RELIABILITY OF THE SENSORY ORGANIZATION TEST IN HEALTHY COLLEGE STUDENTS

by

ROBERT CHRISTOPHER MASON

(Under the Direction of Michael A. Horvat)

ABSTRACT

The purpose of this study was to determine the reliability of the Sensory Organization Test in healthy college students. Reliability of the SOT is imperative in order to accurately assess the effectiveness of balance rehabilitation programs. Thirty healthy young adults were recruited from undergraduate classes at the University of Georgia. The participants were tested on all six conditions of the SOT, which alter incoming sensory information. Participants returned to be retested on the SOT after no more than 7 days. Results indicated a significant increase in several scores generated by the SOT between testing sessions. The stability reliability of the SOT was relatively low compared to the internal consistency reliability which was modest to excellent. Clinicians should consider the amount of motor learning that takes place during the SOT when assessing the efficacy of a particular balance intervention using the SOT.

INDEX WORDS: reliability, postural control, balance, Sensory Organization Test

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Chapter 1

INTRODUCTION

Balance is the ability to maintain the body's position over its base of support while stationary (static) or moving (dynamic). Static balance involves the ability to control postural sway during quiet standing; with increases in postural sway resulting in an overall decrease in static balance (Geuze, 2004). During dynamic balance people must maintain control of the body's center of gravity while moving it over the base of support. Likewise, dynamic balance involves postural sway while moving and also uses internal and external sensory information to coordinate the activation of muscle synergies in response to perturbations of stability. This occurs when upper-body movements shift the center of gravity or during the initiation of movement when the position of the body changes from one location to another (Gabbard, 2000).

Balance and overall stability are regulated by a complex interaction of several sensory systems including the visual, vestibular, and somatosensory systems. Postural control includes organizing these sensory inputs into sensory strategies. This process involves a hierarchical ordering of the senses in order to ensure the appropriate sense is selected for the environment and the task at hand. Sensory strategies, or the relative weight given to a sense, vary as a function of age, task, and environment. Vision provides aid to balance by observing where the body is in space and also the directions of motion. The vestibular system is able to detect the directions of motion, such as turning or forward-backward, side-to-side, and up-and-down motions of the head. Finally, the somatosensory system, including muscle and joint sensory receptors, provides a reference to the brain as to which regions of the body are in motion.

Vision provides a reference for verticality and assists an individual's control of postural sway by providing essential sensory information about body position in space, how fast it is moving, and the presence of obstacles (Witecki, Czapia, Kidon, Pawlas, & Powazka, 2003). If the eyes are closed there is a significant increase in postural sway. Although balance can be maintained with the eyes closed, performance with the eyes open is generally more efficient and contributes to balance control during quiet stance as well as inadequacies or losses in the somatosensory or vestibular systems (Shumway-Cook, & Woollacott, 2001). For example, when information from the visual and vestibular systems responds to head movements, postural reflexes can be triggered by both sensory systems, or in the case of difficulty with the vestibular response, vision can compensate for some loss of vestibular function (Gill-Body, Beninato, Krebs, 2000).

The vestibular system, located in the inner ear, provides information about movements of the head in conjunction with gravity. These receptors provide a static vertical reference during postural standing and reference the head's position during movement. In this context, sway or movement that is minute is detected by head position while other receptors provide a sense of motion within the three planes of the body: frontal, saggital, and horizontal in response to head movements. The vestibular system provides the central nervous system with information about the position and movement of the head with respect to gravity and inertial forces, providing a gravitoinertial frame of reference for postural control (Shumway-Cook et al., 2001). In addition, the vestibular system serves as an absolute reference system to which the other systems (visual and somatosensory) may be compared and calibrated. During visual and somatosensory conflict the vestibular system is especially important for balance control. A decline in vestibular function causes this absolute reference system to be less reliable, and thus the nervous system has difficulty dealing with conflicting information coming from the visual and somatosensory systems. For this reason, individuals with vestibular deficits have problems with dizziness and unsteadiness when they are in environments with conflicting visual and somatosensory inputs. Furthermore, the neurons of the vestibular structures have powerful direct influences over the motor neurons in the spinal cord that activate muscles and thus contribute substantially to balance (Gabbard, 2000).

The somatosensory system provides information related to body contact and position from touch receptors and muscle receptors that provide information about the position of the limbs. Information related to changes of pressure on the body, displacement of the muscles and joints, as well as muscular contractions is utilized in order to achieve and/or maintain balance. The somatosensory system is certainly one of the first systems to develop and under normal environmental conditions, the nervous system may weight the importance of somatosensory information for postural control more heavily than vision and vestibular inputs (Shumway-Cook et al., 2001). The somatosensory system controls many of the functions in quiet stance and can maintain stability with eyes open or closed.

In addition, muscular strength is an important factor involved in maintaining balance since all body movements are produced via contraction of skeletal muscles. The ability to perform activities of daily living, such as housework, carrying groceries, and climbing stairs, declines as muscular strength declines, and each of these activities has a component of balance within them (Islam, Nasu, Rogers, Koizumi, Rogers, & Takeshima, 2004). Since postural control includes the organization of visual, vestibular, and somatosensory inputs, an accurate assessment of overall balance as well as the contributions of these systems is needed.

Rationale for the Study

Balance problems may be associated with impaired ability to integrate the visual, somatosensory, and vestibular systems for determination of body position in space. Inability to use these systems appropriately may be related to disease, injury, or changes occurring in the aging brain (Ford-Smith, Wyman, Elswick, Fernandez, & Newton, 1995). In order to accurately assess all of the components of balance and the contribution of sensory information, specific tests are needed. It is imperative for several specific populations to have access to reliable balance tests. For example, with older individuals there is an increasing incidence of falls due to changes in the sensory systems as well as in muscular strength. For this reason it is imperative to use reliable balance tests to identify individuals at risk for falling and to design effective prevention techniques and intervention programs. Also, balance training is a key component of rehabilitation following sports injury (Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005). It is also gaining recognition as a vital component of injury prevention programs for many athletes, including adolescents (McGuine, Greene, Best, Leverson, 2000). Therefore, accurate measurement of standing balance is essential in assessing the effectiveness of balance training. Several clinical tests have been used in the past to assess balance characteristics such as the Functional Reach Test as well as the Modified Clinical Test of Sensory Interaction and Balance (CTSIB). These tests are usually simple and easy to administer but lack specificity as it relates to outcome measures. Many are functional tests and do not provide information regarding all of the components of balance. More sophisticated tests, such as the Sensory Organization Test (SOT) performed on the NeuroCom Equitest System, using a computerized force platform are now administered clinically to obtain diagnostic information for different individuals. The SOT protocol objectively identifies abnormalities in the patient's use of the three sensory systems that contribute to postural control. With the test's six sensory conditions that alter sensory input, it assesses an individual's ability to suppress inaccurate sensory information. During Condition 1, all incoming sensory information is accurate. Condition 2 involves no visual input. Condition 3 of the SOT provides inaccurate visual information, while Condition 4 consists of inaccurate somatosensory information. No vision and inaccurate somatosensory information are characteristic of Condition 5. Finally, Condition 6 offers inaccurate visual and somatosensory cues. Differences in the amount of body sway under the different sensory conditions determine the patient's ability to organize and select the appropriate sensory information to maintain postural control (Ford-Smith et al., 1995). Computerized dynamic posturography such as the SOT has gained wide acceptance as a method of measuring postural control. However, there is limited information concerning the reliability of moving platforms measures. Ford-Smith et al. (1995) concluded that the SOT protocol would be more statistically reliable for older adults if they were given a score for their effort to remain standing on a given trial, even though they might fall during testing. This recommendation was based on the fact that a subject who sways constantly during an entire trial of the SOT may obtain a score above zero, whereas a subject who stands steady until the second before the end of a trial and then falls will get a score of zero. These researchers suggested modifying the current scoring system to use the equilibrium score obtained approximately ½ second before a fall occurs. This score could then be multiplied by the percent time of the 20-second trial that the subject remained standing to construct a weighted score. According to Ford-Smith et al. (1995) this would make the test more sensitive for assessing patient improvement after intervention. It has not been determined that the SOT is reliable from session to session, therefore, until test-retest reliability is established the information gathered from the SOT may compromise interpretations of the effectiveness of treatment intervention or success of rehabilitation methods.

Purpose of the Study

The purpose of the study is to determine the test-retest reliability of the SOT in a sample of healthy individuals. It is believed that healthy college students should be able to efficiently utilize all sensory information that contributes to maintaining postural control and balance. Therefore, testing the reliability of the SOT with this sample, if deemed reliable, would add to the credibility of the tool when being used to assess the rehabilitation of injuries in young healthy adults.

Hypothesis

1. There will be no differences on composite equilibrium scores from testing session #1 and testing session #2 and the composite equilibrium score will be deemed a reliable measure.

2. There will be no differences on equilibrium scores from individual conditions 1 through 6 from testing session #1 and testing session #2, and these measures will be deemed reliable.

3. There will be no differences on strategy scores from individual conditions 1 through 6 from testing session #1 and testing session #2, and these measures will be deemed reliable.

Chapter 2

REVIEW OF RELATED LITERATURE

Previous research related to balance and stability encompasses a wide spectrum of different topics, populations, and interests. For example, investigators have previously focused on an array of balance issues ranging from falls among the older to injury prevention techniques for athletes. Furthermore, since balance and stability is such a diverse entity, there are many different methods that may be utilized to collect related data and/or information. Balance assessments were initially functional in nature but have evolved into more sophisticated tests which provide in-depth and specific analysis, such as sensory impairment. Related literature illustrates how previous research has shed light on many issues related to balance and stability involving several specific populations and several modes of testing.

Research on Balance in Aging

Much of the literature related to postural stability and balance focuses on older adults; i.e. individuals 65 years of age or older (Gabbard, 2000). Balance problems have been associated with impaired ability to integrate the visual, somatosensory, and vestibular systems for determination of body position in space. Inability to use these systems appropriately may be related to disease, trauma, or changes occurring in the aging brain (Whitney, S., Marchetti, G., Schade, A., 2006). For this reason, older adults tend to exhibit many balance disorders. In the older adult, it is important to distinguish the balance problems associated with decline in the receptivity of both the sensory and motor systems from balance problems associated with aging or pathologic processes (Ford-Smith, Wyman, Elswick, Fernandez, & Newton, 1995). Contributing factors may include a history of injuries, such as concussions, ear infections, or serious sprains or fractures. Some older adults experiencing balance problems have obvious medical conditions such as diabetes, Parkinson's disease, and strokes that are the primary source of the problem.

Several studies have show that vision plays an important role in balance, mobility, and falls in older adults. Older individuals with visual impairment demonstrate a higher rate of falls and balance difficulties than those with no visual and hearing impairment (Lee & Scudds, 2003). Lee and Scudds (2003) compared the balance in older individuals with and without visual impairment. They administered the Berg Balance Scale to 66 subjects who were 65 years or older with varying degrees of visual acuity. The researchers found balance to be more impaired with greater visual impairment which could result in falls and resultant injury.

Although visual, somatosensory, and vestibular functions decrease with age, certain types of training have been shown to retard this process and improve balance among older individuals. Islam, Nasu, Rogers, Koizumi, & Takeshima (2004) examined the effects of combined sensory and muscular training on balance in Japanese older adults was investigated. The study included 29 participants whose ages ranged from 69 to 89 years and consisted of 10 men and 19 women. The participants were divided into a control group and a training group. Each group initially performed static and dynamic balance testing which included a single-leg stance test with eyes closed and eyes open, and also a Limit of Stability (LOS) Test. The LOS is an assessment tool utilized to quantify the maximum distance an individual can intentionally displace their center of gravity, or lean in a specified direction without losing balance (Islam et.al., 2004). After the initial testing, the training group participated in a 12-week supervised exercise program. The program consisted of general warm-up exercises, balance exercises designed to challenge the visual, vestibular, somatosensory, and muscular systems, and cool-down exercises. The researchers found no significant differences at baseline between the training and control groups. However, significant improvements were noted in the LOS, single-leg stance, and muscular strength in the training group but not in the control group. Exercise programs like the one used in this study are effective in improving both static and dynamic balance, as well as lower body strength in older adults. Such improvements reduce their risk of suffering a fall.

Training of older individuals to increase postural stability and reduce the incidence of falls was also the focus of a study conducted by Ryushi, Kumagai, Hayase, Abe, Shibuya, and Ono (2000). Whether or not knee extension strength gain in middle-aged and older persons is associated with improvement in the limits of stability was investigated. The resistance training group completed two bilateral knee extension training sessions, consisting of one set of exercises, per week for 10 weeks. The non-training control group was instructed not to train their legs during the 10-week control period. Limits-of-stability and path length testing was administered to both groups using the Balance Master system. The results of the study indicate strength gain in quadriceps femoris possibly enables accurate movement of the COG farther from the center target towards the rear, suggesting that strength gain has a positive influence on a person’s perception of their ability to avoid falls (Ryushi et al., 2000).

Koceja, Allway, and Earles (1999) investigated the role of a volitional self-paced head-turn movement on the postural sway characteristics of healthy young and older subjects. This study was an attempt by the researchers to identify the particular aspects of balance that decline with age and that contribute to a greater incidence of falling among older adults. Ten young adults with a mean age of 23.3 years and ten older individuals with a mean age of 71.7 participated in the study. Postural sway characteristics of each subject were examined using a Kistler force platform under the following experimental conditions: (1) static condition with eyes open; (2) static condition with eyes closed; (3) volitional head movement with eyes open; (4) volitional head movement with eyes closed. The volitional head movement consisted of a self-paced head turn to a target to the left of the subject, continued head turn to a target to the right of the subject and return to focus on a target directly in front of the subject. The researchers found that during the static conditions, young subjects produced significantly less postural sway than the older group with both eyes open and eyes closed. Also, when asked to initiate and complete a volitional head movement, older subjects significantly altered their sway patterns, whereas young subjects did not. The authors suggest that the results of this study point to two areas of future research: (1) differences in the role of proprioceptive information and vestibular function in regulating postural control during voluntary movement; and (2) identifying those older individuals whose postural control system is compromised when performing voluntary tasks (Koceja et al., 1999).

Falls are one of the major health problems that affect the quality of life among older adults. Ozcan, Donat, Gelecek, Ozdirenc, and Karadibak (2005) investigated the relationship between risk factors for falling and the quality of life in older adults. For the purpose of this study, 116 people aged 65 or older participated. Balance (Berg Balance test), functional mobility (Timed Up and Go), proprioception (joint position sense), muscle strength (back/leg dynamometer), flexibility (sit and reach), and fear of falling (Visual Analogue Scale) were assessed as risk factors for falls. The quality of life was measured by Short Form-12 (SF-12). The results of the study caused the researchers to conclude that the risk factors for falls in older adults are associated with quality of life while flexibility and proprioception are not. Fear of falling is increasingly recognized as a factor that may affect activity, function, and physical condition in older adults (Ozcan et al., 2005).

Research on Balance Assessment in Disability

The intricacies of balance have been investigated across several populations and are not exclusive to older individuals. Balance can be diminished not only by increased age but also by disease, injury, and other conditions that may compromise the efficacy of the balance control system.

One such condition is Parkinson's disease. Parkinson's disease is a chronic progressive neurological disturbance with a significant effect on movement, cognitive functions, autonomous systems and psychosocial activities. Stankovic (2004) analyzed the balance of Parkinson's patients, as well as the effects of physical therapy. The participants were at least 50 years of age and the balance assessments included several stance tests (feet together, feet apart, one foot in front of the other, etc.) which were to be maintained for at least 30 seconds and also a functional reaching test. Physical therapy was then applied for 30 days. The physical therapy included: strategy of movements of daily activities, fall prevention, education on phases in medicamentous therapy, regular physical activity, aerobic strength, and application of physical therapy in one's surroundings. Physical therapy resulted in better values for most of the parameters analyzed, but significant differences were only noted in the functional reach test. These results imply that physical therapy should be systemically applied as part of the standard treatment practice for patients with Parkinson's disease.

Strategies for enhancing balance among individuals with Parkinson's disease are needed, because in the absence of regular physical activity, balance and muscle strength deteriorate in person with Parkinson's disease (Toole, Hirsch, Forkink, Lehman, & Maitland, 2000). Hirsch, Toole, Maitland, & Rider (2003) studied the effects of balance and high intensity resistance training on persons with Parkinson's disease was investigated. The aim of the study was to determine how a specific group rehabilitation program would influence muscle strength and balance patients with idiopathic Parkinson's disease. All participants were first pretested for balance and then pretested for muscle strength on separate days. Balance testing was accomplished by utilizing the Sensory Organization Test (SOT) on the NeuroCom Equitest System. Muscle strength testing was accomplished by the participant performing 4 motions of knee flexion to knee extension with the highest amount of weight the participant could lift. After the initial testing, the participants underwent both balance and resistance interventions. The balance intervention in this study consisted of standing with feet shoulder-width apart on foam and without foam, with eyes open and with eyes closed. The resistance intervention consisted of training exercises performed on Nautilus equipment at a local health facility. After completing the intervention program, the researchers found that balance training improved the performance of the participants on the SOT and this effect was enhanced by concurrent resistance training. The researchers ultimately postulated that a resistance and balance training program may reduce fall risk at home and in the community for individuals with Parkinson’s disease (Hirsch et al., 2003).

Stroke patients are yet another population who suffer balance impairments. Balance dysfunction is common after stroke and results from multiple impairments to motor and sensory systems. It interferes with functional independence and has been shown to be one of the primary factors leading to falls in stroke patients (Nyberg & Gustafson, 1997). The majority of falls occur during performance of voluntary movements that require active shifting of the center of mass for maintenance of equilibrium (Tinetti, Doucette, & Claus, 1995). Therefore, valid assessment of dynamic balance during the rehabilitation process is crucial in identifying problems and potential fallers among stroke patients to plan the treatment program (Ryerson, 1995).

For this reason, Chern, Wang, & Wu (2006) investigated the effectiveness of whole-body reaching as a measure of dynamic balance in patients with stroke. Whole body reaching involves bending over at the waist from a standing position to pick up a target on the floor and then resuming the initial standing position. The balance function of 23 patients with stroke was assessed by using whole body reaching, a Sit-To-Stand Test, and the Berg Balance Scale. The researchers found that correlations between measures of whole body reaching and Sit-To-Stand were positive while correlation between the whole body reaching and the Berg Balance Scale were negative. The researchers concluded that whole body reaching for near targets may distinguish various types of subjects with different levels of dynamic balance, similarly to Sit-To-Stand testing. Also, it was determined that whole body reaching might be more sensitive than the Berg Balance Scale in measuring subjects with high levels of dynamic balance.

Balance characteristics as well as the effects of balance training have also been investigated among those with mental retardation. Individuals with mental retardation, including those with Down's syndrome as well as mildly intellectually delayed individuals, score consistently lower on balance performance than their nondisabled peers and demonstrate increased postural sway and overall coordination deficits (Connolly & Michael, 1986). Smail & Horvat (2005) evaluated balance performance in mildly intellectually delayed individuals without Down's syndrome. The individuals were characterized by deficits in adaptive behaviors that significantly limit performance. The study consisted of 10 participants whose balance was assessed using the NeuroCom Equitest System. Three assessment protocols were used: SOT, weight bearing squat, and the step up and over. The weight bearing squat includes standing on a force plate and performing a squat maneuver by flexing the knees to 0°, 30°, 60°, and 90°. The step up and over quantifies movement parameters that involve stepping up and over an 8 inch stationary box with one foot, lifting the body through an erect position over the box and then lowering the body to land the swing leg on the force plate. The participants were also exposed to a balance training program. This intervention occurred 3 times weekly for approximately 30 minutes and included simple tasks such as standing on one foot and more difficult tasks such as exploring balance through the use of balance boards and incline boards. Smail & Horvat (2005) noticed improvement in balance from pre to post test in all assessments after the completion of the intervention. These results indicate that participation in a specific intervention training program can improve overall balance and weight symmetry in functional movement. Furthermore, it is the authors' belief that it is particularly important to understand how individuals with mental retardation function, as well as to promote motor development and performance of functional tasks.

Functional Balance Tests

Among the most commonly administered functional tests of balance are the Functional Reach Test, Berg Balance Scale, and the Timed Up and Go Test. These three assessments are most commonly administered to older individuals but can be useful to many different age groups. The Functional Reach Test is a measure of balance and is the difference, in inches, between arm's length and maximal forward reach, using a fixed base of support (Whitney, Poole, & Cass, 1999). It can be used to detect balance impairment, change in balance performance over time, and in the design of modified environments for impaired older individuals. The Berg Balance Scale was developed as a performance-oriented measure of balance in older individuals and consists of 14 items that are scored on a scale of 0 to 4 (Steffen, Hacker, & Mollinger, 2002). The test items include simple mobility tasks such as standing unsupported and more difficult tasks like single-leg stance. The Timed Up and Go Test is a test of basic mobility function which involves the patient getting up out of a chair, walking 3 m, turning, walking back to the chair and sitting down (Whitney et.al., 1999).

Steffen et al. (2002) conducted a study in which four clinical tests of mobility were administered to older individuals. The tests included a six-minute walk test, the Berg Balance Scale, as well as the Timed Up and Go Test. Data was analyzed by gender as well as by age cohorts. Mean test scores showed a trend of age-related declines for the six-minute walk, the Berg Balance Scale, and the Timed Up and Go Test. These results coincide with the notion that one's balance capabilities generally decrease with age.

However, in a study conducted later by Lindsay, James, and Kippen (2004) investigating the effectiveness of the Timed Up and Go Test, it was determined that the test alone was unable to identify those patients who were likely to fall. The aim of this study was to establish the effectiveness of the Timed Up and Go Test in identifying those older patients who would fall while in the hospital. During this study the Timed Up and Go Test was administered to 160 individuals admitted to a medical ward. Of the 160 study subjects, 11% (n=17) experienced a fall while admitted. None of the patients who fell had been admitted with documented diagnosis of decreased mobility. The Timed Up and Go Test, used in isolation, did not identify those patients who fell while admitted to the hospital. The researchers concluded that the Timed Up and Go Test should not be solely used to identify those older individuals who may fall.

Other means of functional balance testing and assessment are commonly utilized among the athletic population. One such method is balance board or wobble board training designed to enhance proprioceptive capabilities. Proprioceptive balance training is used in rehabilitation following sports-related injuries and is becoming recognized as an important element in injury prevention in sports (Holme, Magnusson, Becher, Bieler, Aagaard, & Kjaer, 1999). Since balance training is gaining such recognition as a vital component of injury prevention programs, it essential to attain accurate measurement of both standing and dynamic balance. Several different balance assessments as well as training programs have been used in sports and within the athletic population. With ankle injuries as well as knee injuries becoming increasingly more common in a wide variety of sports, it is imperative to find the “gold standard” for the measurement of balance in the athletic population.

There is a particular need in sports medicine for a standing and dynamic balance measure to quantify balance ability in adolescents. Sport is the leading cause of injury requiring medical attention among adolescents (Emery, Cassidy, Klassen, Rosychuk, Rowe, 2005). Each year 8% of adolescents drop out of sports activities because of injury which could lead to significant long-term effects on morbidity and mortality (Paffenger, Kamput, & Lee, 1994). With this trend of injury in mind, Emery et al. (2005) conducted a study to determine the effectiveness of a proprioceptive home-based balance training program in improving static and dynamic balance and preventing sports-related injury in adolescents. The researchers conducting this study randomly selected 127 students from 10 high schools whose ages ranged from 10 to 14 years of age. The participants were divided into a training group and a control group. Baseline measures of balance were taken for each group. Each participant completed, with eyes closed, a timed static unipedal balance test on the gym floor and a timed dynamic unipedal balance test on an Airex Balance Pad. The training group was introduced to a progressive, home-based balance training program to be used daily for 6 weeks and then weekly for the remainder of the 6-month study period. A 16-inch wobble board was used for the purpose of the intervention. The wobble board increased in instability as the training program progressed. At the end of the training program both the control group and the training group had their balance tested for a second time. The researchers found that improvements in static and dynamic balance during the follow up period were greater in the intervention group than in the control group. Emery et al. (2005) ultimately concluded that a home-based proprioceptive balance-training program is effective in improving static and dynamic balance in healthy adolescents and may also reduce the risk of ankle sprain.

Proprioceptive balance board training is a measure used in the rehabilitation following ankle sprain to restrengthen muscles and ligaments and to restore proprioception of the damaged structures around the ankle (Verhagen, van der Beek, Twisk, Bouter, Bahr, & van Mechelen, 2004). Proprioceptive balance board training has also been suggested as an alternative to taping or bracing in the prevention of ankle sprains. Verhagen et al. (2004) investigated the effectiveness of such training on the incidence of ankle sprain in volleyball players. A total of 116 teams consisting of 1127 male and female players agreed to participate in the study. They were divided into control and intervention groups. The intervention group underwent a training program during the season that consisted of 14 basic exercises on and off the balance board. Each week the program included 4 prescribed exercises: (1) 1 exercise without any material, (2) 1 exercise with a ball only, (3) 1 exercise with a balance board only, and (4) 1 exercise with a ball and a balance board. The players in each group were to report any injury of the ankle to a team doctor at any time during the season. At the end of the volleyball season and the study the researchers of the study discovered two main findings: (1) the incidence of acute lateral ankle ligament injuries for players with a history of ankle sprains was lower in the intervention group than in the control group, and (2) the incidence of overuse knee injuries for players with a history of knee injury was higher in the intervention group than in the control group. Verhagen et al. (2004) felt that one explanation for their findings could have been that although they were preventing ankle sprains, they were also shifting the weakest link in the injury chain up to the knee joint. However, the researchers ultimately proposed that a proprioceptive balance board program was effective in preventing recurrence of ankle sprains if no history of overuse knee injury exists.

Computerized Posturography

Several balance tests are used to delineate the underlying processes associated with balance. Many of these tests are clinical in nature; e.g., Functional Reach Test and the Berg Balance Scale. These scales are simple and easy to administer but fail to produce specific and detailed output measures related to the balance control system. However, more sophisticated tests using a computerized force platform are now being conducted clinically to obtain diagnostic information for different individuals (Ford-Smith et al., 1995). Computerized posturography has gained wide acceptance as a method of measuring postural control. Computerized Dynamic Posturography is a unique assessment technique used to objectively quantify and differentiate among the wide variety of possible sensory, motor, and central adaptive impairments to balance control (NeuroCom International, Inc., 2005). It is the only method validated by controlled research studies to isolate the functional contributions of vestibular inputs, visual inputs, somatosensory inputs, central integrating mechanisms, and neuromuscular system outputs for postural and balance control (Black, 2001).

Computerized posturography appears to be a useful tool with which to analyze the mechanism of swaying associated with old age. Fujita et al. (2005) conducted a study with 144 subjects (51 men and 93 women) between 22 and 88 years of age, who had no specific diseases of the nervous, vestibular, or muscular systems. Computerized posturographic measurements were carried out by using a Gravicorder to analyze the tract of the center of gravity when subjects were standing with their eyes open or closed. Track length, track density, and track area were measured. There was an age-associated increase in track length and track area; and a decrease in track density, both indicating decreases in the efficiency of controlling sway. These results coincide with results obtained from previous research that suggest aging is associated with increased body sway and postural instability (Sheldon, 1963). Detailed posturographic analyses of sway parameters are considered to be important to the understanding and alleviation of age-associated sway and its undesirable complications (Fujita et al., 2005).

In another study, balance was investigated as a predictor of ankle injuries in high school basketball players. Ankle sprain injuries occur frequently in basketball players causing them to miss extensive time from competition and place heavy demands on the health care systems (Mcguine, T., Greene, J., Best, T. & Leverson, G., 2000). McGuine et al. (2000), along with other researchers, have examined factors such as proprioception and stabilometry and their possible relationship to ankle injury. McGuine et al. (2000) evaluated the relationship between preseason measures of balance, as measured by postural sway, and ankle injury. The sample for the study included 210 high school basketball players ranging from 18-25 years of age. The balance of all participants was assessed by measuring postural sway with a unilateral stance test on the NeuroCom Balance Master before the start of the basketball season. The test required the participants to stand on a force platform, place their hands on their hips, and raise one leg off the surface of the force platform. Participants performed three trials with their eyes open and with their eyes closed for both legs. Each trial lasted 20 seconds. The unilateral stance test produced a composite sway score for each participant and each athlete was then monitored throughout the season for any type of ankle injury. McGuine et al.(2000)

observed that athletes who recorded higher sway measurements, or swayed more, suffered higher rates of ankle sprain injury during the basketball season. These results indicate that individuals with high sway scores (poor balance) are predisposed to sustain more ankle sprains.

The Sensory Organization Test (SOT) is classified as computerized posturography and is recognized as a method of measuring postural control. The test includes six sensory conditions designed to evaluate a person's standing balance. The test is administered with a computerized system using a movable dual forceplate and a moveable visual screen. The SOT protocol assesses an individual's ability to make effective use of visual, vestibular, and proprioceptive inputs, as well as the patient's ability to organize and select the appropriate sensory information to maintain postural control when cues are inaccurate (Nashner, 1990).

Riley and Clark (2003) focused on recurrence analysis, or the repetition, of human postural sway during the Sensory Organization Test. Their study examined how the availability of and alterations in sensory information during the SOT influenced the amount, variability, and temporal structure of spontaneous postural sway in young, healthy adults. Postural sway tended to increase in amount and variability as the SOT condition became increasingly difficult. In addition, the temporal structure of postural sway tended to become increasingly regular as the SOT condition increased in difficulty. The significance of this study is that the temporal structure of postural sway provides a window into the functional organization of the postural control system (Riley & Clark, 2003).

Whitney, Marchetti, and Schade (2006) described the relationship between SOT scores and reported falls in persons with vestibular and balance disorders. One hundred physical therapy charts of individuals referred to a balance and falls clinic were reviewed. Criteria for inclusion in the study were that the patients had completed the SOT, had a vestibular diagnosis, and had the numbers of falls recorded from patient report within the previous 6 months at the initial examination. The researchers found that patients who reported multiple falls prior to the physical therapy examination had significantly lower SOT composite scores than patients who reported no falls in the previous 6 months. Persons who are recurrent fallers perform worse on SOT than either nonfallers or 1-time fallers (Whitney et al., 2006). Therefore, computerized dynamic posturography performance can help guide the clinician in the development of a safe exercise program.

Ford-Smith et al. (1995) examined the test-retest reliability of the SOT in noninstitutionalized older adults. A volunteer sample of 40 individuals (30 women and 10 men) who were at least 65 years (mean age = 74.8; SD = 3.6) of age participated. The participants were administered the SOT on 2 separate days 1 week apart. The researchers compared the first trial scores of each condition as well as the composite scores of the participants on both days of testing. Single measures intraclass correlation coefficients (ICC's) were calculated to determine reliability. The results of the research conducted by Ford-Smith et al. (1995) showed poor to good 1-week reliability across the six conditions with ICC's ranging from .15 to .70. This could be due to the fact that the conditions are ineffective in altering sensory stimuli. Ford-Smith et al. (1995) also acknowledged fair reliability of the composite score (ICC = .66) generated by the SOT. Ultimately, the results of this study suggest fair to good reliability of the SOT across some of its conditions. The findings in this study imply that the composite score and the number of loss of balance episodes may be most useful in assessing balance performance and treatment effectiveness. However it is suggested that additional research be conducted on the reliability of the SOT with populations differing from older individuals. Even though computerized dynamic posturography such as the SOT is gaining acceptance, until the test-retest reliability is established the diagnostic information gathered from the tool may be negligible. With the increasing incidence of falls among older individuals and sport-related injury, it is imperative to use reliable balance tests to identify individuals at risk for falling and/or sustaining an injury.

Chapter 3

METHODS

Participants

The research study included a convenience sample of 30 participants (13 males, 17 females) ranging from 18-25 years of age. Descriptive statistics regarding participant characteristics can be found in Table 1. Participants were recruited from basic undergraduate physical education classes at the University of Georgia and offered extra credit to participate in the study, as participation was strictly voluntary. Exclusion criteria included having recent surgery and/or injury of the ankles, knees, hips, feet and related musculature. Also, having any known sensory impairments or balance deficiencies that could possibly affect and/or alter test results was part of the exclusion criteria. In order to participate in the study, students were screened with a series of questions related to the exclusion criteria. These questions all required a negative response and were verbally administered as follows: 1) “Have you undergone surgery or suffered from injury to the lower extremities serious enough to disrupt daily physical functioning within the last 12 months?” 2) “Do you have any known sensory impairments such as vision loss or loss of feeling in the lower limbs?” 3) “Do you suffer from reoccurring headaches and/or dizziness?”

Instrumentation

Subject participation included a visit to the Movement Studies Laboratory for height measures and a preliminary orientation of the testing procedures. Subjects also signed informed consent forms before participation was initiated. Subjects were then tested with the Sensory Organization Test (SOT) on the NeuroCom Equitest System

(NeuroCom International, Clackamas, OR). The Equitest System is a computerized assessment tool that has been recomended for the medical management of dizziness, balance, and mobility disorders. The SOT, in particular, quantifies organization of vestibular, somatosensory, and visual inputs to maintaining balance. With this test it is possible to analyze an individual’s ability to maintain or regain postural control under a variety of sensory or environmental conditions and challenges.

During the test procedure, subjects stood on a force platform. The platform remained stable, tilted in a plane horizontal to the floor or translated in the anterior/posterior (front to back) direction. While standing on the force platform and facing forward, the patient's field of view was blocked by an enclosure (visual surround) that could also tilt.

Outcome Measures

The main outcome measures consisted of: a computer-generated composite score, the equilibrium scores gathered during each of the three trials of each condition, and the strategy scores gathered during each of the three trials of each condition. These measures were gathered on both days of testing.

Sensory Organization Test (SOT) scores are based on the assumption that a normal individual can exhibit anterior to posterior sway over a total range of approximately 12.5 degrees without losing balance (Nashner, Shupert, & Horak, 1990). The equilibrium score is calculated for each trial in each condition by comparing the angular difference between the patient’s calculated maximum anterior to posterior center of gravity displacements to this theoretical maximum displacement. The following equation is used to calculate the equilibrium score: $ES = \{12.5 – [\Theta_{max}(ant) – \Theta_{max}(post)]\} / 12.5$, where $\Theta_{max}(ant)$ is the maximum anterior sway angle in degrees during a trial, Θ_{max}(post) is the maximum posterior sway angle in degrees during the same trial, 12.5 is the limit of sway in degrees in the saggital plane for normal stance, and 12.5 is assumed to be the limit of stability for a normal individual (NeuroCom International, Inc., 2001). No movement of the subject results in a perfect score of 100. If the subject falls or the value of the equilibrium score is negative, the subject receives a score of 0. Thus, the equilibrium score ranges between 0 and 100.

The composite equilibrium score is evaluated as a weighted average of the scores from the six conditions of the SOT of a subject, where each condition consists of three identical 20 second trials with force data sampled at 100 Hz. The composite equilibrium score is calculated by independently averaging the equilibrium scores for conditions 1 (accurate sensory information) and 2 (no vision), adding these two scores to the equilibrium scores from each trial of sensory conditions 3 (inaccurate vision), 4 (inaccurate somatosensory information), 5 (inaccurate somatosensory information and no vision), and 6 (inaccurate somatosensory and visual cues), and dividing the sum by 14 (NeuroCom International, Inc., 2001). Conditions 3-6 are weighted more heavily as they are the more difficult conditions. As such, it is expected for persons to have some degree of difficulty with these conditions relative to their first exposure. In essence, the formula for the composite score is a smoothing technique to provide a general, overall index of balance control. Examination of the composite equilibrium score is the first step in interpreting SOT results, providing a global determination of normal versus abnormal. For an SOT to be considered abnormal, the values of the composite score and at least one equilibrium score must be less than those achieved by 95% of the height and age-matched population of subjects with no symptoms or history of disequilibrium (NeuroCom

International, Inc., 2001). When the composite score falls within the abnormal range, the second interpretation step is to examine the equilibrium scores for each condition. This is done in order to identify a possible sensory dysfunction that may be contributing to the overall sensory organization abnormality.

The relative use of movement about the ankle and hips and upper body to maintain balance during the SOT is reflected in the strategy scores. Horizontal shear forces are exerted against the support surface whenever the body’s center of gravity accelerates. Since sway movements about the ankle are confined to low frequencies, the resulting center of gravity accelerations and shear are small. To be effective in moving the center of gravity, hip movements must be fast and therefore, generate larger shear forces which are also higher in frequency (Horak & Nashner, 1986). Strategy scores are calculated by comparing the peak-to-peak amplitude of the shear oscillation to the maximum possible shear of 25 pounds (NeuroCom International, Inc., 2001). This comparison is expressed as a percentage, with scores near 100 indicating little, if any, shear (i.e. full ankle strategy), while scores approaching zero indicate maximum shear (i.e. full hip strategy). For patients who rely abnormally on hip and other upper body movements to maintain balance, the strategy scores will be proportionately lower in relation to their equilibrium scores.

Testing Procedure

Subjects performed standardized testing procedures recommended by NeuroCom International. They stood on the Equitest platform base, facing into the visual surround with the subject's feet centered appriopriately on the dual forceplate based on the subject’s height. The SOT consists of six conditions with varying sensory inputs. All conditions consist of three trials lasting 20 seconds each. During Condition 1 (accurate sensory information) subjects were instructed to stand quietly with hands at their sides and eyes open. In this condition, vision is available while the force platform and the visual surround remain fixed. During Condition 2 (no vision) the subjects were instructed to stand quietly with eyes closed and hands at their sides. Vision is not present although the platform is fixed. Condition 3 (inaccurate vision) called for the subjects to stand quietly with eyes open while the platform remained fixed. During this condition the visual surround sways forward or backward as the subject's center of gravity changes position providing inaccurate visual information. In Condition 4 (inaccurate somatosensory information), the visual surround remained fixed while the force platform moves with the subject's center of gravity and sway. Vision is accurate during this condition although proprioception is not. For condition 5 (no vision and inaccurate somatosensory information), the subjects stand quietly with eyes closed while the force platform tilts forward or backward in relation to the subject’s sway. Vision is not present and the tilting of the support surface results in the provision of inaccurate somatosensory input. Finally, Condition 6 (inaccurate somatosensory and visual information) of the SOT requires the subjects to keep their eyes open while both the visual surround as well as the force platform were sway-referenced according to the sway of the subject's center of gravity. Therefore, although vision is present it is inaccurate as is somatosensory input.

Each participant returned to the Movement Studies Laboratory after no more than 7 days (mean number of days = 4.8, standard deviation = 2.2 days) to be retested on all 6 conditions of the SOT. The order of the test conditions was varied (performed in reverse order) during the second testing session to counterbalance any effects of learning and/or fatigue which could have altered one's score.

Research Design

Reliability is defined as the degree to which a measure is consistent and unchanged over a period of time. For the purpose of this study, a repeated measures research design was used. This is typical for situations similar to the one in this study where physical performance tests or other assessments are administered to a group of people on two different days, usually one to seven days apart (Baumgartner & Hensley, 2006). Therefore, this research design allows for reliability to be determined.

Data Analysis

Descriptive statistics including means and standard deviations were calculated for the following variables: day 1 and day 2 composite scores, day 1 and day 2 equilibrium scores for conditions 1-6, and day 1 and day 2 strategy scores for conditions 1-6. Also, a matched pairs t-test was utilized to assess the difference between ouput measures obtained during the first and second testing session. Single measures, intraclass correlation coefficients (ICC) were calculated using a one-way ANOVA to determine the stability reliablity of the computer-generated composite score, equilibrium score for each condition, and strategy score for each condition. Average measures intraclass correlation coefficients were calculated to determine the internal consistency reliability of the equilibrium and strategy scores on both days. The intraclass correlations were interpreted using the following scale: 0.75-1 (excellent), 0.4-0.74 (modest), and 0-0.39 (poor) (Fleiss, 1986).

Table 1. Descriptive Statistics of Participants *(mean ± standard deviation)*

Sex	13 males, 17 females
Age (yrs.)	23.5 ± 4.02
Height (in.)	67.3 ± 3.53

Figure 1. Description of the Six Conditions of the SOT

Condition	Representation*	Characteristics	Sensory Systems Compromised**
1		Eyes Open Fixed Surface	None
2		Eyes Closed Fixed Surface	No Vision
3		Eyes Open Sway Referenced Fixed Surface	Inaccurate Vision
4		Eyes Open Surface Sway Referenced	Inaccurate Proprioception
5		Eyes Closed Surface Sway Referenced	No Vision Inaccurate Proprioception
6		Eyes Open Sway Referenced Surface Sway Referenced	Inaccurate Vision Inaccurate Proprioception

*Shumway-Cook, A. & Woollacott M. (2001).
**Assessing Movement Skill Foundations

Chapter 4

RESULTS

Composite Score

The composite scores for all 30 participants of the study were well within the normal ranges for the ages involved on both testing sessions. During the first day of testing the composite scores ranged from 76-92 with a mean score of 85.6 and standard deviation of 3.6. The matched-pairs t-test that compared first and second day scores revealed a significant increase, $t(29) = -5.37$, $p<.05$, in composite scores among participants. Composite scores of the participants obtained from the second testing session ranged from 78-92 with a mean score of 88.1 and standard deviation of 2.9. A comparison of composite score means can be found in Figure 2. Despite the fact that the matched-pairs t-test revealed a significant increase in composite equilibrium scores of the participants between testing sessions, the calculated intraclass correlation of .467, according to Fleiss' criteria, shows modest reliability.

Equilibrium Scores

Equilibrium mean scores for all six sensory conditions generally increased or remained the same between testing sessions. A matched-pairs t-test revealed significant increases in equilibrium score means for Condition 4 (inaccurate somatosensory information), $t(29) = -3.93$, p<..05, Condition 5 (inaccurate somatosensory information and no vision), $t(29) = -4.67$, $p<.05$, and Condition 6 (inaccurate somatoasensory and visual information), $t(29) = -2.29$, $p<.05$. The average of the three trial scores were within the normal limits for all 6 conditions for all participants. Descriptive statistics and comparisons between test 1 and test 2 equilibrium scores for conditions 1-6 can be found in Table 2 and Figure 3 respectively. Conditions 4 (inaccurate somatosensory information), 5 (inaccurate somatosensory information and no vision), and 6 (inaccurate somatosensory and visual information) consistently produced the lowest scores among participants in the study.

Variations in the calculated single measures intraclass correlation coefficients existed between the different conditions of the SOT. Only Conditions 3 (inaccurate vision) and 5 (inaccurate somatosensory information and no vision) displayed at least modest reliability with ICC's of .497 and .425 respectively. The ICC's for the remaining conditions all fall into the poor range of reliability. Conditions 1(accurate sensory information) and 4 (inaccurate somatosensory information) of the test showed the poorest reliability with ICC's of .264 and .268. Conditions 2 (no vision) and 6 (inaccurate somatosensory and visual information) also fell into the poor range, with Condition 2 (no vision) having an ICC of .322 and Condition 6 (inaccurate somatosensory and visual information) having an ICC of .367.

The calculated average measures intraclass correlation coefficients showed less variation during both testing sessions. During day 1 of testing all intraclass correlation coefficients showed at least modest reliability. Condition 2 (no vision) and Condition 6 (inaccurate somatosensory and visual information) both showed excellent reliability with ICC's of .824 and .793 respectively. All other ICC's during day 1 showed modest reliability. Although ICC's for day 2 equilibrium scores were on average lower, all showed at least modest reliability with the exception of Condition 3 (inaccurate vision). Condition 3 had an ICC of .396 during day 2. Average measures ICC's for all day 1 and day 2 equilibrium scores can be seen in Table 4.

Strategy Scores

Strategy mean scores for all conditions increased during the second testing session with two conditions showing a significant increase according to the matched-pairs t-test. Conditions 5 (inaccurate somatosensory information and no vision), $t(29) = -3.26$, $p<.05$, and 6 (inaccurate somatosensory and visual information), $t(29) = -3.09$, $p<.05$, displayed a significant increase in mean scores between testing sessions and repeatedly produced the lowest scores among the participants. Descriptive statistics for strategy scores for each condition can be found in Table 5.

Single measures intraclass correlation coefficients ranged from poor to excellent across the six conditions of the SOT. The strategy score for Condition 2 (no vision) exhibited the lowest reliability with an ICC of .369. Conditions 1 (accurate sensory information), 3 (inaccurate visual information), and 4 (inaccurate somatosensory information) all showed modest reliability for strategy scores with calculated ICC's of .495, .638, and .572. Finally, Conditions 5 (inaccurate somatosensory and no vision) and 6 (inaccurate somatosensory and visual information) showed excellent reliability for strategy scores. Their ICC's were .796 and .757 respectively. All single measures ICC's can be seen in Table 6.

Average measures intraclass correlation coefficients for strategy scores on day 1 were higher than those calculated for day 2 scores. For day one, Condition 3 (inaccurate vision) and Condition 5 (inaccurate somatosensory information and no vision) had ICC's of .704 and .700 respectively. The remaining conditions all showed excellent reliability with ICC's ranging from .815 to .895. All average measures ICC's can be seen in Table 7. Condition 5 (inaccurate somatosensory information and no vision) and Condition 6 (inaccurate somatosensory and visual information) showed excellent reliability according to the average measures ICC's calculated for day 2 strategy scores. The ICC's for Conditions 1 (accurate sensory information), 2 (no vision), and 4 (inaccurate somatosensory information) on day 2 were .435, .513, and .727 respectively. Condition 3 (inaccurate vision) showed poor internal consistency reliability on day 2 with an ICC of .239.

Figure 2. Comparison of Composite Equilibrium Score Means

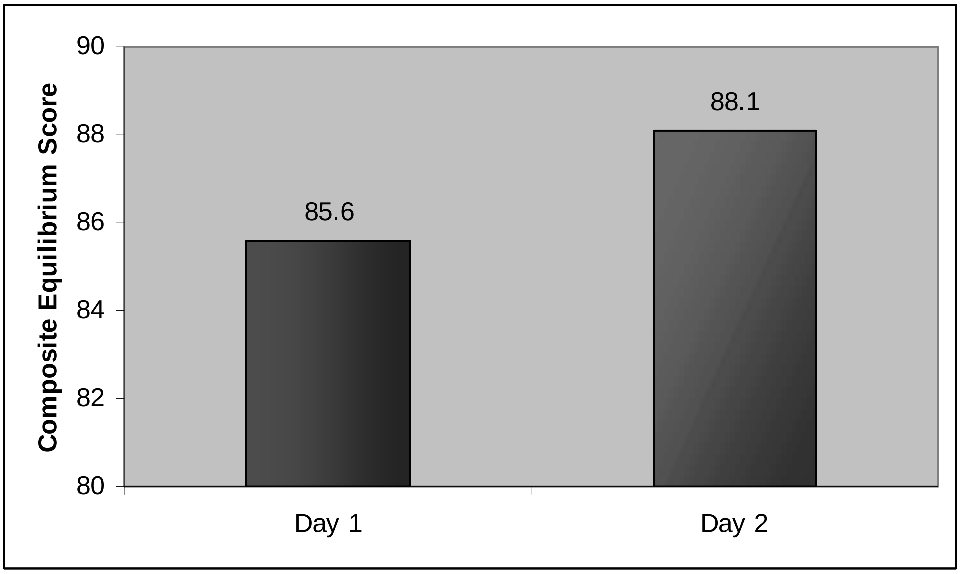

Table 2. Test 1 vs. Test 2 Mean Equilibrium Scores (*mean ± standard deviation*)

Variable	Test 1	Test 2
Composite	85.6 ± 3.6	88.1 ± 2.9
Condition 1	94.6 ± 1.6	94.3 ± 1.9
Condition 2	92.5 ± 2.5	92.3 ± 1.8
Condition 3	93.9 ± 2.0	94.1 ± 1.9
Condition 4	88.3 ± 4.2	91.0 ± 2.7
Condition 5	74.7 ± 6.7	79.2 ± 5.5
Condition 6	80.6 ± 9.5	84.5 ± 7.1

Figure 3. Comparison of Equilibrium Score Means

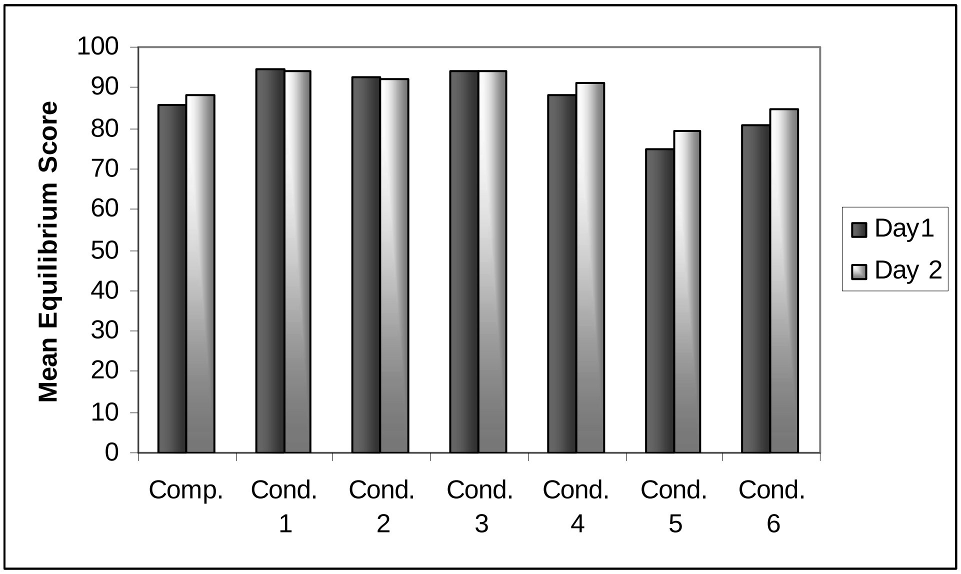

Table 3. Stability Reliability of Composite and Condition Equilibrium Scores

Variable	ICC	95% C.I.
Composite	0.467	.139, .704
Condition 1	0.264	-.096, .565
Condition 2	0.322	-.032, .607
Condition 3	0.497	.177, .723
Condition 4	0.268	-.091, .568
Condition 5	0.425	.087, .677
Condition 6	0.308	-.048, .597

Table 4. Internal Consistency Reliability of Equilibrium Scores

Condition	Day 1 ICC	95%C.I.	Day 2 ICC	95%C.I.
1	0.612	.293, .802	0.518	.121, .754
2	0.824	.680, .910	0.575	.224, .783
3	0.697	.446, .845	0.396	-.103, .692
4	0.666	.391, .830	0.571	.218, .781
5	0.441	-0.020, .715	0.625	.315, .808
6	0.793	.622, .894	0.757	.557, 876

Table 5. Test 1 vs. Test 2 Mean Strategy Scores (*mean* ± *standard deviation*)

Variable	Test 1	Test 2
Condition 1	98.8 ± 1.1	98.9 ± 1.9
Condition 2	98.1 ± 1.8	98.2 ± 2.7
Condition 3	98.2 ± 2.1	98.7 ± 1.8
Condition 4	88.0 ± 4.2	88.9 ± 3.3
Condition 5	78.9 ± 7.6	81.4 ± 7.7
Condition 6	83.6 ± 6.3	85.8 ± 5.8

Figure 4. Comparison of Strategy Score Means by Condition

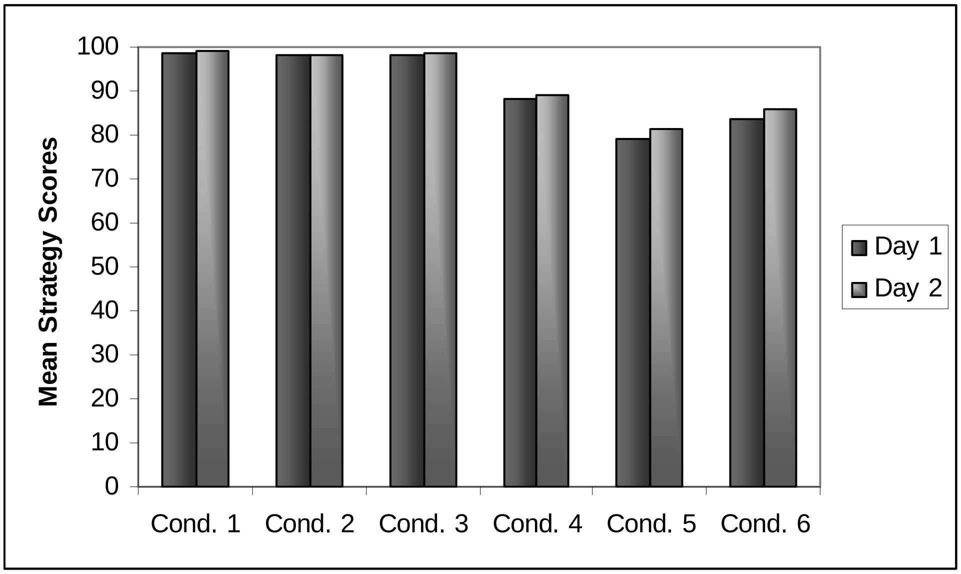

Table 6. Stability Reliability of Strategy Scores by Condition

Variable	ICC	95% C.I.
Cond. 1	0.495	.174, .722
Cond. 2	0.369	.020, .639
Cond. 3	0.638	.370, .809
Cond. 4	0.572	.276, .770
Cond. 5	0.796	.618, .897
Cond. 6	0.757	.552, .876

Table 7. Internal Consistency Reliability of Strategy Scores

Condition	Day 1 ICC	95% C.I.	Day 2 ICC	95% C.I.
1	0.895	.808, .946	0.435	-.032, .711
2	0.835	.698, .916	0.513	.111, .751
3	0.704	.459, .849	0.239	-.389, .611
4	0.817	.666, .907	0.727	.501, .860
5	0.700	.453, .847	0.905	.827, .952
6	0.815	.663, .906	0.757	.556, .876

Chapter 5

DISCUSSION

The purpose of this study was to determine the reliability of the Sensory Organization Test on the NeuroCom Equitest System in healthy college students. The results of this study, in some respects, were as expected. The sample that participated in the study was thought to be able to adequately perform all trials and conditions of the SOT. For this reason, it was assumed that all participants would produce scores that were within the normal limits defined by their age and height. As expected, all participants did indeed score within the normal limits for composite, equilibrium and strategy scores on both days of testing. It was initially hypothesized that there would be no difference in the scores produced for the three outcome measures over two test sessions. However, the statistical analysis showed that the composite score, equilibrium scores for conditions 4-6, and strategy scores for conditions 5 (inaccurate somatosensory information and no vision) and 6 (inaccurate somatosensory and visual information) actually increased significantly from the first to the second testing session. The results concerning the composite score, equilibrium scores, and the strategy scores will be individually discussed. An explanation of the calculated single and average measures intraclass correlation coefficients will then follow.

Composite Score

As it relates to the composite score, none of the participants in the study scored within the abnormal range on the SOT scale. Also, no participants scored lower than day 1 on day 2 of testing. Interestingly, the composite scores of the participants were significantly higher on the second day of testing. The procedure for this study required the SOT protocol to be administered in reverse order during the second testing session. Performing the test in reverse order calls for the more difficult conditions to be performed first and the simplest conditions last. Conditions 4 (inaccurate somatosensory information), 5 (inaccurate somatosensory information and no vision), and 6 (inaccurate somatosensory and visual information) are generally considered more difficult to perform than the other conditions because they are more dynamic in nature. The platform of the NeuroCom is sway referenced during these conditions which requires the participant to activate muscles of the lower extremities at a greater rate to maintain balance. One could argue that the stabilizing muscles used to sustain balance during the SOT may fatigue throughout the test especially during Conditions 4-6. Completing these conditions first, during the second testing session, may have compensated for the effects of fatigue causing an increase in the composite score. Muscle fatigue is the failure to maintain the required or expected force. The rate of fatigue depends on the muscles employed and whether or not the contractions are continuous or intermittent (McComas, 1996). Although the muscle contractions produced while performing the SOT are the result of perturbations stemming from the apparatus and are generally not continuous, it is conceivable that fatigue could be a factor; especially to populations who exhibit strength limitations such as older individuals. Support for this interpretation comes from a study conducted by Cohen, Heaton, Congdon, and Jenkins (1996) who examined the difference between the responses of young (18-44 years) and older (70-89 years) adults to the SOT. A significant age-associated decline in overall score and changes in movement strategy were observed. These results suggest that the components of the body involved with balance have age-related declines through the end of the life span; and that these changes do not level off but continue into the ninth decade (Cohen et al., 1996). With aging comes a deterioration in muscle mass of approximately 25% to 30% (Gabbard, 2000). Reduction of muscle strength impairs physical function and increases susceptibility to falls, which can lead to injury and a loss of independence. However, it should be noted that the period of peak strength during the human lifespan generally occurs between the ages of 25 and 29 (Gabbard, 2000). Therefore, since the sample of this study is approaching peak strength, it is not likely that fatigue alone is responsible for the increase in composite scores.

Initially, the reverse order protocol was devised as a means to counteract any effects of learning that might have occurred after performing the test for the first time. Motor learning is defined as a set of internal processes associated with practice or experience leading to relatively permanent changes in the capability for motor skill (Schmidt & Lee, 1999). With all things being equal, more learning will occur if there are more practice trials. Since each condition of the SOT consists of three trials, it is possible that learning can take place after completing the SOT just once. In spite of the order of the conditions being reversed on day 2, the increased scores for many of the tested variables suggest some degree of learning took place. Along with practice, motivation is also important when learning a motor task in order for maximally effective learning to occur (Schmidt et al., 1999). The desire of the participants to focus and surpass their score on the previous testing session was evident on several occasions by way of self-competitive comments. Thus, motivational factors may have also affected the composite scores on the second day of testing. Many participants were interested in whether or not their "overall score" increased which suggests that they indeed were motivated to improve their score.

Equilibrium Scores

Conditions 1(accurate sensory information), 2 (no vision), and 3 (inaccurate vision) displayed minimal increases in equilibrium scores between testing sessions. However, the largest increase in equilibrium scores occurred within Conditions 4-6. These last three conditions of the SOT all increased significantly between testing sessions. As previously mentioned, Conditions 4-6 involve movement of the force platform in response to the sway of the participants' center of gravity. The dynamic nature of the platform during these conditions requires the utilization of somatosensory input to maintain balance. This involves muscular activity and once again implies the possibility of fatigue throughout the 9 trials included in these 3 conditions. With Conditions 4-6 administered first and assuming the participants did not engage in any strenuous activity before the second testing session, the musculature utilized to maintain balance would have been "fresh" and more apt to perform efficiently during these conditions. This could explain the heightened increase of equilibrium scores during these conditions. However, once again assuming the healthy nature of the participants it is more conceivable that motor learning and not fatigue had more of an impact on the higher scores during the second testing period.

Theories of motor learning conceptualize learning in terms of specific stages (Fitts & Posner, 1967). At the onset of learning a new motor task, an individual's motor performance is usually characterized by inaccuracy, slowness, awkwardness, and inconsistency. Depending on numerous factors (e.g. difficulty of the task) individuals eventually reach the associative stage of learning, during which they are able to make adaptations to meet environmental demands. Considerable practice typically leads to the autonomous stage of learning. This final stage is characterized by movements which seem automatic and involve less cognitive aspects. The Fitts and Posner theory of motor learning can be applied to the SOT. Practice effects have, in fact, been observed in previous research using the SOT. Broglio, Tomporowski, and Ferrara (2005) examined participants' improvement in balance under a dual-task condition in terms of the refinement of motor control strategies acquired from practice. Repeated motor performance experiences, or simply practice, can increase a person's level of motor learning, even when the person is oblivious to the components of the task that are producing the change (Schmidt & Wrisberg, 2004). This concept of implicit learning implies that every time individuals engage in motor performance, some type of motor learning is taking place. In the context of this study, the participants may have implicitly learned motor strategies to the novel balance task that is the SOT. Implicit learning is likely to have occurred despite reversing the order of the conditions of the SOT during the second testing session. Conditions 4 (inaccurate somatosensory information), 5 (inaccurate somatosensory information and no vision), and 6 (inaccurate somatosensory and visual information) are more complex and dynamic in nature than the static conditions (1-3) of the SOT and therefore require more involved motor strategies. It is conceivable that the effects of practice were greater for these conditions; hence, the significant increase in scores for Conditions 4-6.

Strategy Scores

The SOT also generates a strategy score which illustrates the relative amounts of movement about the ankles (ankle strategy) and about the hips (hip strategy) that the participants used to maintain balance during each procedure. The ankle strategy restores the center of gravity to a position of stability through body movement centered primarily about the ankle joints. The ankle strategy appears to be used most commonly in situations in which the perturbation to equilibrium is small and the support surface is firm. Hip strategy, on the other hand, controls motion of the center of gravity by producing large and rapid motion at the hip joints. Researchers have suggested that the hip strategy is used to restore equilibrium in response to larger and faster perturbations or when the support surface is compliant or smaller than the feet. Older adults generally use a strategy involving hip movements rather than ankle movements significantly more often than young adults (Shumway-Cook et al., 2001). The preferential use of a hip strategy by older individuals could be due to conditions such as ankle muscle weakness or loss of peripheral sensory function. Typically, hip movements are used by young adults when balancing on a short support surface that does not allow them to use ankle torque to compensate for sway (Lin, 1998). Therefore, considering the size of the platform on the NeuroCom, the small perturbations associated with the SOT, as well as the youth of the participants, it was expected for the participants to display a predominant ankle strategy.

Participants' strategy scores reflected a predominant ankle strategy during all conditions of the SOT. This strategy was heightened during the second testing session. Similar to the equilibrium scores, the strategy scores associated with the more difficult conditions of the SOT also exhibited larger increases from day 1 to day 2 of testing than the other conditions. Mean strategy scores for Conditions 5 and 6 both significantly increased between testing sessions. The increase in strategy scores by the participants suggests that they tended to convert to a more efficient ankle dominant strategy to maintain balance on the second day of testing. The fact that participants became more efficient in performing the motor tasks associated with the varying conditions of the SOT, provides evidence of implicit motor learning.

Reliability of Scores

The single measures intraclass correlation coefficients (ICC's) calculated to determine the stability reliability of the composite score, equilibrium scores, and strategy scores were low implying low reliability. In fact only two of the thirteen variables (strategy scores for conditions 5 and 6) had ICC's high enough to be classified as excellent with the rest being either modest or poor. The low reliability of the outcome measures may be explained in terms of implicit motor learning. The amount of motor learning that took place by administering the SOT twice, regardless of the order of the conditions, to the participants seems to have resulted in an increase in most of the scores. Eleven of the thirteen measured variables had an increase in score means on day 2 of testing and six of the thirteen measured variables actually showed statistically significant increases in score means after day 2 of testing. This increase in scores appears to have affected the reliability of the outcome measures.

After completing the study the participants had performed six trials for each of the six conditions of the SOT. Six exposures to each condition and the motor tasks that they entail, creates an opportunity for the effects of practice and ultimately learning to occur. However, in a typical clinical situation the SOT would only be administered to an individual one time. The average of the three trials per condition is reported as the individual's equilibrium and/or strategy scores. This is a more accurate depiction of an individual's true balance as the effects of practice are still present, but lessened greatly compared to if the test is given twice. Therefore, in a typical clinical environment the internal consistency reliability, or the reliability of the SOT between trials for each condition, would take precedence over its stability reliability. The modest to excellent internal consistency reliability of the SOT during the participants' first exposure is an improvement upon the low reliability shown between days. This adds to the credibility of the tool in a typical clinical environment. The increased levels of internal consistency reliability of the SOT supports the notion that testing on one day only, offers a more accurate portrayal of a young and healthy individual's natural ability to perform the SOT. However, the relatively low stability reliability of the SOT and the increase in scores between testing sessions allows for an important conclusion to be drawn. The SOT is sensitive to an individual's change in performance between testing sessions. The sensitivity of the SOT is important as the assessment of change in performance allows for the effectiveness of balance rehabilitation programs to be determined. However, when using the SOT to assess one's progress during a balance rehabilitation program, clinicians should take into account the effects of motor learning as well as the effects of the intervention being utilized.

Limitations of the Study

This study was limited by a relatively small sample size, especially considering the number of variables that were measured. It is possible that repeating the same study with a larger sample could change the results. Also, future research should consider the sex of the participants when investigating the levels of reliability of the SOT. Differences in the scores produced by the SOT may differ between males and females. The age, sex, experience, and such characteristics of the individuals tested may have influenced the reliability of the data (Baumgartner & Hensley, 2006). Therefore, future research should continue to investigate the reliability of the SOT in all possible populations.

Conclusion

The purpose of this study was to determine the reliability of the Sensory Organization Test in healthy college students. Reliability of the SOT is imperative in order to accurately assess the effectiveness of balance rehabilitation programs. Thirty healthy young adults (18-25 years of age) were recruited from basic physical education classes at the University of Georgia and offered extra credit to participate. The participants were tested on all six conditions of the SOT, which alter incoming sensory information and require the use of inaccurate sensory input. Participants returned to be retested on the SOT after no more than 7 days (mean number of days = 4.8; standard deviation = 2.2 days). The order of the six conditions was reversed on day 2 of testing to counterbalance the effects of fatigue and learning. A matched-pairs t-test was used to assess the difference between day 1 and day 2 test scores. Both single measures and average measures intraclass correlation coefficients were calculated to determine stability and internal consistency reliability of SOT scores. Results indicated a significant increase in several scores, including the composite score. It is possible that the increase in scores between day 1 and day 2 is the result of the effects of practice and implicit motor learning. Thus, stability reliability of the SOT was relatively low. The internal consistency reliability of the SOT was modest to excellent for both equilibrium scores and strategy scores. The SOT's sensitivity to change in individual's performances is advantageous when using it to determine the effectiveness of balance rehabilitation programs. However, clinicians should be considerate of the motor learning that occurs during the multiple trials of the SOT when assessing the efficacy of a particular balance intervention.

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Appendix

Appendix A

Consent Form

Reliability of the Sensory Organization Test in Healthy College Students

I, _____________, agree to participate in a research study titled "RELIABILITY OF THE SENSORY ORGANIZATION TEST IN HEALTHY COLLEGE STUDENTS" conducted by R. Christopher Mason from the Department of Kinesiology at the University of Georgia (706-542-3389) under the direction of Dr. Michael Horvat, Department of Kinesiology, University of Georgia (706-542-4455). I understand that my participation is strictly voluntary and I can terminate my involvement at any time with no penalty. My participation or non-participation will have no impact on my class standing. Furthermore, I understand that all data collected will remain confidential and in no way be made public.

The purpose of this study is to determine the reliability of the Sensory Organization Test (SOT) which is performed on the NeuroCom Equitest System. As a participant of the research study I will be provided with extra credit in the courses from which I was recruited. Extra credit will still be awarded if I must withdraw from the study without completing the testing. Also, I will be provided with quantified information regarding my balance. This information can be educational as it may aid in the prevention and rehabilitation of certain injuries related to balance and stability.

If I volunteer to participate in this study, I will be asked to do the following:

1) Have height measured
2) Perform all six conditions of the SOT which include three, 20-second trials respectively.
3) Participate in two testing sessions that will be conducted exactly one week apart. Both testing sessions will be conducted in the Movement Studies Lab located at the Ramsey Student Center. Time commitment will be no more than 30 minutes total during two days of testing within a span of 7 days.

The SOT protocol is non-invasive in nature and should involve no psychological, social, legal, or economic risk. Minimal physical discomfort may occur as balance may be slightly disturbed, but not to the point of falling. Safety harnesses will be worn by all participants to minimize the risk of falling.

The investigator will answer any further questions about the research, now or during the course of the study (706-542-3389).

The computer generated scores from the SOT will only be reviewed by the researcher and members of the researcher's advisory committee in order to analyze the data. Data will remain confidential and will not be made public in any way. The FDA may inspect the research records.

I understand that I am agreeing by my signature on this form to take part in this research study and I understand that I will receive a signed copy of this consent form for my records.

___________________	__________________	__________
Name of Researcher	Signature	Date
___________________	___________________	__________
Name of Participant	Signature	Date

Pleas sign both copies, keep one and return one to researcher

Additional questions should be addressed to the Chairperson, Internal Review Board, UGA, 612 Boyd Graduate Studies Building, Athens, GA 30602-7411; (706) 542-3199; IRB@uga.edu