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Modified head shake sensory organization test: Sensitivity and specificity

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ABSTRACT

The Sensory Organization Test (SOT) of Computerized Dynamic Posturography (EquiTest™ equipment) is a valuable tool for investigating how an individual uses balance system sensory input (vestibular, vision, proprioception/somatosensory) to maintain quiet stance; however, it is limited as a screening tool for identifying peripheral vestibular system dysfunction. Previous research has shown that adding horizontal head-shake to portions of the standard SOT battery improved the identification of peripheral vestibular system asymmetry; however, flaws in the methods were noted. The objective of this work was to evaluate the sensitivity and specificity of the modified head-shake SOT (HS-SOT) protocol for identification of peripheral vestibular system lesion. Fifteen patients with chief complaint of instability, vertigo, and/or lightheadedness, with and without a caloric unilateral weakness (UW) and fifteen age-matched healthy controls were included in the final analysis. Ten of the 15 patients demonstrated a caloric UW $\geq$ 25%. Participants completed standard conditions 2 and 5 of SOT with head still and during four horizontal head-shaking tasks (i.e., HS-SOT2-60°/s, HS-SOT2-120°/s, HS-SOT5-15°/s, and HS-SOT5-60°/s). Average equilibrium scores decreased as condition difficulty increased (SOT2, HS-SOT2-60°/s, HS-SOT2-120°/s, SOT 5, HS-SOT5-15°/s, and HS-SOT5-60°/s) for each group; as expected, a lower decline was noted for controls (slope = −6.59) compared to patients (slope = −11.69). The HS-SOT5-15°/s condition was superior for identifying peripheral vestibular asymmetry (AUC = 0.90 sensitivity = 70%, specificity = 100%), with the strongest correlation to caloric UW% (r_s = −0.743, p = 0.000006). HS-SOT5-15°/s appears to be a promising screening measure for peripheral vestibular asymmetry.

1. Introduction

Our ability to maintain balance is influenced by coordination of sensory input (vestibular, vision, and proprioception) and motor output, which sends commands to lower extremities and muscles. The Sensory Organization Test (SOT) of Computerized Dynamic Posturography evaluates the ability to utilize vision, vestibular and biomechanical sensors at the joints and on the plantar surface of the foot to maintain balance [1,2]. Changes in center of pressure are quantified during six increasingly challenging conditions that disrupt portions of balance sensory input (Fig. 1). An equilibrium score for each condition trial is calculated by comparing the angular difference between the patient's calculated maximum and minimum sagittal plane body sway to a theoretical maximum displacement (12.5°), and referenced as a score between 100 (no body sway) to 0 (fall) [3].

$$\text{Equilibrium} = 12.5^\circ - (\theta_{max} - \theta_{min})/12.5^\circ \times 100$$ [3].

The SOT measures the functional ability to coordinate balance after an injury or disease affects the balance system [4,5]; however, it is a limited tool to screen for peripheral vestibular asymmetry, with respect to site-of-lesion [4–8]. In many cases, measures of postural control will be normal within a short period of time after unilateral vestibular loss [9–11].

The addition of horizontal head-shake during standard SOT testing decreases postural control ability [12,13] and improves SOT performance for identifying unilateral vestibular loss [14]. During head-shake, the vestibular system is stimulated; therefore, the individual's postural control system is challenged [15].

Abbreviations: CDP, computerized dynamic posturography; HS-SOT, head-shake posturography; SOT, sensory organization test; UW, unilateral weakness.

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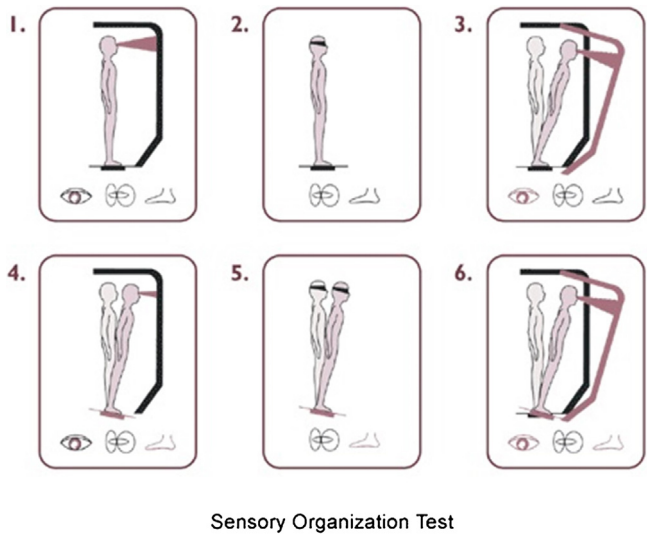

Fig. 1. Graphic of the Sensory Organization Test (SOT) depicting the six increasingly challenging conditions. Reprinted with permission from Neurocom International, online resources: http://resoursesonbalance.com/program/role/cdp/protocols.aspx.

Furthermore, when the individual is receiving inaccurate visual and/or proprioceptive sensory information and the vestibular system is activated (i.e., head-shake), discrimination between the head-shake and body sway must be made by the brain [16]. Individuals with vestibular dysfunction are unable to distinguish between the body sway and the vestibular system input, which ultimately leads to increased body sway (i.e., reduced postural control). Thus, head-shake SOT (HS-SOT) may be appropriate for individuals presenting with persistent symptoms, but appear to be compensated due to normal or near-normal SOT performance.

Mishra et al. [14] examined HS-SOT 60°/s during conditions 2 (eyes closed and stable support surface; HS-SOT2-60°/s) and 5 (eyes closed and sway reference support; HS-SOT5-60°/s); however, there were ceiling and floor effects. A modification to the HS-SOT protocol was then evaluated in 40 healthy controls [15] that included the same head-shake conditions proposed by Mishra et al. [14], but included head-shake with peak head velocity at 120°/s during SOT condition 2 (HS-SOT2-120°/s), and head-shake with peak head velocity at 15°/s during SOT condition 5 (HS-SOT5-15°/s). The inclusion of the HS-SOT2-120°/s and HS-SOT5-15°/s eliminated the observed ceiling and floor effects, respectively.

Therefore, the purpose of this study was to evaluate the performance of the modified HS-SOT test proposed by Honaker et al. [15] in patients with and without peripheral vestibular asymmetry. We hypothesize the modified HS-SOT will increase sensitivity and specificity for identifying unilateral vestibular dysfunction.

2. Methods

2.1. Subjects

Patients were randomly selected from individuals referred to the University of Nebraska-Lincoln (UNL) and Boys Town National Research Hospital (BTNRH) vestibular clinics. Consistent with Mishra et al. [14] all patients presented with the chief complaint of instability, vertigo, and/or lightheadedness, with and without peripheral vestibular system asymmetries as determined by caloric testing. All patients received open loop bithermal (44 °C and 30 °C) caloric irrigations, which were analyzed using Jongkee's formula [17] to determine presence or absence of clinically significant caloric unilateral weakness (UW; ≥ 25% slow-phase eye velocity asymmetry between right and left ears). Standard SOT was performed to verify inclusion for the study. Patients were excluded from participation based on the following criteria: (1) central nervous system involvement; (2) bilateral hearing loss that would interfere with communication; (3) orthopedic condition that would interfere with standing balance; (4) cervical range-of-motion limitations that would interfere with horizontal head movements; (5) inability to complete SOT, and (6) fall reactions on SOT conditions 5 and 6.

Also included were age-matched controls recruited from community sources near the participating care facilities. Through a screening interview, all controls verified negative history of: (1) dizziness lasting longer than 1 hour in duration or recurring for greater than 1 day; (2) active middle ear disease; (3) perceived unilateral hearing loss; (4) disorders interfering with mobility and stance; (5) disorders limiting cervical range-of-motion that would interfere with horizontal head movements; (6) central nervous system involvement; and (7) alcohol consumption within 24 hours of participation. Standard SOT was performed to verify inclusion for the study; control subjects were excluded if they were unable to complete SOT or if fall reactions on SOT conditions 5 and 6 were observed. The healthy control subjects did not receive caloric testing.

2.2. Procedure

All participants provided written informed consent approved by the Institutional Review Boards (IRB) at UNL and BTNRH. Participants were instructed to stand on the EquiTest™ System (NeuroCom International, Inc), force plate with shoes removed while wearing a safety harness; proper positioning of the feet was executed [2]. Participants were asked to maintain quiet upright stance, without touching the walls or harness, and to keep their eyes closed during each task. First, three 20 second trials of standard SOT conditions 2 and 5 were performed. Next, a NeuroCom International software, version 8.3.0 (Clackamas, OR, USA), head mounted rate sensor (InertiaCube2+, 3DOF gyro) was placed on each participant's head to monitor horizontal head movement (15° excursions to the right and left) and velocity (°/s). The participants repeated three 20 second trials of SOT conditions 2 and 5 with horizontal head-shake to the right and left during different head velocities in the following order: 1) SOT condition 2 at 60°/s (HS-SOT2-60°/s), 2) SOT condition 2 at 120°/s (HS-SOT2-120°/s), 3) SOT condition 5 at 15°/s (HS-SOT5-15°/s), and 4) SOT condition 5 at 60°/s (HS-SOT5-60°/s). An audible signal cued by a metronome was used during all trials to maintain appropriate head velocity. These conditions were not randomized based on a pragmatic decision to improve the application of the test to use in a routine clinical population. Breaks were offered as needed to reduce the effects of fatigue.

2.3. Statistical Analysis

Descriptive statistics, means (*M*), standard deviations (*SD*) and ranges, of the modified HS-SOT equilibrium scores were calculated within each group. Linear regression slopes between condition task difficulty rank (condition 1 = SOT 2, condition 2 = HS-SOT2-60°/s, condition 3 = HS-SOT2-120°/s, condition 4 = SOT 5, condition 5 = HS-SOT5-15°/s, condition 6 = HS-SOT5-60°/s) and equilibrium score were calculated to quantify change in performance with increasing difficulty of the task. While learning effects are noted across condition trials [18], the standard clinical analysis approach for calculating equilibrium score was performed [1]. Specifically, an equilibrium score was calculated for each trial, and the average score across all three trials was used [1]. Subjects who were unable