Normative data for the NeuroCom Sensory Organization Test in United States Military Special Operations Forces

Context: Postural stability is the ability to control the center of mass in relation to a person's base of support and can be affected by both musculoskeletal injury and traumatic brain injury. NeuroCom's® Sensory Organization Test (SOT) can be used to objectively quantify impairments to postural stability. The ability of postural stability to predict injury and be used as an acute injury evaluation tool makes it essential in a screening and rehabilitation process. No published normative data of NeuroCom's SOT in a healthy, highly active population are available for use as a reference for clinical decision making.

Objective: To present a normative database of SOT scores in a United States Military Special Operations population that can be used for future comparison.

Design: Cross-sectional study

Setting: Human Performance Research Laboratory

Patients or Other Participants: Five hundred forty-two active military operators from Air Force Special Operations Command (n=121), Army Special Operations Command (n=171), Naval Special Warfare Command, Sea Air and Land (n=101) and Naval Special Warfare Combatant-Craft Crewmen (n=149).

Main Outcome Measure(s): Participants performed all six of the sensory organization test's conditions and repeated each three times. Scores for each condition, total composite score and ratio scores for Somatosensory, Visual and Vestibular systems were recorded.

Results: Significant differences across all groups for SOT1 (p=0.000), SOT2 (p=0.001), SOT4 (p=0.000), SOT5 (p=0.000), SOT6 (p=0.001), SOTcomp (p=0.000), VIS (p=0.000), VEST (p=0.002) and PREF (p=0.000) NeuroCom scores.

Conclusions: This study found that there are statistical differences in distribution of postural stability across United States Special Operations Forces. This normative database for postural stability, assessed by the NeuroCom SOT, can provide context when assessing a Special Operations Forces population or any other groups that maintain a high level of conditioning and training.

Key Words: normative data, NeuroCom, Sensory Organization Test

INTRODUCTION

Lower extremity musculoskeletal injury and low back pain in the military population are associated with high medical costs and lost or modified time from duty, lessening military readiness. In 2004, lower extremity overuse injuries resulted in 3 million days of limited duty for the Department of Defense.[1] In addition, blast injuries have been defined as the signature injury of conflicts in Iraq and Afghanistan. This is concerning in the military population because of the associated short term disability, potential long term cognitive effects, chronic pain and possible permanent neurologic injury.[2]

With the high occurrence of musculoskeletal injuries in the military, new injury prevention approaches are needed to reduce their impact. Many of these injuries occurring during dynamic activity,[3] where a person's center of mass is constantly changing to maintain balance. Postural stability is the ability to control the center of mass in relation to a person's base of support and can be affected by both musculoskeletal injury and traumatic brain injury.[4] By studying deviations in center of mass, movement away from an upright body position and its subsequent corrective torques, the amount of postural sway can be established.[5] Increased postural sway has been shown to be a predictor of future ankle and knee injury in athletic populations.[6,7] Decreased postural stability is one risk factor associated with new and recurrent lower extremity injuries in an active population.[8] Diminished postural stability has also been shown after previous ankle[9], knee[10] and low back[11] injuries.

The ability of postural stability to both predict injury and be used as an acute injury evaluation tool makes it essential to include in a screening and/or rehabilitation process. Postural stability can be measured by large variety of tests including instrumented and noninstrumented measures. Force plates are a commonly used method to quantitatively measure postural sway as an assessment of injury status or to track the effect of rehabilitation and training.[12,13] The use of postural stability testing has traditionally been used to test for musculoskeletal deficits, however it has recently become method of assessment in a concussed population.[14] NeuroCom's® Balance Manager Systems utilizes Computerized

Dynamic Posturography, an assessment technique used to objectively quantify and differentiate among sensory, motor, and central adaptive impairments to postural stability. During its Sensory Organization Test (SOT) protocol, the participant's sensory information is altered through calibrated "sway referencing" of the support surface and/or visual surround, which tilt to directly follow the patient's anterior-posterior body sway.[15]

Objective measurements of postural stability are important in an active population, especially in the United States Military. The United States Special Operations Command (USSOCOM) encompasses the Special Operations Forces (SOF) of all branches of military. The SOF Operators have a high physical demand placed upon them during year-round military training and tactical missions across a wide variety of environmental conditions. Air Force Special Operations Command (AFSOC) core mission is to provide rapid global employment to enable airpower success through tactical air and ground integration. United States Army Special Operations Command (USASOC) Naval Special Warfare Command, Sea Air and Land (NSW-G2) are trained to operate in all environments for which they are named (sea, air and land) but are uniquely trained for maritime areas. The United States Navy's Special Warfare Combatant-craft Crewmen (SWCC), under NSW, are primarily responsible for the insertion and extraction of Navy Sea Air and Land (SEAL) platoons as well as other SOF. These continuous, rigorous physical demands under extreme conditions often lead to musculoskeletal injuries.[16] The high level of physical fitness among elite service members influences their ability to maintain postural control, possibly giving them above average NeuroCom Sensory Organization Test scores compared to a general population. Subtle changes in training methods across SOF groups may result in differences in postural stability scores.[17] This indicates the need to have NeuroCom scores specific for this population. To aid in the prevention or mitigation the potential for lower extremity musculoskeletal injury, a comprehensive screening process should be implemented. A key component of this comprehensive screening, based on its ability to predict future injury, is balance.

Normative data for NeuroCom SOT scores have been published relative to children,[18] the elderly[19] and patients with vestibular disorders,[20] but there has been no normative data published on a highly active or military specific population. The primary purpose of this study is to present a normative database on NeuroCom Sensory Organization Test scores in a United States Military Special Operations population that can be used for future comparison with any groups who maintain a high level of conditioning and training. The secondary purpose is to investigate whether performance differed between Special Operations Forces.

METHODS

Participants:

Participants consisted of 542 active duty military operators from Air Force Special Operations Command (AFSOC) (n=121), United States Army Special Operations Command (USASOC) (n=171), Naval Special Warfare Command, Sea Air and Land (NSW-G2) (n=101) and Naval Special Warfare Combatant-craft Crewmen (SWCC) (n=149) (table 1). Subjects were excluded from the study if they were not cleared for full active duty. Descriptive statistics, including age, height, weight and body fat, of each Special Operations group is included in Table 1. All operators tested were male due to the nature of this specific population. All participants were informed of testing procedures and provided written consent that was approved by the University's Institutional Review Board. All testing was conducted at the Human Performance Research Laboratory of each respective SOF Component.

Instrumentation:

A NeuroCom Balance Master equipped with the Data Acquisition Toolkit version 2.0 Software (NeuroCom International, Inc., Clackamas, OR) was used to assess postural stability. The NeuroCom is furnished with two 9 x 18-inch force plates connected by a pin joint. Both the support surface and the visual surround rotate in the anterior–posterior plane referenced to the subject's sway and sway velocity.

Procedures:

Participants were asked to remove all footwear and then were positioned with a standardized foot placement relative to their height. They were then instructed to stand with their arms relaxed at their sides, look straight forward, and stand as still as possible. The participants performed all six of the SOT's conditions and repeated each trial three times.[21] Each trial was twenty seconds in duration. Each subject completed in the standardized order as shown in Table 2.

By controlling use of sensory information through sway referencing and/or eyes open/closed conditions, the SOT protocol systematically eliminates useful visual and/or support surface information and creates sensory conflict situations.[22] Participants need to overcome these sensory conflicts to maintain good postural stability.

An Equilibrium Score was generated based on an equation of how well the participant remains in their theoretical limits of stability (established as a total of 12.5° in the anterior-posterior direction). Less postural sway in the anterior–posterior directions results in a higher equilibrium score, indicating greater postural stability. If the participant falls or receives a negative value (sway more than the theoretical limit of 12.5°) they will receive an Equilibrium Score of zero for that condition's trial.[15] An overall composite equilibrium score was computed using the weighted average of all scores, the more difficult conditions (3 – 6) receiving a higher weight. A higher composite score is indicative of better postural control.[14] Using the average Equilibrium Scores of each condition, ratio pairs are generated to see how well the participant uses specific sensory systems displayed in Table 3.The Sensory Analysis Interpretation of the ratio scores for Somatosensory, Visual and Vestibular express how well a participant is able to use those specific cues for balance. The Preference ratio defines how well a participant can ignore inaccurate visual clues in a situation of visual conflict.[22]

Data Analysis:

All statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL). Descriptive statistics (mean, median, standard deviation) for all groups combined and each Special Operations Forces group were calculated. Normality was tested using a Shapiro Wilk test (alpha = 0.05) and all data were found not to be normally distributed. A Kruskal-Wallis test was used to compare SOT scores between all groups (alpha = 0.05). Post hoc testing with the Mann-Whitney U test was completed for variables that were statistically significant. Post hoc test were considered statistically significant using a Bonferroni correction.

RESULTS

All Operators successfully performed all three trials of each condition, with none receiving an Equilibrium Score of zero. Mean and standard deviations for each SOT condition and ratio score are presented by individual Special Operations Forces groups and all groups combined in Table 4. A Kruskal-Wallis comparison showed significant differences across all groups for SOT1 ($p<0.001$), SOT2 ($p=0.001$), SOT4 ($p<0.001$), SOT5 ($p<0.001$), SOT6 ($p=0.001$), SOTcomp ($p<0.001$), VIS ($p<0.001$), VEST ($p=0.002$) and PREF ($p<0.001$) NeuroCom scores (Table 4). Table 4 also includes median and interquartile ranges for all SOF combined, but not used within analysis. Post hoc analysis using the Mann-Whitney test with a Bonferroni correction shows significant differences of median NeuroCom scores between groups, displayed in Table 5.

DISCUSSION

This study provides a normative database of postural stability assessed by the NeuroCom Sensory Organization Test for United States Special Operations Forces. Poor postural stability has been shown to be a risk factor for ankle, knee and low back injury.[6,7] This is the first study to present NeuroCom Sensory Organization Test scores across military SOF. Data from our study will assist clinicians working with a military or highly active population by providing a comparison value in a similar population. These normative values could also be used in evaluation of patients with traumatic brain

injuries to see if they are returning to normal postural stability assessed by the SOT. Furthermore, there is potential to use this data in screening for risk of lower extremity injury once the relationship between SOT score and injury is established.

Postural control requires the coordination of multiple sensory-motor systems to maintain center of mass within limits of stability.[23] The Sensory Organization Test uses a combination of fixed and sway-referenced motion to test and score balance. These scores provide information about the assimilation of visual, proprioceptive and vestibular components of balance.[15] Previous literature has looked at the Sensory Organization Test as a way to assess and track rehabilitation progress in participants with vestibular deficits,[20,24] central nervous system disorders[25] and in an aging population.[26,27] The utilization of the NeuroCom in a healthy population is a relatively new concept. NeuroCom scores in this military population are similar to the healthy young adult population (aged 20-22)[28] and a collegiate athletic population.[29] Average data for our Special Operations Forces is lower across conditions as compared to healthy volunteers, aged 21 to 30 years, used by Borah et al.[30] These data are cited in NeuroCom's Clinical Interpretation Guide: Appendix A[21] as a reference of relevance. Only ten subjects were used for each age group, grouped in ten year intervals. However, our averages are higher than the data currently used for Normative Values and listed in NeuroCom's Clinical Interpretation Guide: Table A1,[21] indicating a need for a military specific or highly active population database of normative values.

The results of this study show that the multi-dimensional components of postural stability may be affected by the tactical demands of individual military branches. The statistical difference in distribution of Sensory Organization Test scores between groups emphasizes the need to have a normative database specifically for individual SOF (Figure 1). Statistical differences were seen between Operators for SOT Conditions 1, 2, 4, 5, 6 as well as the composite, visual, vestibular and preference scores. Similarities in distribution between groups for SOT Condition 3 and somatosensory scores may be due to Condition 3 having a disadvantaged visual system (sway-referenced surround), therefore

forcing the participant to rely on the somatosensory system. Differences between groups may be a result of their specific tactical training, mission environment and equipment. Balance and proprioception improvements have been shown to occur in an athletic population as a result of participating in their sport.[31] In our experience with Special Operations Forces, there are different tactical demands between groups that may lead to subtle postural stability differences.

Using a normative database to compare an individual's current postural stability score can help determine who may be at risk of future injury. Along with adaptations to tactical training, balance training programs can be utilized to decrease the possible risk of injury. Balance training has commonly been used for performance improvement and injury prevention in an active population.[32] Training focuses on heightening the sensorimotor system for more efficient automatic muscular response to maintain postural control.

One limitation of this study is that participants may have had a previous injury, including concussion, which currently affects balance when tested in isolation but are still cleared for full military active duty. A limitation of the NeuroCom itself is it has a theoretical limit of stability of 12.5°. If a subject has a postural sway greater than 12.5°, their equilibrium score would end up being negative. The sample assessed for this study consisted of over 100 SOF Operators of each the Navy, Army and Air Force. This allows for a good characterization of postural stability for a specifically defined population. A future prospective study should look at performance on the NeuroCom Sensory Organization Test as a predictor of future injury. It should also be used to look at the effect of balance training on postural stability of members in the Special Forces.

In conclusion, this study found that there are statistical differences in postural stability across United States Special Operations Forces. This normative database for postural stability, assessed by the NeuroCom SOT, can provide context when assessing a Special Operations Forces or other highly active population.

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