODUCTION

Symptoms of dizziness are one of the most common complaints among older adults. Dizziness has been reported in up to 30% of adults over the age of 65 and increases in prevalence with age.[1] Surveys have reported dizziness to be most commonly provoked by postural change and head and neck movement.[1] Dizziness also has been associated with functional disability, falls, and a reduction in quality of life.[2,3]

The monitoring of outcomes for individuals with balance problems and symptoms of dizziness requires the implementation of tests and measures that are both reliable and valid. Such measures are an important part of clinical decision making, such as monitoring the effectiveness of treatment, and justifying reimbursement by third party payers.

The Head Shake (HS) Sensory Organization Test (SOT), (HS-SOT) provides additional information to the SOT and may be a useful outcomes tool for individuals who would otherwise be considered 'well compensated,' that is, able to score within functional limits on tests of sensory organization and functional balance. Because the HS-SOT is a relatively new enhancement of traditional sensory organization testing, its use as an outcomes measure has thus far not been documented. The purpose of this case report is to describe the use of the HS-SOT as an outcome measure in the rehabilitation intervention of an individual presenting with head movement provoked symptoms of imbalance. Preliminary studies using the HS modification are outlined to provide a foundation for further investigation of this new tool, the HS-SOT.

The ability to maintain balance requires sensory input from the visual, somatosensory, and vestibular systems.[4,5] The SOT protocol of computerized dynamic posturography objectively measures an individual's ability to use visual, somatosensory, and vestibular information to maintain postural control while standing. During the first 3 test conditions, the support surface, which is a force plate used to measure postural responses, is fixed. Conditions 2 and 3 assess use of somatosensory information, with eyes closed and eyes open, with sway-referenced visual surround for inaccurate visual inputs, respectively. Use of visual information is tested in condition 4, where the subject is now standing on a sway-referenced support surface. Vestibular inputs are measured with eyes closed, and in the presence of inaccurate visual and somatosensory information in conditions 5 and 6, respectively. Figure 1 provides details on all 6 sensory conditions encompassed by the SOT. Analysis of the test results is then compared to age-matched normative data.[4] While this functional evaluation does not offer site-of-lesion information, it has been a useful outcome measure in vestibular rehabilitation programs.[6]

The use of sensory organization testing as an outcome measure and its sensitivity to detect vestibular abnormalities have been challenged in several studies.[7-10] Badke et al recently assessed balance, dynamic gait, and dynamic visual acuity, and documented outcomes in a retrospective study of 20 outpatients. Outcome measures used included the Berg

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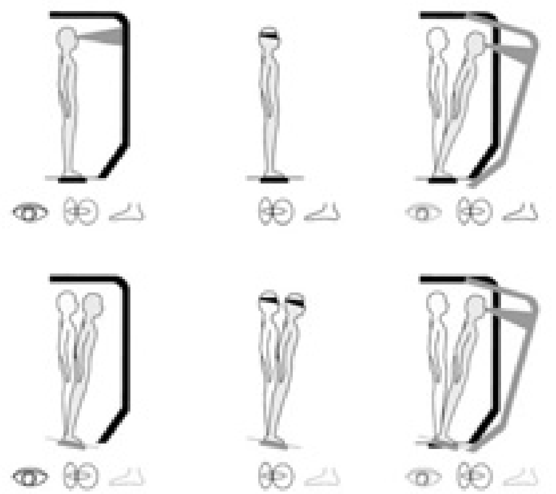

Top row, from left: conditions 1, 2, 3
Bottom row, from left: conditions 4, 5, 6
(Darker symbols indicate sensory information available during test condition)
**Image used with permission by NeuroCom, International, Inc.*

Figure 1. Sensory conditions in Sensory Organization Testing with dynamic posturography.

Balance Scale, the Dynamic Gait Index, Dynamic Visual Acuity Test, and SOT. There was no significant difference between pretherapy and post-therapy SOT scores.[7] One possible explanation for this could be that the SOT was not sensitive enough to detect postural abnormalities with these subjects.

The SOT is relatively insensitive in the detection of abnormalities in patients with vestibular disorders who are well compensated.[8] Well compensated individuals have vestibular hypofunction; yet have been able to effectively use alternate strategies to maintain postural control (ie, increased use of somatosensory information or selective, appropriate use of vision), or have obtained central nervous system compensation or adaptation mechanisms to improve eye-head coordination.[8]

The HS-SOT is an enhancement to the SOT available with NeuroCom's systems including the SMART Balance Master. The clinician is able to assess conditions 2 and 5 with head motion (see Figure 1). Its components include a 3 axis integrating gyro headband and an internal tracking system (Figure 2). The InterSense headband and tracking system can monitor head motion in 3 axes: pitch (flexion/extension), yaw (axial rotation), and roll (lateral flexion). During the HS-SOT for horizontal head movement (yaw axis), patients stand on the same force plate platform used with posturography, and are asked to close their eyes and rotate their head through an arc of approximately 30° to the right and to the left in time with an auditory beep provided with the tracking system (Figure 3). Head motion occurs at approximately 1 cycle per second. This procedure is performed for both conditions 2 and 5 of the SOT.[8]

Figure 2. **InterSense IS-300, 3 axis gyro headband.**

Figure 3. JM performing HS-SOT.

The HS modification on SOT conditions 2 and 5 can measure postural control in patients in whom head movements provoke symptoms and disrupt balance during stance and ambulation. Head shaking on condition 2 (eyes closed, fixed surface), which examines use of somatosensory information, and head shaking on condition 5 (eyes closed, sway referenced surface), which tests vestibular inputs, are enhancements to the traditional SOT protocol.[8]

Preliminary research which aided the development of the HS-SOT was performed using an 'enhanced' SOT to determine both sensitivity and advantages of a modified protocol for sensory organization testing for individuals who appear to be 'well compensated' (ie, scored within normal limits during SOT test). Nashner described the testing methods and findings from 2 different research settings, the University of Michigan and the Naval Aerospace Medical Research Laboratory.[8] At the University of Michigan, Shepard et al compared the sensitivity of the HS-SOT to the SOT on 27 subjects with known vestibular disorders who scored within normal limits on the SOT. Subjects were then compared to 51 normal subjects. Condition 5 scores were significantly different for the vestibular disorders group and the normal subject group ($P < 0.001$) when trials were associated with HS but not when the head was fixed ($P = 0.589$).[11]

Similarly, the Naval Aerospace Medical Research Laboratory developed tests of orientation and balance for aviation candidates. The goal for testing was to determine if an enhanced SOT would detect changes in vestibular function following a 10-minute exposure to stressful aviation simulations. The 35 subjects had significant differences in pretest/post-test scores of equilibrium with the HS-SOT versus no difference with the SOT.[12] The modified version of the SOT is now part of the Pensacola Vestibular Test Battery, which assesses personnel for spatial disorientation, vertigo, or airsickness.[13]

Shepard et al examined the sensitivity of the HS-SOT for identifying patients whose head movements disrupted their postural control and patients who had peripheral vestibular dysfunction.[14] The sensitivity of the test was 78% and 75% for the 2 groups, respectively. The specificity of the test was poor, 25% and 20% for the groups (respectively). The authors concluded that the protocol was too difficult for screening purposes. They suggested, however, that the HS-SOT would serve well as a means of quantifying complaint of head movement provoked symptoms.[14]

One benefit of the HS-SOT is that it is challenging enough to detect postural sway in head movement related activities in stance. This benefit is clinically important, because many individuals who report imbalance are able to score within normal limits on the SOT[8] and even on the Berg Functional Balance Test. Thus, utilizing the HS-SOT can help validate a person's complaint of difficulty performing community ambulation. For example, walking across a parking lot or grocery shopping requires visual scanning of the surrounding environment, which can elicit symptoms of dysequilibrium. Also, from a documentation and reimbursement standpoint, this test can objectively measure an individual's impairments with head movements and postural control, thereby providing evidence of necessity of intervention. The HS-SOT can identify a vestibular abnormality which previously may have been overlooked. Identification of such impairment provides invaluable insight into the underlying source of the patient's reported problem and assists with clinical decisions related to treatment planning.

CASE DESCRIPTION

History

JM was a 71-year-old female referred for outpatient physical therapy with complaints of imbalance and difficulty walking. She was diagnosed as having 'balance dysfunction' by her physician. In addition to her balance and ambulatory problems, JM's medical history included: diabetes (controlled with diet); left breast cancer, with subsequent modified radical mastectomy in September 2000; and lumbar osteoarthritis.

JM lived at home with her husband in a 2 story house. Her interests and activities included gardening, traveling to a mountain cottage, spending time with her grandchildren, and attending football games at her alma mater. Most, if not all of JM's interests required a fair amount of physical activity, including walking on trails, working in the garden, and negotiating stairs without railings (ie, the steps in the football stadium). These activities had been curtailed somewhat, over the past several years because of episodic imbalance when either walking on uneven surfaces or turning her head while walking. JM described her symptoms as 'moderately disabling,' affecting her social interests and activities. In addition, JM complained of decreased ambulatory endurance, loss of balance, difficulty with tub transfers, and difficulty getting up from the floor or the ground. She stated that her greatest fear was falling. During the previous month JM had slipped on the ice, fallen, and strained her left hip adductor muscles.

Prior to her fall, JM was seen for a comprehensive evaluation. A computerized dynamic posturography SOT revealed a vestibular dysfunction pattern, indicating that JM had difficulty using vestibular function alone for maintaining postural control in stance. The Motor Control Test[15] which measures reactions following an unexpected induced sway demonstrated JM's reduced use of ankle strategy and plantar surface cutaneous somatosensory inputs. JM was also evaluated by a physical therapist and had been provided with a home exercise program. At that time she was referred to outpatient physical therapy for continued rehabilitation. Her goals for therapy were to be able to ascend and descend stairs without use of a railing and to increase her ambulatory endurance. JM chose her goals with hopes to resume her recreational and social interests.

Examination

JM's initial examination and subsequent intervention addressed her balance and ambulatory problems as well as her left hip pain which occurred as a result of a fall, the previous month. JM was first evaluated for left hip pain and returned several days later for a balance and vestibular evaluation.

During her first visit, JM described persistent hip pain, which had progressively lessened since her fall one month prior. She rated her pain to be '4/10' (10 equaling the worst possible pain). This hip pain did not limit her active range of motion. Lower extremity strength was measured in a seated position with the Microfit 2™ hand held dynamometer and was considered to be weak bilaterally. JM's knee extension strength, was below the normative range reported by Bohannon.[16] Results are outlined in Table 1. Palpation revealed point tenderness and strain along the left adductor muscle group and a secondary strain along the pelvic origin of the rectus femoris. Her gait speed for 10 meters was .83 meters/sec. Thus, JM's gait speed would be considered within the normal range (.71m/sec-1.8m/sec) for women walking at their comfortable speed.[17]

Table 1. Strength Measurements Obtained Pre- and Postintervention

Muscle Action	Preintervention		Postintervention	
	Left	Right	Left	Right
Hip flexion	17	21	25	26
Hip abduction	17	16	24	14
Hip adduction	12	17	21	18
Knee extension	25*	32*	39	39
Knee flexion	15*	13*	20*	25*
Ankle dorsiflexion	15	16	25	25

Measurements are in pounds.
**Compared to reported normative references,[16] these measures were below normal or at the low end of the normal range for women. Hip and ankle strength measures were not compared as they were obtained using procedures different than reported in the normative data study.*

Several days later, JM returned to the clinic for a vestibular evaluation. JM presented with intact gaze stability for smooth pursuit, saccades, and vestibular ocular reflex. The Berg Functional Balance Test[18] was administered and JM scored 45/56 possible points. Areas of difficulty included: sit to stand; standing with feet together; functional reach; alternating stool touch; heel to toe stance; and unilateral stance. The SOT was performed on the Smart Balance Master by NeuroCom.™ Prior to testing, JM was outfitted in the system's safety harness and was instructed to stand in an upright position throughout testing. In addition, JM received education on each of the test conditions prior to each test. JM was assured by the therapist that if she lost balance or went beyond her limits of stability, the trial would be stopped and considered a 'fall.' She fell in the first 2 trials of condition 5 where vestibular information is needed to maintain postural control in the absence of visual and somatosensory inputs. JM also fell in the first trial of condition 6 where vestibular information is used in the presence of inaccurate visual information and absence of somatosensation. A composite score was then calculated by the Smart Balance Master system, taking into account postural sway responses to each condition, compiling a score which represents how well an individual uses somatosensory, visual, and vestibular information to maintain an upright, steady position. Despite her 'falls,' JM's overall composite score of 66 was within normal limits for age-matched normal subjects.[19] The HS-SOT was used to quantify JM's complaints of dysequilibrium which she reported while walking, especially when walking and turning her head.

Due to time constraints, the HS-SOT was performed during the next scheduled visit. JM was able to maintain her balance through HS-SOT 2 (eyes closed, fixed surface with head shaking in the horizontal or 'yaw' plane of motion). During HS-SOT 5 (head shaking, eyes closed, sway-referenced surface), JM fell in all 6 trials. Her overall composite equilibrium score was 12. These results were consistent with JM's complaints of difficulty ambulating with simultaneous head motion. The identification of this impairment with the HS-SOT which correlated to the patient's complaints of decreased ambulatory function strengthened her need for physical therapy intervention and aided in treatment planning.

Evaluation

Based on the findings from our initial evaluation, JM was judged to have the following problems: hip pain; lower extremity weakness; decreased functional balance with increased risk for falls;[20] and impaired performance on the HS-SOT, indicating a decreased use of vestibular inputs during head motion. These results most likely explain JM's complaints of decreased ambulatory endurance, difficulty walking, and her overall sense of feeling 'off balance.'

JM's performance on the Berg Functional Balance Test was interesting. JM's areas of impairment included alternating stool touch, heel to toe stance, and unilateral stance. At the time of her evaluation, she reported some discomfort in performing these measures due to her left hip pain. If not for further clinical testing, the balance deficits listed above could have been attributed to her recent fall and subsequent left hip pain and strain.

Further examination of JM's sensory organization was helpful in her evaluation, intervention, and ultimately her outcome. JM's below normal score on the HS-SOT also suggested that she had residual deficits with respect to use of vestibular information. Although the database in the Michigan study was small, (n=51), normative values for individuals 70 to 79 for HS-SOT condition 2 were 89 and HS-SOT condition 5 were 57.[11] Based on her within normal limits SOT score alone, her physical therapy intervention would not have had elements of vestibular rehabilitation specifically aimed at improving vestibular inputs during ambulation and stance. Rather, a more traditional course of balance and gait retraining would have been employed.

Intervention

JM's intervention included a comprehensive clinic and home exercise regimen. All of her impairments and functional limitations were addressed. JM was followed 2 times a week for 8 weeks, then once a week for 4 weeks. JM's hip pain was addressed in the first 2 to 3 sessions with provision of a home exercise strengthening and flexibility program and modalities for pain management. The majority of her rehabilitation included lower extremity strength training with cuff weights and closed chain exercises, balance retraining activities, and vestibular rehabilitation.

Dynamic gait activities and training on the Smart Balance Master were key elements of JM's vestibular rehabilitation. Based on JM's impaired performance on the HS-SOT (indicating a decreased use of vestibular inputs during head motion), ambulation with head motion, and direction changes was important. Dynamic gait activities incorporating vestibular inputs included walking and rotating head and neck, looking up and down, stopping abruptly, and quickly changing directions with pivot turns.

Balance retraining with emphasis on compensatory strategies using both somatosensory information and appropriate visual inputs was also integral part of her vestibular rehabilitation. Training to increase somatosensory awareness and decrease visual over-dependence was done in the clinic as well as in the Smart Balance Master. A variety of cushions, wedges, and obstacles was used in the clinic. The Smart Balance Master provided somatosensory challenges with its moveable support surface and accessories. The Smart Balance Master's brightly colored visual surround was also sway-referenced (moving in response to JM's weight shifting) which provided training to decrease over-use of visual inputs to maintain balance (for example, walking in a grocery store). Although training occurred on the same system, the Smart Balance Master portion of JM's intervention did not include any of the tasks required to maintain balance throughout HS-SOT procedure.

Results/Outcomes

JM made substantial progress in all problem areas after her course of treatment. As hip pain subsided early on in her program, the remaining sessions were devoted to vestibular rehabilitation and to balance and strength training. JM's strength improved throughout her lower extremities (Table 1). JM made notable improvements with the Berg Functional Balance Test, scoring 55/56 total points at the time of discharge. Interestingly, she scored 55 in the latter two-thirds of treatment but she continued to have difficulty with walking and head motion. It was not until the end of her session that her HS-SOT improved to within normal limits. JM fell during the first trial of HS-SOT 5 and then maintained her balance in the subsequent 5 trials, giving her an overall equilibrium score of 55 (within normal range for her age group). In essence, the HS-SOT indicated that further treatment was necessary to address JM's symptoms of imbalance.

Functionally, JM was able to resume her previous activities. She increased her community ambulation, including shopping, attending a home exposition in a large convention center, and going to college football games where she managed stadium steps without a railing.

DISCUSSION

The HS-SOT identified a vestibular impairment in this individual who presented with complaints of difficulty walking and head movement provoked symptoms of imbalance and dysequilibrium. The component of abnormal vestibular inputs during head motion most likely contributed to several of the patient's functional limitations including difficulty with community ambulation, shopping, walking with head turns, stair negotiation without the use of a railing, and hiking on trails by her mountain home. Figure 4 is a schematic summary of JM's problems, impairments, and restrictions, illustrating how a vicious cycle of impairments, functional limitations, and disability can occur if problems are not addressed in a comprehensive rehabilitation intervention.

During the patient's examination, the HS-SOT was critical in diagnosis of the impairment, the documentation of necessity of treatment and in guiding the therapist towards the appropriate course of intervention. The results of the SOT for JM were within normal limits. Gaze stabilization tests of occulomotor function and the vestibular ocular reflex were intact. The Berg Functional Balance Test indicated a risk for falls and also provided evidence of functional balance deficits. Based on these results, however, vestibular function appeared to be intact. Therefore, no further treatment in the area of vestibular rehabilitation and dynamic gait training would have been indicated.

It was further testing of vestibular inputs while the head is in motion (the HS-SOT) that identified a key impairment in this individual. The importance of the HS-SOT is 2-fold: the test provided evidence needed to warrant extensive treatment in this area; and it also guided the therapist towards appropriate intervention for this individual.

To date, no other studies have examined this test as an outcome measure for rehabilitation interventions. Further testing is needed to validate this instrument. A future study could examine the correlation between the HS-SOT and the Dynamic Gait Index[21] and the Berg Functional Balance Test.[18] Demonstrating a relationship between these measures would provide support for its construct validity. Future investigations could also include an objective measure of fear of falling, which though one of JM's concerns, was not addressed in her examinations. Finally, further research involving multiple subjects is warranted as it is inappropriate to generalize from a case study.

CONCLUSION

The HS-SOT is an objective measure for identifying abnormal vestibular inputs which may be observed during head motion while maintaining postural control. It can be a valuable tool for quantifying patient complaints of imbalance and dysequilibrium during dynamic gait activities. The HS-SOT also is beneficial in documenting the necessity of treatment (particularly in patients who score within normal limits on the SOT but have complaints of dizziness and imbalance) and response to treatment.

In the case of this patient, the HS-SOT helped to guide her rehabilitation, including her education regarding her condition. Increased use of vestibular stimulation and adaptation coupled with walking activities led to the overall success of this intervention. This case report would support further investigation of the usefulness of HS-SOT to quantify impairment and assess efficacy of vestibular rehabilitation.

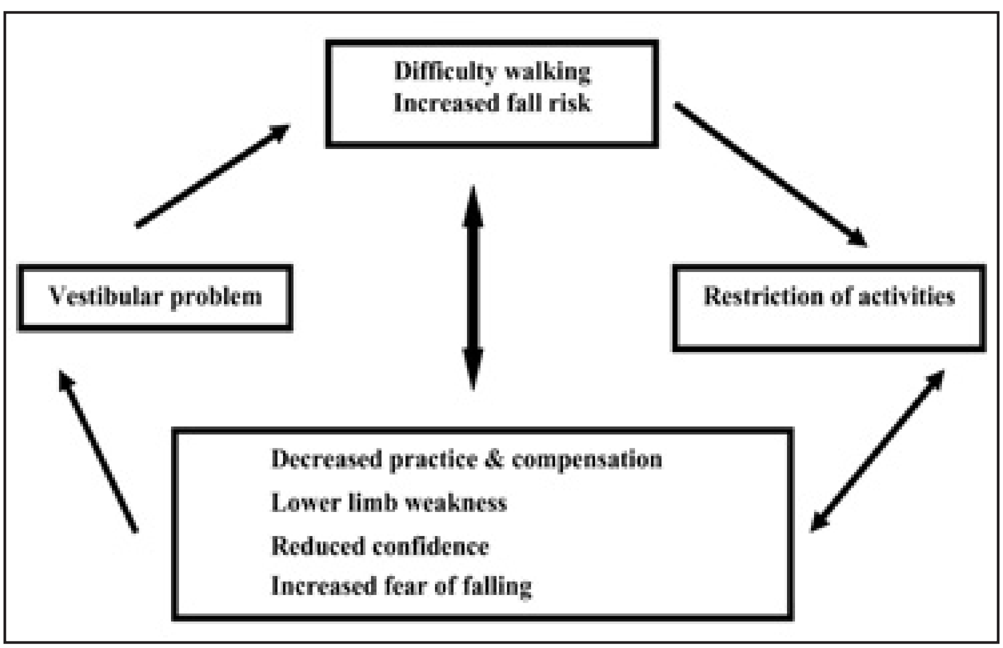

Figure 4. Schematic summary of JM's problems, impairments, functional limitations, and disability.

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