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The Head Shake Sensory Organization Test (HS-SOT): Normative Data and Correlation with Dynamic Visual Acuity Testing

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Background: Among healthy (asymptomatic) subjects and patients, the relationship between performance on the Head Shake Sensory Organization Test (HS-SOT) and performance on the Dynamic Visual Acuity (DVA) testing has not been reported. The purpose of this study was to establish normative data for the HS-SOT and compare performance on the HS-SOT and the DVA test. **Hypothesis:** A strong positive correlation would exist between the DVA and the HS-SOT. **Study Design:** A cross-sectional design was used**. Level of Evidence:** Level 3. **Methods:** Sixty asymptomatic subjects (34 females, 26 males, ages 20 to 26 years, 23.7±1.6) participated. Each subject's dynamic balance and visual acuity were assessed using the HS-SOT and DVA testing on the NeuroCom Balance System per manufacturer's protocol. **Results:** Equilibrium scores for the HS-SOT condition 2 (eyes closed, fixed surface) = 93.23±1.99, 95% CI = 92.7-93.8; and condition 5 (eyes closed, sway-referenced surface) = 66.69±1.13, 95% CI=64.4-70.0. The equilibrium score ratio (ESR) for condition 2 = 1.01±.003 (δ^2=.001), and condition 5 = .94±.03 (δ^2=.055). ESR fixed surface was negatively correlated with DVA loss symmetry % [R= - .36, p=.004, R^2=.13] and with DVA errors (right) [R=-.30, p=.02, R^2=.09]. **Conclusion:** Subjects demonstrated good dynamic postural stability on the HS-SOT and had minimal loss in their ability to maintain visual acuity during head movements. **Clinical Relevance:** Clinically derived HS-SOT data can be compared to normative data to assist the clinician with accurate assessment of postural instability. **Keywords:** *balance, postural control, HS-SOT, dynamic visual acuity*

INTRODUCTION

Maintaining balance and upright posture requires normal functioning of the postural control system. This system includes the visual system, the vestibular apparatus, and somatosensory input as shown in Figure 1. In natural environments humans rely on both visual and vestibular input to define our orientation in space.[6] The *proprioceptive* (or sensorimotor) system and the visual systems are thought to be the primary systems involved in the maintenance of balance when the demand is 'low' (e.g. static upright standing); when the demand is 'high,' however (e.g. when visual input is eliminated and/or the support surface is unstable), all three systems are utilized.

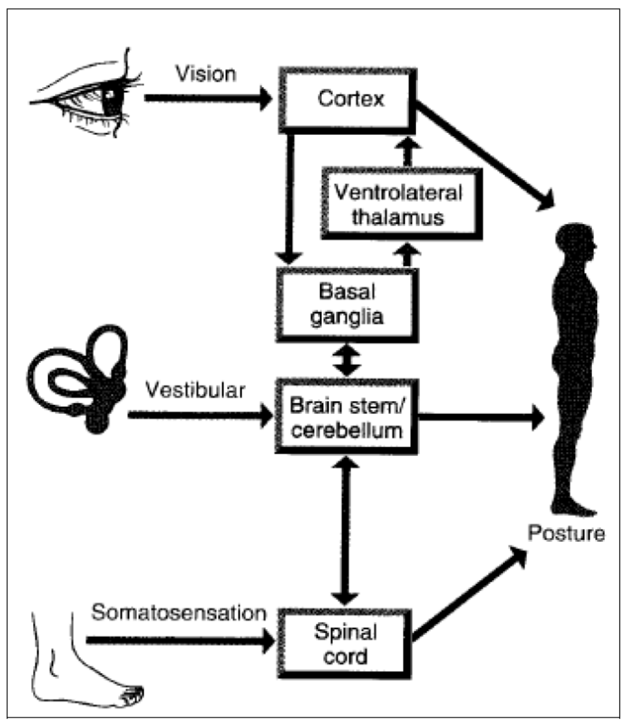

Figure 1. Sensory influences on postural control (reprinted from Lundy-Ekman L. Neuroscience: Fundamentals for Rehabilitation. Philadelphia, PA: W.B. Saunders; 1998

Computerized dynamic posturography (CDP) is a method for quantitatively assessing an individual's static and dynamic balance using computerized force-plate technology. CDP is defined by the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) as the test protocol consisting of the Sensory Organization Test (SOT), motor control test (MCT), and adaptation test (ADT) protocols. Together, these tests quantify and identify the sensory (visual, vestibular, and somatosensory inputs) and motor functions involved in balance control under a variety of changing task conditions. CDP is considered the "gold standard" in the impairment-based diagnosis of patients with dizziness/vertigo and disequilibrium, as well as medical case management.[2] CDP is recognized as a necessary component in the disability evaluation of patients with chronic balance or dizziness disorders and is considered to be medically appropriate in the evaluation and treatment of patients with suspected vestibular disorders.[1] Sensory Organization Test (SOT), motor control test (MCT), and adaptation test (ADT) protocols. Together, these tests quantify and identify the sensory (visual, vestibular, and somatosensory inputs) and motor functions involved in balance control under a variety of changing task conditions.

The Sensory Organization Test (SOT) is a clinical test of balance designed to systematically disrupt the sensory selection process by altering the information available to the somatosensory and or visual systems.[9-11] Under normal conditions an individual is able to maintain standing balance by using incoming information from the visual, vestibular and somatosensory systems. If one of these systems is deficient, e.g. following mild traumatic brain injury, the other systems must compensate for this deficiency. The SOT was developed to isolate which sensory system is most involved in regulating posture, and to determine how the interactions between systems affects postural control.[14] The SOT systematically eliminates visual and/or support surface (somatosensory) information and creates sensory conflict situations; these conditions isolate the vestibular system as well as stressing the adaptive responses of the central nervous system. The primary outcome measure of the SOT is the equilibrium score - the average center of gravity sway for each trial for each test condition. A composite equilibrium score on the SOT is a weighted average of the six conditions derived from the individual equilibrium scores and it describes a subject's overall level of performance on all of the test trials. Relative differences in equilibrium scores are also calculated using ratios to reveal specific information about each sensory system (e.g., the vestibular ratio indicates the relative reduction in postural stability when the visual and somatosensory inputs are simultaneously disrupted). The validity of the SOT in identifying balance impairments has been demonstrated among athletes with mild traumatic brain injury.[4-5, 8, 15]

The HS-SOT is a two-condition enhancement to the standard SOT which can be used to identify impairments in a subject's ability to effectively use vestibular inputs for balance while simultaneously moving the head, as well as isolate impairments to left-right, up-down, or side to side movement axes. The HS-SOT is an important extension of the SOT because it provides additional challenges to the sensory organization of balance and can detect subtle sensory control problems, i.e. an inability to maintain upright stability during head rotation (on the HS-SOT) despite performing within normal limits on the SOT.[12] The HS-SOT identifies impairments in a subject's ability to effectively use vestibular inputs to maintain balance while simultaneously moving the head. Head movements challenge the subject by generating a vestibular stimulus in addition to that generated by the subject's sway. To maintain balance in the absence of visual and somatosensory inputs while moving the head, the brain must differentiate between 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 the subject's stability during head movement. Even subtle sensory control problems can negatively impact athletic performance by impairing an athlete's ability to actively balance while independently moving their head and eyes. Because the vestibular system is composed of multiple, direction-specific sense organs, these degradations may be axis-specific (vertical, horizontal, or lateral), creating postural instability only when head movements occur about the involved axis. Additionally, the HS-SOT may reveal problems associated with the attentional demands required of the task (i.e. an individual's ability to maintain an upright stance posture with eyes closed while simultaneously rotating the head at a pre-determined rate) rather than structural or physiological changes affecting the vestibular receptors.

Normative data for the SOT have been previously reported.[3, 13] Normative data is currently not available for the HS-SOT. Establishing normative data for the HS-SOT would permit researchers to accurately and efficiently interpret HS-SOT data, and would provide a mechanism for clinicians to quantitatively assess patient-derived data.

The DVA test assesses impairments in a subject's ability to perceive objects accurately while actively moving the head. The DVA test assesses static visual acuity (i.e. visual acuity while the head is stationary) and dynamic visual acuity (i.e. while the head is oscillated manually or actively). This test quantifies the impact of VOR impairments on a patient's ability to accurately perceive objects while moving the head at a given velocity on a given axis. The subject's dynamic visual acuity can be measured separately in each of three movement axes (yaw [rotation of the head], pitch [forward-backward movement of the head], and roll [lateral flexion of the head]).

Among healthy (asymptomatic) subjects and patients, the relationship between performance on the HS-SOT and performance on the DVA testing has not been reported. Both tests include a head movement component, typically a specified axis of movement (yaw, pitch, or roll) and a predetermined head movement velocity. Quantifying how much variability in HS-SOT performance is accounted for by performance on DVA tests (and visa versa) is unknown. Determining a relationship between these variables would enable clinicians and researchers to develop prediction models for impairments in postural stability (HS-SOT) and gaze stabilization (DVA) during head movements.

The purpose of this study was twofold: (1) to establish normative data for the HS-SOT in a sample of healthy young adults, and (2) to compare performance between the HS-SOT and visual acuity tests [static visual acuity (SVA), perception time test (PTT), gaze stabilization test (GST), and the dynamic visual acuity (DVA) test].

METHODS

Study Design and Setting

After University IRB approval was obtained, a prospective, cross-sectional design was used. The independent variable was gender; the dependent variables included: (a) data derived from the HS-SOT [equilibrium score ratio and equilibrium score], (b) static visual acuity [expressed as both a Snellen fraction and LogMar], (c) gaze stabilization [(GST), average velocity achieved, maximum GST velocity, and velocity symmetry], and (d) dynamic visual acuity [DVA loss, DVA loss symmetry, visual acuity, and average head velocity]. For the SVA testing, Snellen Fraction is defined as a ratio, for instance measuring the acuity of a person's eyesight compared to a standard observer with normal acuity (e.g. 20/20); the LogMAR represents the Log of the Minimum Angle Resolvable and is a unit of measure that describes the size of an image based on a ratio of its absolute size to its distance from the eye.

All data collection took place in a University research laboratory.

Subjects/Participants

All subjects read and sign an approved Informed Consent Form prior to participation in the study. Participants were 60 healthy young adults (34 females, 26 males, age 23.7 ± 1.6 years; height 172.0 ± 12.9 cm; mass 72.1 ±15.5 kg). Exclusion criteria included: any neurological condition producing symptoms of imbalance, dizziness, and/or vertigo; closed head injury including concussion in the previous 6 months); any lower extremity injury or surgery in the preceding 6 months; visual loss or uncorrected vision worse than 20/20; and neck pain or limited neck mobility.

Instrumentation

The NeuroCom SMART Balance Master ® (NeuroCom International, Inc., Clackamas, OR) system was used for the assessment of SOT and HS-SOT. Visual acuity (static and dynamic) was assessed using NeuroCom's inVision™ program.

Procedures

Each subject performed the following four tests in sequential order: Sensory Organization Test (SOT), the Head Shake Sensory Organization Test (HS-SOT), Static Visual Acuity (SVA), Perception Time Test (PTT), Gaze Stabilization Test (GST), and Dynamic Visual Acuity (DVA) test.

The SOT protocol consists of three, 20-second trials under three different visual conditions (eyes open, eyes closed, or 'sway-referenced') and two different surface conditions (fixed or 'sway-referenced'). Sway-referenced refers to the titling of the support surface and/or the visual surround, following the subject's center of gravity sway. A depiction of the six testing conditions of the SOT is shown in Figure 2**.** The functional relevance of the six SOT test conditions are listed in Table 1.

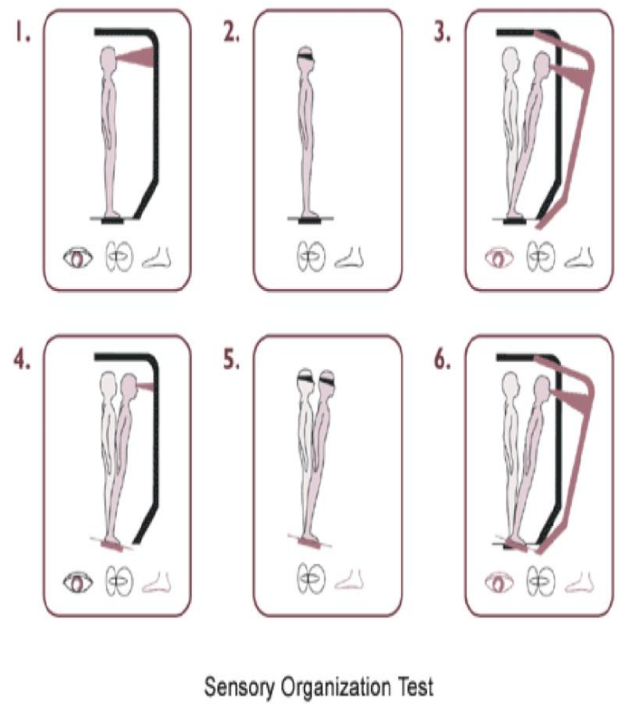

Figure 2. The Sensory Organization Test (SOT) six sensory conditions.

The SOT testing series involves 18 trials overall and a composite equilibrium score is automatically calculated following the testing session. These outcome measures include a composite equilibrium score, a sensory analysis ratio (visual, vestibular or somatosensory), a strategy analysis (ankle or hip strategy), and center of gravity alignment.

Table 1. Sensory analysis ratios and their functional relevance (reprinted from NeuroCom Internal, Inc., www.onbalance.com, accessed April 30, 2012).

Ratio	Comparison	Functional Relevance
Somatosensory (SOM)	Condition 2 Condition 1	Patient's ability to use input from the somatosensory systems to maintain balance
Visual (VIS)	Condition 4 Condition 1	Patient's ability to use input from the visual system to maintain balance
Vestibular (VEST)	Condition 5 Condition 1	Patient's ability to use input from the vestibular system to maintain balance
Preference (PREF)	Condition 3+6 Condition 2+5	The degree to which a patient relies on the visual information to maintain balance even when the information is incorrect

Following the SOT, each subject performed the HS-SOT. The HS-SOT incorporates conditions #2 (eyes closed, firm surface) and #5 (eyes closed, sway referenced surface) of the SOT while the subject wears a head-tracking device (see Figure 3).

Figure 3. Subject wearing head-mounted tracking device during performance of the HS-SOT.

Subjects stood on the NeuroCom dual-plate force-support surface with their eyes closed, fixed surface, while rotating their head at a predetermined velocity of 85 degrees per second (condition 2 of SOT). Audible and visual feedback was provided to each subject using the HS-SOT
protocol to obtain the desired velocity and direction of head movement. Each subject performed a continuous rhythmical head movement about a longitudinal axis producing rotation. This was repeated with the support surface sway-referenced (condition 5 of SOT). Each subject was instructed to maintain a specific frequency of approximately one turn of the head per second through a range (or arc) of motion of 20 degrees in each direction. For each test condition, the subject was given one practice trial followed by five 15 second scored trials. The outcome measures of HS-SOT included: an (ESR(a comparison of three trial average equilibrium score on each head-shake condition to the average score achieved on the comparable condition performed with the head fixed), and the movement axis velocity (or average head movement velocity scores for each selected head movement axis).

Upon completion of the HS-SOT, the head tracker device was removed and the subject was instructed to sit in a standard chair positioned 10 feet (3m) in front of the NeuroCom computer monitor. Each subject then underwent visual acuity testing according to the NeuroCom protocol, to include the Static Visual Acuity (SVA) test and Perception Time Test (PTT). The SVA and PPT precede the DVA tests, establishing a baseline measurement of visual acuity and minimal perception time to ensure the subject can perceive the visual stimuli within the time allotted in the DVA test protocol.
The SVA is a test of the subject's static visual acuity. With the head stationary, the subject

correctly identifies the orientation of a given optotype (the letter "E"), the size is reduced and the process repeated until the orientation of the optotype can no longer be reliably determined. The PTT measures the fastest perception time (ranging from 250 to 20 msec) that the subject can correctly perceive the ototype, i.e. the shortest presentation time that the optotype can be accurately identified.

The Dynamic Visual Acuity Test (DVA) test assesses impairments in a subject's ability to perceive objects accurately while actively moving the head. In normal individuals, losses in visual acuity are minimized during head movements by the vestibular ocular reflex (VOR) system that maintains eye fixation during head rotation by moving the eyes in the opposite direction of the head movement. The VOR incorporates information from the visual and the vestibular systems, integrating information from the semicircular canals and eye fixation, thereby permitting an individual's gaze to be fixed during head movements. When the VOR system is impaired, visual acuity degrades during head movements.

For the DVA test, the head-mounted tracking device was placed on the subject's head to measure head rotation velocity. The subject was instructed to rotate their head side-to-side at a predetermined velocity between 85 to 120 degrees/second; visual and auditory feedback was provided via the *InVision* system to ensure the subject maintained the appropriate head rotation velocity during the DVA test. The automated protocol will calculate the difference between static (head fixed) and dynamic (head moving) optotype "E" identification. Outcome measure from the DVA test include: (a) minimum perception time [the minimum time required to accurately perceive the orientation of the optotypes that are 0.2 logMAR larger than the subjects static visual acuity], (b) visual acuity difference [difference between static and dynamic visual acuity], (c) percentage left to right loss symmetry [differences in visual acuity between movement directions of a given axis], and (d) average achieved velocity [the average head velocity for each direction of movement].

In contrast to the DVA that examines changes in visual acuity with fixed velocity head movements, the Gaze Stabilization Test (GST) quantifies the head movement velocities over which the patient is able to maintain an acceptable level of visual acuity. Like the DVA, the GST can be used to test impairments in gaze stabilization for each axis of head movement: yaw, pitch, and roll. Using the head-mounted sensor to measure head movements, the subject is instructed to perform the required head movement at a predetermined velocity and to identify the orientation of the "E", which is presented only while the head is moving at the prescribed velocity on the selected axis. If the subject successfully identifies the orientation of at least 3 of 5 presentations, the head velocity needed to trigger the presentation of the "E" is increased and the process is repeated until the subject fails to achieve the minimum number of correct responses. If the subject fails to identify correctly 3 of the 5 orientations during the initial trials, the velocity required to trigger the display is reduced and the process is repeated until 3 correct orientations are identified. Outcome measures from the GST include: (a) minimum perception time [minimum time required to accurately perceive the orientation of the ototype in comparison to their static visual acuity], (b) maximum gaze velocity [the maximum head movement velocities at which the subject can maintain the visual acuity reference level], and (c) % left to right symmetry differences [maximum gaze velocity between the two directions of a given axis, expressed as a percentage of the sum of the two velocities].

Statistical Analysis

All statistical analyses were performed with SPSS software (PAWS statistics 18.0, SPSS

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Inc., Chicago, IL). Descriptive statistics and measures of central tendency and variability were calculated to summarize the Descriptive analyses were used to summarize the HS-SOT outcome measures. An independent samples t-test was conducted to determine any differences between males and females on the HS-SOT and DVA tests. To determine the relationship between the HS-SOT and DVA, a Pearson product moment correlation (r) was computed. An *a priori* alpha level of P<.05 was applied to all data to determine statistical significant.

RESULTS

Descriptive statistics for the HS-SOT are presented in Table 2. Mean ± standard error of the mean (SEM), standard deviation (SD), and 95% confidence intervals are reported.

Table 2. Descriptive Statistics for the Head Shake Sensory Organization Test (HS-SOT) in Healthy Young Adults (n=60)

Variable		Mean	SEM	SD	Range	95% CI	
						Lower	Upper
Equilibrium Score (condition 2)	Males	93.8	0.40	2.03	89.7-96.7	93.0	94.7
	Females	92.8	0.32	1.86	88.0-96.3	92.1	94.4
	Total	93.2	0.26	1.99	88.0-96.7	92.7	93.8
Equilibrium Score (condition 5)	Males	67.8	1.77	9.04	44.5+81.0	64.1	71.4
	Females	65.9	1.47	8.59	39.8-81.8	62.9	68.8
	Total	66.7	1.13	8.76	39.8-81.8	64.4	70.0
Equilibrium Score Ratio (Fixed Surface)	Males	1.01	0.004	0.02	0.98-1.08	1.00	1.02
	Females	1.01	0.005	0.03	0.96-1.13	1.00	1.03
	Total	1.01	0.003	0.24	0.96-1.13	1.00	1.02
Equilibrium Score Ratio (Sway-Referenced)	Males	0.91	0.04	0.20	0.08-1.20	0.83	0.99
	Females	0.96	0.04	0.26	0.62-2.08	0.87	1.05
	Total	0.94	0.03	0.24	0.08-1.00	0.88	1.00

A comparison of the equilibrium scores (conditions 2 and 5) and equilibrium score ratios (fixed and sway referenced surfaces) between genders revealed a significant difference for the equilibrium scores on the fixed surface (condition 2) of the HS-SOT [t (59) =2.20, p=.032] with male subjects performing better (93.86±2.0) compared to females (92.77±1.86). Figure 4 depicts the equilibrium scores and equilibrium score ratios for males and females. No significant differences were observed between males and females for equilibrium scores on the sway-referenced surface (condition 5) or for the equilibrium score ratios (fixed or swat-referenced) [p>.05].

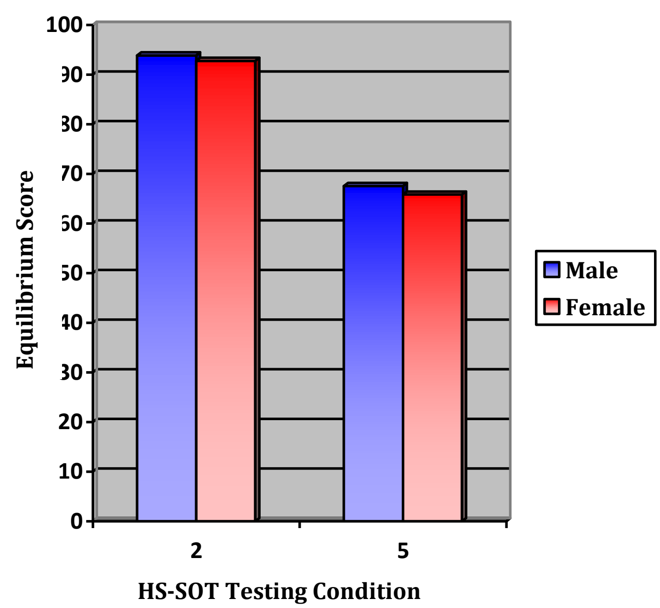

Figure 4.1 Equilibrium scores (conditions 2 and 5) compared by gender. *significant difference, p<.05.

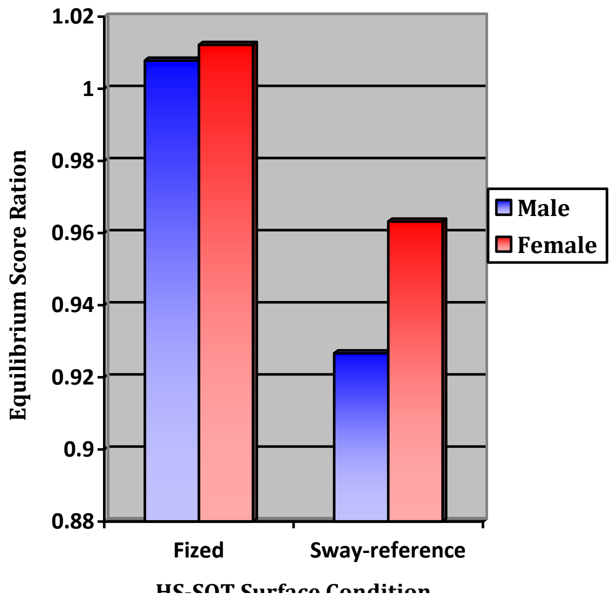

Figure 4.2 Equilibrium score ratios (fixed and sway referenced surfaces) compared by gender. *significant difference, p<.05.

DVA loss symmetry % was significantly negatively correlated with ESR on a fixed surface (condition 2 of the SOT and HS-SOT) [$R=-.363$, $p=.004$, $R^2=.131$]. DVA errors to the right side were significantly negatively correlated with ESR on a fixed surface [$R=-.297$, $p=.020$, $R^2=.088$]. There were no other statistically significant correlation between HS-SOT variables and the DVA measures ($p>.05$).

DISCUSSION

Identifying the factor(s), which contribute to deficits in postural control, will enable clinicians to more readily and accurately identify those individuals with balance dysfunction and, therefore, initiate prompt and appropriate interventions to restore normal postural control. Early identification of the possible pathological mechanisms responsible for decreased postural control will ultimately aid in appropriate medical management of patients with vestibular dysfunction and other conditions affecting postural stability.

The HS-SOT is an important extension of the SOT because it allows the clinician to identify subtle balance impairments in patients who perform within normal limits on the SOT yet remain symptomatic.[12] This test quantifies impairments in a person's ability to use vestibular inputs to maintain balance while simultaneously moving his/her head in three movement axes: yaw (horizontal plane), pitch (sagittal plane) and roll (frontal plane). Head movements generate a vestibular stimulus in addition to that generated by the patient/subject's postural sway, challenging the individual's ability to maintain balance in the absence of visual and somatosensory inputs.[12] Thus, the HS-SOT provides an objective measure of the functional output of the vestibular system in a high-demand condition. Equilibrium scores on conditions 2 (fixed surface) and 5 (sway referenced surface) of the SOT are automatically compared to scores obtained on the same test conditions during head movements on the HS-SOT, producing an equilibrium score ratio [ESR fixed surface and ESR sway referenced]. Normative data on the HS-SOT for an asymptomatic sample will enable clinicians and researchers to compare performance in symptomatic patients and populations with known or suspected vestibular impairments [7]. We have presented the mean ± 1 standard deviation, standard error of the mean (SEM), range, and 95% confidence intervals for the SOT (composite equilibrium scores) and the equilibrium scores of conditions 2 and 5 on the HS-SOT and the ESR for fixed and sway-referenced surfaces (Table 2).

Equilibrium scores for condition 2 (fixed surface) were higher than equilibrium scores for condition 5 (sway-referenced surface): 93.2 ± 1.9 [95% CI 92.7-93.7] and 66.7 ± 8.8 [95% CI 88-96.7] respectively. Subjects in this sample demonstrated greater variance in their performance on the sway-referenced, eyes closed, head-shake component (condition 5, $\delta^2 = 3.96$) compared to the fixed surface, eyes closed, head-shake component

(condition 2, δ^2=76.8). The unstable support surface on condition 5 produces increased postural sway during simultaneous head movement performed by the subject. Male subjects performed slightly better on the fixed surface (condition 2) of the HS-SOT compared with female subjects [males = 93.86±2.00, females 92.77±1.86, t(59)= 2.20, p=.032] but no significant differences were observed for the sway-referenced (condition 5) component of the HS-SOT. The two groups (male and female) demonstrated equal variance on the dependent measure 'equilibrium score – fixed surface' (F=.883, p=.351).
Equilibrium score ratios, which compare the subject's performance on the SOT and HS-SOT for conditions 2 and 5 (fixed and sway-referenced, respectively) demonstrated a mean (±SD) of 1.01 ± .003 [ESR fixed] and 0.94 ± .23 [ESR sway-referenced], indicating that asymptomatic subjects age 23.7 (±1.3 years) perform as well on the HS-SOT as they perform on the SOT for the two absent visual input test conditions.

Subject performance on the HS-SOT was not significantly correlated with performance on the DVA testing (P>.05), with the exception of the significant negative correlations noted between ERS fixed surface [which represents the ratio of equilibrium scores on condition 2 (eyes closed, fixed surface) of the SOT with condition 2 of the HS-SOT], DVA loss symmetry and DVA errors (right only). DVA loss symmetry accounted for only 13% of the variance in equilibrium score ratios on a fixed surface (R^2=.131) while DVA errors accounted for only approximately 9% of the variance in ESR fixed surface (R^2=.088). In the absence of any other statistically significant correlations between HS-SOT and DVA variables, these correlations are probably not clinically meaningful. The lack of any clinically relevant correlations between subject performance on the HS-SOT and the DVA testing is likely due to the sample tested and the constructs being measured. We investigated a normal, healthy (asymptomatic) sample of young adults 23.7 ± 1.6 years; assessing the potential relationship between HS-SOT and DVA performance in an impaired population, e.g. following mild traumatic brain injury or among patients with peripheral vestibular disorders, may yield significant positive correlations between these variables which could be used by clinicians and researchers to develop prediction models for outcomes on these measures. An alternate explanation for the lack of a significant relationship between these two measures are the underlying constructs which each assesses; the primary purpose of the HS-SOT is to quantify an individual's ability to maintain postural stability during head movements while the DVA assesses the ability to maintain visual acuity (i.e. a stable gaze) during head movements. Future research in a patient population may demonstrate a relationship between the HS-SOT and DVA outcomes that is clinically meaningful for clinicians.

The limitations of the present study include the generalizability of the results to a larger population since we only examined an asymptomatic sample of individuals aged 18 to 26 (mean 23.7±1.6 years). A methodological limitation of our study was the assessment of upright postural stability during horizontal plane head movement (i.e. 'yaw' as compared to 'pitch' or 'roll') using the HS-SOT protocol. Head rotation during the HS-SOT conditions 2 and 5 preferentially activates the horizontal (or lateral) semicircular canal [SCC] but does not provide specific information about the anterior (superior) or posterior SCC. Additional limitations of the study are a potential test-order effect and practice effects; the testing sequence was not randomized in the current study, the effect of practice on subject performance on the HS-SOT and DVA test components was not controlled, and the potential for fatigue or other symptom provocation during the testing procedures was not included in the study design. Each of these potential influences on subject performance needs to be further investigated. This study was conducted on an asymptomatic sample and the results, therefore, may not be applicable to a population with vestibular-related symptoms. Additionally, fatigue and provocation of vestibular-related symptoms were not assessed in the current study but warrant further investigation. Subjects were asked to complete the SOT, HS-SOT, and DVA testing sequentially with no rest periods between testing components; fatigue and/or the provocation of vestibular-related symptoms during HS-SOT and DVA testing may have an impact on subject performance on these tests. Future research among symptomatic and asymptomatic subjects should assess what symptoms suggestive of possible vestibular dysfunction (e.g. vertigo, oscillopsia) are produced or exacerbated during dynamic head movements of the HS-SOT and DVA.

CLINICAL IMPLICATIONS

The purpose of this study was to establish normative data for the HS-SOT in an asymptomatic sample of young adults, and to identify any possible relationship between performance on the HS-SOT, gaze stabilization test, and the dynamic visual acuity test. Clinicians will be able to use this normative data on the HS-SOT among asymptomatic adults to compare to those of patients with various vestibular pathologies contributing to poor postural control. This data may also help the clinician to diagnosis subtle vestibular deficits among individuals who perform within normal limits on the SOT, and will ultimately assist in accurately identifying individuals with balance deficits associated with vestibular impairments. Future research studies should seek to establish normative data for a younger (<18 years) and older (>26 years) sample to permit greater generalization of the HS-SOT outcomes data to a larger population. The HS-SOT and DVA tests appear to measure different constructs associated with head movements, but each provides unique and clinically relevant information about postural stability and dynamic visual acuity, and may be included as a portion of the comprehensive test battery.

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