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The role of visual, vestibular, and somatosensory systems in postural balance

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by

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ABSTRACT

The Role of Visual, Vestibular, and Somatosensory System in Postural Balance

by

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The integration of visual, vestibular, and somatosensory components are used to maintain one's postural balance. Postural control changes over time and body sway increases with age. The different sensory systems begin to develop and refine starting when children are young, while in older adults it begins to decline. Hence, it is important to study the changes that occur in postural balance.

There is very little known about balance of younger adults. If balance issues are identified early in adult life it is possible to prevent exacerbation of balance decline as one ages. If nurse practitioners are aware of what dominant sensory systems for balance young adults use, perhaps strategies to preserve these can avoid falls as they age. The purpose of the study is to examine what sensory system predominates to maintain balance (e.g., visual, vestibular, and somatosensory) among people in their twenties and thirties.

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CHAPTER 1

INTRODUCTION

The integration of visual, vestibular, and somatosensory components are used to maintain one's postural balance. Postural control represents a complex interplay between the sensory systems which involves perceiving environmental stimuli, responding to alterations, and maintaining the body's center of gravity within the base of support (Shaffer & Harrison, 2007).

The primary sensory information to maintain postural balance is the visual system. Although the vestibular input is difficult to isolate and has not been studied extensively, it appears to work together with the visual and somatosensory system to maintain postural control (Merla & Spaulding, 1997). The somatosensory system is also involved in maintaining postural balance by making the body's musculoskeletal framework aware of the spatial and mechanical status regarding sense of position, movement, and balance.

Postural orientation and equilibrium are two main functional goals of postural control. Postural orientation control the body's alignment and tone with respect to gravity, support surface, visual environment, and internal references (Horak, 2006). The coordination of sensorimotor strategies to stabilize the body's center of mass during both self-initiated and externally triggered stimuli constitutes postural equilibrium (Horak, 2006). The central nervous system uses external, static references (e.g., wall), to interpret movement relative to the reference as movement of the body (Merla & Spaulding, 1997). The body uses compensatory mechanisms such as swaying in relation to the reference to maintain/restore an upright orientation.

As one ages, the sensory systems used for balance decline as established (Poole, 1991; Cohen, Heaton, Congdon, & Jenkin, 1996; Merla & Spaulding, 1997; Cook & Woollacott, 2000; Liaw, Chen, Pei, Leong, & Lau, 2008; Ricci, Goncalves, Coimbra, & Coimbra, 2009). Numerous studies have shown optimal control of postural sway is achieved during late adolescence and maintained until about the age of 60 years (Liaw, Chen, Pei, Leong, & Lau, 2008).

Younger adults use distinct patterns of response and strategies to maintain their balance (Ricci, Goncalves, Coimbra, & Coimbra, 2008). The responses and strategies related to balance that young adults use might not be the same as for other age groups. For example, a study conducted by Choy, Brauer, and Nitz (2003), showed reliance on vision for postural stability was evident in different support surfaces in women from 40 to 80 years old. The age of the individual had an effect on trunk sway measurements, which can also be used to determine postural stability. However, the lack of studies among individuals in their 20s and 30s lead to the speculation that postural balance at peak efficiently. According to Allum, Carpenter, Held-Ziolkowska, Adkin, Honegger, & Pierchala (2001) lack of vision had detrimental consequences on performance for all two-legged stance task; trunk sway increased 3-fold with the eye closed. This supported the need to evaluate the sensory system that predominated in the younger age group since balance in this sector of the population is not well studied.

To analyze the components of the sensory interaction for postural stability, a Sensory Organization Test (SOT) evaluation is performed and the goal is to identify the postural control dominance of people in their twenties and thirties. The Sensory Organization Test (SOT) of Computerized Dynamic Posturagraphy can objectively identify any abnormalities in the visual, vestibular, and somatosensory systems. The test isolates various sensory contributions by either removing or distorting the visual and/or somatosensory inputs to the postural-control (Wrisley, Stephens, Mosley, Wojnowski, Duffy, & Burkard, 2007). The SOT is comprised of six sensory conditions: (1) normal vision with fixed support (baseline for eyes open); (2) absent vision with fixed support (baseline for eyes closed); (3) swayed-reference vision with fixed support; (4) normal vision with swayed-referenced support; (5) swayed-reference support with absent vision; and (6) swayed-referenced vision with swayed-referenced support.

Problem Statement

Among the younger population, good balance may be a precondition for certain types of occupations such as rescue or construction work, where balance needs to be optimal (Era, Sainio, Koskinen, et al., 2006). Postural deficits such as impaired cognitive function, decline in sensory input, decline in motor responses, and deterioration in sensory integration systems are contributing factors to an increased likelihood of falls (Cook & Woolacott, 2000; Liaw, Chen, Pei, Leong, & Lau, 2008).

Various studies are published concentrating on postural control among the young old or older old population. However, there are few or no adequate studies on postural stability pertaining to the young population and what sensory system used for balance dominates. Furthermore, by knowing norms for these specific age groups, NPs can intervene and minimize further deterioration of the postural control and perhaps develop effective prevention strategies to minimize decline in postural stability that may occur with advancing age.

Background and Significance to Nursing

There is very little known about balance in younger adults. If balance issues are identified early in adult life, preventing exacerbation of balance decline as they age can be avoidable. If NPs are aware of what dominant sensory systems for balance young adults use, perhaps strategies to preserve decline of one or more of these systems can prevent falls as they age.

Nurse practitioners have advance training to properly assess, evaluate, and prescribe therapeutic interventions, therefore, are in a position to take information from studies such as this one and incorporate proper evidence-based health promotion strategies to maintain balance.

Purpose of Study

The purpose of the study is to examine what dominant feature of the sensory system (e.g., visual, vestibular, and somatosensory) is used to maintain balance among people in their twenties and thirties.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Search and Review Process

The literature review process was conducted on hundreds of articles covering the period from 1985-2009. Criteria for this literature review included peer-reviewed empirical studies, which addressed sensory interaction and postural balance and any combination of the following topics: assessment, measure, stability, and control. The exclusion criteria included letters to the editor and reviews. To retrieve articles from search engines, the following words, both individually and in combination were used: sensory system; sensory organization; sensory organization test; balance; young adult; middle-age adult; vestibular; visual; proprioceptive; exercise, and somatosensory system. The literature review process yielded 14 articles that met the above criteria.

Documents were retrieved from research databases: Academic Search Premier, CINAHL, Cochran Library, HealthSource: Nursing/Academic Edition, PubMed, Scopus, and Sports Discus through the University of Nevada, Las Vegas. In addition to an Internet search, hard copies of books were obtained from the University of Nevada, Las Vegas.

Literature on the different sensory systems and its contribution to postural balance were reviewed and analyzed. Literature on postural stability across the lifespan were reviewed and discussed. In addition, published research articles on the effects of exercise in balance were also reviewed and discussed.

The Dynamic of the Balance System

The Visual System

The sensory system and the development of the individual senses occur in the afferent and efferent motion perception. The afferent motion is the movement of the objects pertaining to the environment; whereas, efferent is consecutive to movements to the eyes, body or head (Kapoula & Thuan, 2006). The afferent motion perception consists of two visual systems: focal and ambient. The focal system also known as central vision, specializes in object motion perception and object recognition; whereas, ambient or peripheral vision is sensitive to movement scene and is thought to dominate both perception of self-motion and postural control. The retinal slip, a part of the afferent motion perception, is related to a person's displacement by the central nervous system (CNS), and is used as feedback for compensatory sway (Guerraz & Bronstein, 2008). Although it is a known fact that vision is the primary sensory system used in balance (Poole, 1991; Merla & Spaulding, 1997; Uchiyama & Demura, 2009); it must be noted that one can stand in the dark and remain upright. However, research has shown spontaneous lateral body oscillations are largely reduced when standing objects fixate a small light emitting diode (LED) in an otherwise darkened environment (Guerraz & Bronstein, 2008). Therefore, postural stability increases with the improvement of the visual environment. There are also other contributing parameters that affect visual control of posture such as object size and localization, binocular disparity, visual motion, visual acuity, depth of field, and spatial frequency.

The peripheral vision on postural control deserves some recognition. The peripheral vision rather than the central vision plays an essential role in maintaining stable quiet stance. A study conducted by Berencsi, Ishihara, & Inanaka (2005), showed visual stimulation of the peripheral visual field decrease postural sway in the direction of the observed visual stimulus to the antero-posterior rather than medial-lateral. The authors concluded peripheral vision operates in a viewer-centered frame of reference. Therefore, "peripheral vision is used either for visual stabilization of spontaneous body sway or visually-induced body sway is more likely due to the size of stimulated field manipulated than to functional specialization of the peripheral vision for postural control" (Guerraz & Bronstein, 2008, p. 394).

There are two hypotheses that attempt to explain how individuals maintain stability despite eye movements: *inflow* and *outflow* theory. The *inflow* theory proports proprioceptive receptors (e.g., muscle spindles) of the extraocular muscle provide the information about the position and displacement of the eyes in the orbit. Whereas, the *outflow* theory states the branches of the neural outflow (e.g., corollary discharge) or an *efference copy* (e.g., signals about the eye movements) informs the CNS to maintain visual consistency (Guerraz & Bronstein, 2008).

The Vestibular System

The vestibular system is unique from other systems because it becomes immediately multisensory and multimodal. For example, the vestibular system interacts with the proprioceptive system coupled with corollary discharge of a motor plan allowing the brain to distinguish actively generated from passive head movements (Angelaki & Cullen, 2008). Also, both visual and proprioceptive systems interact with the vestibular system throughout the central vestibular pathways and are essential for gaze and postural control.

The brain stem contains premotor neurons and second-order sensory neurons that receive afferent input and send it directly to the motoneurons, making it a streamlined circuitry of short latencies. “Simple pathways also mediate the vestibulo-spinal reflexes that are important for maintaining posture and balance”(Angelaki & Cullen, 2008, p. 127). The interaction of multisensory and multimodal pathways is important for higher level of function such as self-motion perception and spatial orientation and it is largely due to inherent complexity.

The Somatosensory System

To maintain normal quiet, stance and to safely accomplish the majority of activities of daily living, individuals rely primarily on proprioceptive and cutaneous input. The CNS processes multimodal afferent input and integrates it at various levels, resulting in efferent processing for coordinated firing of multi alpha motoreurons and their corresponding muscle fibers (Shaffer & Harrison, 2007).

The muscle spindles play an important role in proprioception. It is mechanoreceptors that provide the nervous system with information about the muscle’s length and velocity of contraction, thus contributing to the individual’s ability to discern joint movement and position sense (Shaffer & Harrison, 2007). The muscle spindles also provide afferent feedback that translates it to appropriate reflexive and voluntary movements.

Another organ that contributes to proprioceptive information is the golgi tendon organ (GTO). The GTO located at the muscle tendon interface relays information about tensile forces, and is sensitive to very slight changes (Shaffer & Harrison, 2007). When GTO is activated, the afferent neuron synapses in the spinal cord interneurons, which inhibit the alpha motoneuron of the muscle resulting in decreased tension within the muscle and the tendon.

The Difference between Visual and Vestibular Channel

The visual and vestibular channels are recognized to be responsible for compensatory action and are usually considered to occur automatically and at a low level response of when to produce a balance response (Guerraz & Day, 2008; Guerraz & Bronstein, 2008). However, evidence shows the visual channel under certain situations, is able to suppress the inappropriate balance response. For example, in a visual perturbation study, when the wall is moved unpredictably, it elicits a whole body response to the subject in the same direction. When the subject obtained control of the direction and timing of the wall movement, the response was totally suppressed (Guerraz & Day, 2008). These data suggest cognitive processes interact and suppress the balance control channel.

There are important differences between the two channels. The visual channel is used to convey to the person the direction of a moving object, whereas, the vestibular channel responses exclusively to motion of the head in space and not external phenomena (Guerraz & Day, 2008). Guerrez and Day (2008) studied postural response to galvanic vestibular stimulation (GVS) to evoke a whole-body response in standing subject. The subjects comprised a group of six (age range 23-33 years) and a group of 12 (age range 23-49 years) healthy adults. The study's protocol allows one to tell the subject beforehand how the stimuli would make him feel in a particular direction. During stimulation of GVS (0.5mA for 3 sec) the body responded by bending and tilting towards the side of the anode. The average score across all trials (the steady tilt-in-space) using was significant $F(2, 10) = 25.5$ $p < .01$ and greater for the head than for the trunk, [mean (*SD*) 1.31 (0.42) ^{0} and 1.07 (0.41) ^{0}]. The results showed the space-time characteristics of the GVS were not affected by the predictability of the forthcoming event (Guerraz & Day, 2008). However, this result is in contrast when the visual channel was tested under similar conditions. In the visual experiment, the subjects' visual channel was suppressed but still had two channels (i.e., vestibular and somatosensory) of self- motion information. In contrast to the vestibular experiment, the subjects' vestibular information was suppressed and they were left with a single channel (i.e., somatosensory) to be used for postural balance. Restricting the visual and somatosensory information may have altered the predictability effect. Looking at the vestibular system, the subjects had access to visual information while they were being stimulated with GVS. The result for GVS evoked-response was reduced approximately 40% when vision was available compared to when vision was restricted (Guerraz & Day, 2008).

The vestibular channel differs fundamentally from the visual channel when it comes to balance control (Guerraz & Day, 2008; Caudron, Boy, Forestier, & Guerraz, 2008). Twelve (age range 20-25 years) subjects participated in a study by Caudron, Boy, Forestier, and Guerraz (2008). They investigated whether postural responses evoked by proprioceptive perturbation, were automatic and immune to expectation or were cognitively penetrable. When the visual channel was suppressed, the subject was aware of the upcoming disturbance most likely to be caused by an external agent rather than self motion (Guerraz, Thilo, Bronstein, & Gresty, 2001). This was not true with the vestibular channel. The vestibular channel detected unambiguous acceleration of the head in space, and always signaled self-motion (Caudron, Boy, Forestier, & Guerraz, 2008). There is no consistent effect on the evoked whole-body response on vestibular perturbation, either through voluntary action or through prior knowledge of the event or timing cues. "Suppression did not occur although subjects knew when the stimulus would happen and had the potential to make them sway sideways" (Guerraz & Day, 2008, p. 466).

Proprioceptive Contribution of Postural Control

Vaugoyeau, Viel, Amblard, Azulay, and Assaiante (2007), isolated the role of proprioception to keep the body in an upright position. In their study, 10 healthy subjects (aged 28.6 $\pm$ 8) went through a series of tests while the subjects stood on a motorized, one-directional rotating platform with their eyes closed, with the platform rotating sinusoidally at 0.01 Hz (10^0 peak to peak) in either the pitch or roll direction. The following were the criteria for the study: (1) maintain a vertical posture as steady as possible; (2) keep feet 15 cm apart without flexing their knees; and (3) remain upright for 106 seconds. The maximum angular acceleration of the platform was $0.2^0/s^2$; a value well below the vestibular canal's detection threshold. If any angular head acceleration occurred beyond the threshold value, it did not result directly from the platform movements, therefore, was not involved in correcting the experimentally induced postural disturbances (Vaugoyeau et al., 2007).

To assess the visual contribution to both segmental orientation and stabilization, preliminary experiments were performed on five subjects. The subjects were tested with their eyes open and closed while a lateral perturbation was applied to the supporting platform; there was no significant effect of vision. The authors continued to explore the effects of perturbations under eyes closed conditions, which seem to be the most relevant condition for the proprioceptive contribution to postural control (Vaugoyeau et al., 2007).

The result showed good stabilization of the segments in space was significantly positive in the case of lateral platform perturbations: $t = 7.19$, $p < 0.0001$; $t = 6.54$, $p < 0.001$; $t = 8.57$, $p < 0.0001$; $t = 3.35$, $p = 0.01$, for head and shoulders, trunk, and pelvis respectively; and in the case of antero-posterior platform perturbations: $t = 4.46$, $p < 0.01$; $t = 9.04$, $p = 0.00001$; $t = 6.81$, $p = 0.0001$, for head, trunk, and thighs respectively.

The data confirmed the predominance of the use of proprioceptive information in the control of postural orientation with the absence of vision; postural perturbations applied below the vestibular canal detection threshold did affect upright stance in healthy young subjects (Vaugoyeau et al., 2007). It is probably safe to say that using the proprioceptive input helped to stabilize the body rather than the vestibular system.

Postural Stability Across the Lifespan

Postural control changes over time and body sway increases with age. “Deterioration in balance function clearly starts at relatively young ages and further accelerates from about 60 years upwards” (Era, Sainio, Koskinen, Haavisto, Vaara, & Aromaa, 2006, p. 204). According to Poole (1991), maintenance of posture and balance requires the integration of the visual, vestibular, and somatosensory systems. The different sensory systems begin to develop and refine starting when children are young, while in older adults it begins to decline. Hence, it is important to study the changes that occur in postural balance.

Liaw, Chen, Pei, Leong, and Lau (2008) compared the balance characteristics among different age groups using computerized dynamic posturography (CDP). The population in the study comprised 107 healthy subjects between 16 and 80 years old, divided into three groups: young (16-39 years old), middle-aged (40-59 years old), and elderly (60-80 years old). The participants stood on a fixed platform and was subjected to six conditions: (1) standing on fixed platform with their eyes open, (2) standing on fixed platform with eyes closed, (3) visual surrounds swayed with a fixed platform, (4) eyes opened and platform swayed, (5) platform swayed and eyes closed, and (6) both visual surround and the platform surfaced swayed with eyes open. The purpose of the six conditions was to isolate the different sensory systems (i.e., visual, vestibular, and somatosensory) used for balance. Conditions one and two measured the patients' baseline stability. In condition three the visual surround was conflicted, while condition four only the somatosensory input was conflicted. Whereas, in condition five and condition six the visual surround and somatosensory inputs were conflicted; this test isolates the vestibular system.

There was a statistically significant difference between the middle age and young groups (81.7 $\pm$ 8.9 vs. 87.6 $\pm$ 6.9 $p < 0.01$ in condition four; 65.0 $\pm$ 10.4 vs. 74.9 $\pm$ 8.0 $p < 0.01$ in condition five and; 65.1 $\pm$ 11.0 vs. 72.0 $\pm$ 11.6, $p < 0.01$ in condition six, respectively). Overall, the elderly group had the lowest average scores for maximal and average stability in all SOT subtests. The average stability score of the elderly group is 67.6$\pm$ 6.5, and was statistically different from the other groups (vs. 76.3 $\pm$ 5.7 young group, $p < 0.01$; vs. 69.9 $\pm$ 5.8 middle aged group, $p < 0.05$). The elderly group's average maximal stability scores were also significantly different from the young group in subtests 4-6 (79.0 $\pm$ 9.0 vs. 87.6 $\pm$ 6.9, $p < 0.001$). The data also showed the majority of falls occurred under condition five and six (Liaw et al., 2008). Since only vestibular input is available as an accurate orientation reference, there may be a deficit in vestibular function or possible central nervous system dysfunction when there is no adaptive response to simultaneously altered visual and somatosensory cues (Liaw et al., 2008).

Era, Saino, Koskinen, Vaara, and Aromaa (2008) randomly tested 7,979 subjects aged 30 years and over for postural balance control using a force platform and consisting of four test conditions: normal standing with eyes open and closed (both 30 seconds), semi-tandem (20 seconds), and tandem stand with eyes open (20 seconds). The study's findings showed there are differences in balance between different age groups, which are pronounced among young and middle-aged subjects. The force platform result for the first test, normal standing for 30 seconds with eyes open indicated a clear and significant age-related increase in the speed in the anterior-posterior (AP) and mediolateral (ML) for the movement of the center of pressure (COP), $p < 0.0001$. The difference is between the middle-aged groups (30-39, 40-49, and 50-59 years old), but this difference became more obvious after the age of 60 years old (Era et al., 2008). Whereas, ML speed was on average threefold greater in the younger age group compared with normal standing with eyes open. For tandem standing, the younger age groups (30-39, 40-49, and 50-59 years old) scored from 94.1 to 98.4%, which also indicate a clear test ceiling effect in these age groups. This findings indicate there is a significant increase from 30-39 years of age and on up to 80+ years in mean speed and movement in the COP during standing in the normal position with eyes open and closed, and during semi-tandem and tandem standing (Era et al., 2008).

The results of the study suggest postural control mechanism starts to deteriorate during early years and the difference is evident among young and middle-aged subjects (Era et al., 2006). The differences among the young and middle-aged subjects were seen more observable on the more demanding test condition (i.e., standing with eyes closed) than during normal standing with eyes open.

Changes in Sensory Organization Test Score

There is a difference in kinematics of movement between young adults and older adults, and between young and middle-aged adults (Cohen Heaton, Congdon, & Jenkins, 1996). To test the differences among the four age groups: 18-44 years old (young), 45-69 years old (middle-aged), 70-79 years old (old), and 80 to 89 (elderly), posturography was administered using the EquiTest (NeuroCom International) computerized dynamic postural test system. The six conditions of the sensory organization test (SOT) as previously described by Era et al. (2006) were administered to the subjects.

The equilibrium score on SOT showed significant main effects for age: $F\ (3,90) = 23.24$, $p < 0.0001$, and test condition: $F\ (5,90) = 355.91$, $p < 0.0001$, and a significant age by test condition interaction: $F\ (3,5,15) = 8.1$, $p < 0.0001$. Bonferroni tests at the one percent level of significance showed no significant difference among the groups for condition one (e.g., fixed platform with eyes open). The young subjects had significantly higher scores than the old subjects on condition two (e.g., fixed platform with eyes closed), four (e.g., eyes opened and platform swayed), and five (e.g., eyes closed and platform swayed); and in condition two through six; (e.g., both visual surround and the platform surfaced swayed with eyes open) the young subjects had a significantly higher scores than the elderly subjects. On conditions four through six middle-aged subjects had significantly higher score than the elderly subjects. Using the Bonferroni tests at the five percent level of significance, young and middle-aged subjects had significantly higher scores than old subjects on condition three. In general, tests of homogeneity of variance in condition five and six showed younger subjects had less variability than older subjects and in condition six, the young subjects differed from the other groups at less than the one percent level.

The collected data of the study indicated there are age-associated changes in the ability to maintain dynamic balance, which may reflect age-related anatomical changes in the vestibular system (Cohen, Heaton, Congdon, & Jenkins, 1996). This finding may be beneficial for some of the implications for therapy among younger and older adults. If younger and older adults use different strategies to maintain their balance successfully, then training should vary. Standard training regimens may benefit younger subjects, but these regimens may not benefit older adults, whose movement patterns may vary more as their individual physical capabilities decline (Cohen, Heaton, Congdon, & Jenkins, 1996).

Effects of Exercise in Balance

There are many health benefits in performing exercise (Subasi, Gelecek, & Aksakoglu, 2008; Malliou, Gioftsidou, Beneka, & Godolias, 2004; McLeod, Armstrong, Miller, & Sauers, 2009). Some of the health benefits include improvement of postural balance and proprioception, reduction of lower extremities injuries, and prevention of sports related injury among young individuals.

To prevent possible injuries during physical or sports activities, warm-up exercises are performed. Subasi, Gelecek, and Aksakoglu (2008) explored the effects of different warm-up periods on knee proprioception and balance in context of injury prevention. The researchers recruited 30 healthy subjects (19 women, 11 men; mean age 20.70 $\pm$ 0.99 years) and divided the participants randomly into a control (n=10) and two exercise (n1=n2=10) groups. Proprioceptive and balance measurements were obtained preexercise and postexercise among the two exercise groups. The exercise groups were given warm-up exercises of different length (group 1, 5 minutes; group 2, 10 minutes), whereas, the control group was not given an exercise program. Proprioceptive and balance measurements were also taken and repeated after 10 minutes between warm-up exercises.

In the exercise groups, Joint Position Sense (JPS) was tested at 15^0, 30^0, and 60^0 knee flexion (KF) on a JPS device and balance was measured using the NeuroCom Balance Master System. The participants' balance was evaluated using Modified Clinical Test for the Sensory Integration of Balance (mCTSIB) and Limits of Stability (LOS). The tests were repeated three times with ten-second rest periods between each test.

The main outcome of the study showed a significant improvement for KF of JPS of 30^0 right (R) KF, 15^0 left (L) KF, and 60^0 L KF in group one. In group two, KF of JPS values increased for all angles of both knees except 60^0, R KF. The result of the balance measurements showed a significant improvement for standing on foam with eyes closed (EC) and velocity in group one compared with preexercise ($P < 0.05$). In group two, the second set of measurements, LOS measures postexercise significantly improved compared with preexercise.

The study showed warm-up exercises had important roles in preventing musculoskeletal injuries during exercise, sport activities, and improvement of position sense and balance parameters (Subasi, Gelecek, & Aksakoglu, 2008). In addition, those who engaged in the 10-minute warm-up exercise period showed a greater improvement in proprioception than the group doing the 5-minute warm-up period.

Balance exercises may improve proprioception due to the training of the brain to recognize the segment position of the body every moment (Malliou et al., 2004).

Mechanoreceptors of the anatomical elements such as tendons, muscles, and ligaments are activated and prevent limb injuries, thus, may decrease skeletal injuries and increase balance ability.

Malliou et al. (2004) investigated the effect of balance training on proprioception and on lower limb injuries. Using a sample of 100 young soccer players from four different soccer teams (e.g., experimental group N=50 and control group N =50). The experimental group received proprioception-training program twice a week, and with 20-minute sessions. The proprioception-training program included balance exercises performed on: (1) "Biodex Stability System" balance device, (2) mini trampoline, and (3) balance boards. More specifically, in the experimental group, the participants attempted to maintain balance while they were performing soccer agilities, such as headers (Malliou et al., 2004). The control group received the same soccer training as the experimental group, but did not receive the proprioceptive-training program.

Using ANOVA with repeated measures, the experimental group revealed significant differences between pre and post training measures. The experimental group showed an improvement in all balance tests: total stability index $F(1,49) = 44.57$ $p < 0.001$, anterior-posterior stability index $F(1,49) = 35.220$ $p < 0.001$, and medial-lateral stability index $F(1,49) = 3.527$ $p < 0.05$.

The results of the study indicated the balance training protocol used was an effective means of improving proprioceptive ability and it also reduced the lower limb injury rate. The injury rate from the experimental group was reported at 60 lower limb injuries, whereas, the control group reported 88 lower limb injuries. These results further emphasized the importance of exercise by helping to improve proprioception, decrease muscle stiffness, and restore muscle imbalance (Malliou et al., 2004).

"Poor balance has been associated with increased injury risk among athletes" (McLeod, Armstrong, Miller, & Sauers, 2009, p. 465). It was reported that over 6,000 athletes suffered a sport-related injury and over 25% of these injuries result in a loss of more than seven days of participation. Therefore, it is imperative to identify mechanisms that prevent injuries and may improve balance.

A nonrandomized-controlled trial was used to determine whether there is balance gain after participation in a neuromuscular-training program. The subjects consisted of 62 female high school basketball players divided into two groups: training (n = 37) and control (n = 25). The training-group was given six-weeks of neuromuscular-training including plyometric, functional-strengthening, balance, and stability-ball exercises. The program consisted of two sessions per week for six weeks, lasting one and one-half hours and included a pretest and posttest. The subjects were then rotated through four different stations: (1) functional strengthening (30 minutes), (2) plyometrics (20 minutes), (3) agility training (10 minutes), and balance training (10 minutes). The control group also had a pretest and posttest but had no formalized neuromuscular training was given.

The data were obtained for the Balance Error Scoring System (BESS) and Star Excursion Balance Test (SEBT) before and after the six-week period for both the intervention and control group. The training-group showed a significant decrease in total BESS errors at the posttest, compared with the pretest and control group (P = .003). Balance training particularly in the single-foam and tandem-foam conditions also scored significantly fewer errors in BESS among the trained group compared to controls. This study demonstrated a neuromuscular-training program can increase the balance and proprioceptive capabilities among high school female athletes, and it is sensitive to clinical balance measures such as BESS and SEBT.

Summary

In summary, postural balance is achieved through the integration of visual, vestibular, and somatosensory systems. According to numerous research articles, the visual system is the primary sensory system used to maintain upright postural control (Kapoula & Thuan, 2006; Shaffer & Harrison, 2007; Poole, 1992; Uchiyama & Demura, 2009). The vestibular system interacts with the proprioceptive system coupled with corollary discharge of a motor plan, allowing the brain to distinguish actively compared to from passive head movements. (Angelaki & Cullen, 2008). In addition, both visual and proprioceptive systems interact with the vestibular system throughout the central vestibular pathways and are essential for gaze and postural control. The somatosensory system contributes to maintain normal quiet stance and to safely accomplish the majority of activities of daily living.

Postural changes and increased sways can be seen across the lifespan. Deterioration in balance function can be seen in early years and progressively deteriorate from about 60 years upwards (Era, Sainio, Koskinen, Haavisto, Vaara, & Aromaa, 2006). The SOT is a tool that may help clinicians determine the affected sensory systems that contribute to postural balance, so that proper interventions can be instituted. Furthermore, exercise or balance-training programs have shown to help improve balance among young athletes. Hopefully, this study will show the readers the importance of exercise and its role with improvement of postural balance.

CHAPTER 3

CONCEPTUAL FRAMEWORK

The theoretical model for this study is presented and discussed. Research question, hypotheses, and definitions developed from the components of this model are also presented and discussed.

The Neuman Systems Model

The Neuman Systems Model was developed while Betty Neuman was lecturing in community mental health at University of California, Los Angeles, and it was first published in 1972. The Neuman model uses a system approach that focuses on human needs for protection or relief from stress. Betty Neuman believes the causes of stress can be identified; and through the process of identification, the nurse can remedy the situation by mutually agreeing on goals, and using the concept of prevention as an intervention. The Neuman systems model is also wellness oriented and holistic. The model integrates five variables, which consist of physiological, psychological, sociocultural, developmental, and spiritual. The variables interact and ideally function harmoniously in relation to internal and external environmental stressor (Neuman, 1995).

There are ten assumptions of The Neuman's system model: (1) each individual client or group as client system is unique; (2) many known, unknown, and universal stressors exist. Each differs in its potential for disturbing a client's usual stability level or normal line of defense; (3) each client/client system has evolved a normal range of responses to the environment that is referred to as the normal line of defense and it can be used as a standard from which to measure normal health deviation; (4) the stressors break through the normal line of defense when the flexible line of defense can no longer protect the client/client system against the environmental stressor; (5) whether in a state of wellness or illness, the client is a dynamic composite of the interrelationships of the variables; (6) the lines of resistance functions to stabilize and realign the client to the usual wellness state; (7) primary prevention relates to the general knowledge applied in the client's assessment and intervention, to identify and reduce or mitigate possible or actual risk factors associated with environmental stressors to prevent possible reaction; (8) secondary prevention is when the client/client system react to stressors, appropriate ranking of interventions are prioritized, and treatments are implemented to reduce their noxious effects; (9) tertiary prevention moves the client back in a circular manner toward primary prevention by reconstitution and maintenance factors; and (10) the client as a system is in dynamic constant energy exchange with the environment (Neuman, 1995).

According to Neuman (1995), the normal line of defense is an adaption of health developed over time by the individual or system. The normal line of defense may be used as a standard or as base line for an individual or system and it may help the clinician to distinguish from situation of wellness to deviance. How well the five variables adjust to environmental stressors determines the client's stability or usual wellness state. The flexible line of defense is a protective barrier that surrounds and protects the normal line of defense from invasion of stressors (Neuman, 1995). When the flexible line of defense is unable to protect the client from stressors, the stressor creates a reaction within the client by invading the normal line of defense. The normal line of defense, which is considered dynamic—expands or contracts over time.

This study focused on the normal line of defense in relation to young adults and postural balance. By performing SOT on young adults, the data collected identified the norms for this age group regarding sensory systems predominance in postural balance; thus, the result can be used as a standard for wellness. Any stressors from the environment can greatly affect postural balance and stability especially when the flexible line of defense is inadequately protecting it. By knowing the normal values of each of the sensory systems that young adults use predominantly to achieve postural balance and prevent falls, the NP can use these values to strengthen the normal line of defense by applying interventions to help clients maintain stability during stress conditions. The data collected can also be further explored to help the clinicians in develop therapeutic interventions geared toward the young adults population.

Research Questions

Based on the components of the Neuman system model, the study attempted to answer the following research questions:

1. Which of the three postual systems (visual, vestibular, or somatosensory) is used predominantly to maintain balance among adults in their 2nd and 3rd decade of life?

   Hypothesis: Young adults in their 2nd and 3rd decade of life predominantly use the visual system to maintain balance rather than vestibular or somatosensory systems.

2. Are there differences in postural stability in young adults in their 20s compared to those in their 30s?

   Hypothesis: There will be a difference in postural stability indicating postural decline in those adults in their 30s compared to those in their 20s.

3. Do young adults who report routine exercise (in any given form or duration of time) have better balance than those who do not exercise?

Hypothesis: Young adults who report routine exercise (in any given form or duration of time) have better balance than those who do not.

Definitions

The key terms used in this thesis are operationally defined below:

1. *Young adult* is defined as male or female ranging in age from 20-29 for those in their 20s and 30-39 years old for those in their 30s.

2. *Postural balance* is optimally distributed body mass relative to the force of gravity using the visual, vestibular, and somatosensory systems.

3. *Visual system* is defined as condition four divided by condition one on the SOT as measured by the balance master NeuroCom machine.

4. *Vestibular system* is defined as condition five divided by condition one on the SOT as measured by the balance master NeuroCom machine.

5. *Somatosensory system* is defined as condition two divided by condition one on the SOT as measured on the balance master NeuroCom machine.

6. *Sensory intergration* is defined as the complete score of conditions one through six on the SOT on the NeuroCom machine.

7. *Exercise* is defined as performing any physical activity in any type or duration of time as self-reported by the subject on the questionnaire.

Assumptions

The following statements assumptions were made for this study:

1. Participants will answer the qualifying questionnaire truthfully.

2. Participants are able to comply with directions given by the primary investigator (PI) (i.e., open eyes or close eyes).

CHAPTER 4

METHODOLOGY

This descriptive cross sectional study examined the predominant sensory systems used in balance among adults' ages 20s and 30s. This data is a subset of data for an ongoing larger study, which is assessing balance across the lifespan. The methodology conducted for this study is described below.

Setting and Design

A descriptive cross-sectional design examined the sensory systems used in balance among adults' in 20s and 30s. The testing took place at UNLV in the physical therapy research laboratory. The participants were placed on a balance machine (i.e., Smart Balance Master) and instructions were given. The test lasted approximately 20 minutes.

Power Analysis

Based on Cohen's (1988) estimation of median effect size (F=25), power of 80% and alpha = 0.05, for a correlation study the sample size set at of N=125. This study included data for 194 individuals ages 20s and 30s, which satisfied the sample size according to the power analysis.

Sample

The participants were volunteers, recruited from the student population and/or were employees at UNLV. The convenience sample was obtained by approaching classes where instructors were willing to have their students participate in the study. As an incentive, the instructors gave the students extra credit if they participated in the study.

The students interested in participating were asked to contact the PI via email to schedule an appointment for testing.

Those included in the study met the following inclusion criteria:

1. No ankle or knee trauma requiring medical attention including surgery within the past year.
2. No history of dizziness, loss of consciousness, cardiovascular disorders, or cardiovascular insufficiencies.
3. No history of inner ear disorders.
4. No history of nervous system or psychiatric disorders.
5. No history of unexplained falls.
6. No history of low back pain or hip pathology/pain that may affect balance.
7. No uncorrected visual problems.
8. Willingness to participate and able to understand instructions.

Exclusion criteria:

1. Participants who currently have a history of any of the above mentioned conditions cited.
2. Taking medications that could alter balance.

Procedure

The instructors were approached and allowed the primary investigator (PI) to speak to the class about the study. If the instructor approved, a short presentation was presented to the class. The students who were interested in participating were asked to contact the PI via email. Once scheduled for testing, each participant was sent an email reminder the day before scheduled testing, to assure a low no-show rate. On the day of testing, the participant was asked to sign an informed consent and to complete the screening questionnaire. The researcher reviewed the screening questionnaire to determine eligibility. If the student was able to participate, the researcher took their anthropometric measurements (e.g., height, weight, waist circumference, and leg length), BMI and waist-to-hip ratio were calculated.

Each participant was then placed on the balance machine (NeuroCom) and instructions were given. The SOT test consists of six conditions to test the different sensory systems for balance. Each participant was tested three times on all six conditions. The first set of the SOT test, the participant was given explicit instructions (i.e., eyes closed or eyes open) and what to expect prior to each of the conditions. When the participant completed the first set of conditions, he/she was asked to pick a number from one through 12 and based on the number they selected, the researcher randomly administered the next two sets of the SOT conditions and the participants were only told to either keep their eyes open or closed. Once the participants completed the testing, he/she was given a copy of the test results and explanations of their results for their records to keep.

Instrumentation

The instruments included an 11- item screening questionnaire (See Appendix C), demographic data sheet, anthropometric measurements, and NeuroCom balance machine.

Demographic Data Sheet

Demographic data were developed by the researcher for the purpose of obtaining information such as birthday, age, employment status, student status, gender, ethnicity, number of years of education completed, marital status, and income level

(See appendix D).

Anthropometric Measurements

Anthropometric measurements for following: height, weight, BMI, waist circumference, hip circumference, leg length, and waist-to-hip ratio were taken following the standard protocols by Jarvis (2004). Height measurement was taken by having the participant stand face away from the measurement scale, which was maintained on the wall. The back of the head, back, buttock, calves and heels were in the upright position and feet were together with shoes on.

The weight was obtained by using an electronic standing scale and recorded to the nearest ounce. The body mass index (BMI) was used to indicate body mass, which suggest normal, overweight, and obesity status. BMI is calculated by using the BMI calculator provided by National Heart, Lung, and Blood Institute (http://www.nhlbisupport.com/bmi). According to National Heart, Lung, and Blood Institute the BMI is categorized as follow: underweight= < 18.5, normal weight = 18.5 – 24.9, overweight = 25-29.9, and obesity = BMI of 30 or greater.

The waist circumference is measured in inches at the smallest circumference below the rib cage and at the level of the naval. The participant was asked to extend the arms out to the side with palms up, stomach relaxed and measurement was obtained while breathing out. The measurement was recorded to the closest one-fourth inch. The hip circumference was measured in inches at the largest circumference of the buttocks. The participant stood with feet close together (about 12-15 cm apart) with weight equally distributed. The measuring tape was held snuggly but loose enough to allow the researcher to place one finger between the tape and the participant’s body. Waist-to-hip ratio was calculated by dividing the waist circumference by the hip circumference. The equation to calculate the waist-to-hip ratio was divided by hip circumference (i.e., waist circumference/hip circumference).

The leg length was measured by having the participant lay down on a table in the supine position. The researcher used a tension type measuring tape and measured from the anterior iliac spine to the medial malleolus on the medial aspect of the leg crossing the medial side of the knee.

Balance Master

The Smart Balance Master machine (See Appendix E) utilizes a dynamic dual force plate and consists of two 22.89 cm x 45.72 cm footplates connected by a pin joint. The balance machine consists of a three-sided booth, moveable dual force plates, a moveable monitor, and overhead attachment for a safety harness strap. The machine also consists of four corner transducers mounted under the footplates on a supporting center plate, and a fifth transducer which is bracketed to the center plate directly beneath the pin joint. The function of the corner transducers measure the vertical forces, whereas, the center transducer measures the shear forces in the plane parallel to the floor. The balance machine has rotation capabilities and it can measure vertical forces exerted by the individual’s feet and a moveable visual surround.

The balance machine can provide an objective assessment and it has the capability of retraining the sensory and voluntary motor control of balance with visual biofeedback on either stable or unstable support surface and in a stable or dynamic visual environment (NeuroCom International, Inc.). According to the NeuroCom manufacturing company, the SOT protocols objectively identify abnormalities of the three sensory systems that contribute to postural control: visual, vestibular, and somatosensory. During the administration of SOT, useful information delivered to the participant's eyes, feet, and joints is effectively eliminated through calibrated "sway referencing" of the support surface and/or visual surround, which tilt to directly follow the participant's anteroposterior body sway (NeuroCom, International, Inc.). Being able to control the sensory (visual and proprioceptive) information through sway referencing and/or eyes open/closed conditions, the SOT protocol can systematically eliminate useful visual and/or support surface information and it creates sensory conflict situations. These conditions are meant to isolate vestibular balance control, as well as stress the adaptive responses of the central nervous system. In short, it may display either an inability to make effective use of individual sensory systems, or inappropriate adaptive responses, resulting in the use of inaccurate senses (NeuroCom International, Inc).

The NeuroCom International Inc. developed minimum standards including protocols, sensitivity and specificity that is sensitive to detect the smallest clinically relevant changes in the individual's performance. There were several studies conducted to ensure the test-retest reliability, sensitivity, and validity for the SOT protocol (Black, Paloski, Reschke, Igarashi, Guedry, & Anderson, 1999; Forizetti, Fanzer, & Reding, 2000; Guskiewicz, Riemann, Perrin, & Nashner, 1997; Rose & Clark, 2000; Topp, Mikesky, & Thompson 1998). The UNLV's balance machine is calibrated and maintained yearly by Neurocom Company to ensure its reliability.

Data Analysis

Data entry and analysis were utilized using the Statistical Package for the Social Sciences (SPSS), Version 16.0 software program. Descriptive analysis such as frequencies and measures of central tendencies was used to describe the population such as average age, gender, and ethnicity. In order to answer research question one, one-way analysis of variance (ANOVA) was used. To find any significance of each of the three conditions tested, Bonferroni correction test was used. In order to answer question two and three T-test were used.

CHAPTER 5

FINDINGS

The results of the sensory systems that predominate in postural balance among individuals aged twenties and thirties is summarized and explained within this chapter. The participants' demographic information was described and statistical analyses such as frequencies and measurement of central tendencies were used to describe the population. One-way Anova was used to answer research question one, Bonferroni correction was used to find which sensory system predominated in the young population. T-test was used to answer research questions two and three.

Sample Description

This study is part of a bigger study entitled postural balance across the lifespan. The participants used in this research consisted of adults in their twenties and thirties. From a total of 275 participants between 18-60+ years old, 194 (N=194) participants in their 2nd and 3rd decade comprise this study. There were 54 males (28%, n=54) and 140 females (72%, n=140); the majority were Caucasians (57%, n=110), followed by Asian (23%, n=44), Hispanic (9%, n=17), African American (5%, n=9), and other/mix (3%, n=6) ethnicity (See Table 1). Participants in their 20s were comprised of 79% (n=153) and 21% (n=41) were in their 30s.

The breakdown of weight of the participants indicated 52% (n=131) were of normal weight, 21% (n=41) were overweight, and 10% (n=20) met the criteria for being obese. Eighty four percent (n=107) of subjects in their 20s were of normal weight, 28% (n=35) were overweight, and 9% (n=11) were obese versus 59% (n=24) who were in their 30s with normal weight, 20% (n=8) were overweight, and 22% (n=9) were obese.

Furthermore, 67% (n=102) of participants in their 20s engaged in some form of physical activity and 33% (n=50) stated they did not. Seventy eight percent (n=32) of participants in their 30s engaged in physical activity while 22% (n=9) stated they did not. The waist-to-hip ratio standard criteria established by the American Heart Lung and Blood Institute was used to determine future disease development with results as follows: 54% of participants (n=104) were at low risk for disease, 22% (n=43) had moderate risk, and 23% (n=45) had high risk for developing disease in the future.

A comparison study was done between gender and BMI: 40.7% (n=22) were male with normal weight, another 40.7% (n=22) were overweight, and 18.5% (n=10) were obese. Whereas, 77.9% (n=109) of female were at normal weight, 15% (n=21) were overweight, and 7.1% (n=10) were obese.

Comparisons of participants' BMI and the three systems used for balance were assessed. Normal weight participants who used their visual system for balance had mean scores of 93.8 (lower = 93.4 and upper = 94.2), overweight individuals had scores of 93.4 (lower= 92.9 and upper = 94.0), and obese had a mean score of 94.0 (lower = 92.7 and upper 94.4); participants who have normal weight and used the vestibular system for balance had mean scores of 90.8 (lower =90.3 and upper = 91.2), overweight individuals were at 90.0 (lower = 89.1 and upper = 91.0), and obese individuals had mean scores of 89.1 (lower = 87.9 and upper 90.2).Normal weight subjects who used their somatosensory system predominantly had mean scores of 90.5 (lower = 90.0 and upper = 91.0).

A total of 134 (N=134, M= 83.7, SD= 3.66) participants reported engaging in some form of exercise versus 59 participants (N=59, M= 80.0, SD= 3.56) who did not engaged in any form of exercise

Results

The following are the results of the inferential statistical analysis of the study's three research questions.

Research Question 1

"Which of the three systems (visual, vestibular, or somatosensory) is used predominantly to maintain balance among adults in their 2^{nd} and 3^{rd} decade of life?"

In order to test potential interactions between age and sensory systems, a 2-way ANOVA was performed and compared with each sensory system. Age was not found to be a significant factor: F (1,576)=.026, p=.871. Once we discovered there was a significant main effect for sensory systems (2, 576) = 81.71, p<.001; a one-way ANOVA was used to test for predominant differences among the three sensory systems. There was a significant difference among the three sensory systems for postural balance among the young population, F (2, 576)= 111.741, p < .001. To determine the significant difference between the group means *post hoc* Bonferroni test was used. *Post hoc* Bonferroni tests were maintained at the 0.05 level which showed significance for the visual system compared to vestibular and somatosensory system (See Table 4): visual (M=93.7, SD= 2.07); vestibular (M= 90.4, SD=2.74); and somatosensory (M= 90.0, SD= 3.13). Based on the results, the visual system is the predominant sensory system used by young adults to maintained optimal postural balance.

Research Question 2

Are there differences in postural stability in young adults in their 20s compared to those in their 30s?

The composite scores for the SOTs measurements were used to examine the differences in postural stability in young adults in theirs 20s and 30s. Each of the SOT conditions' scores ranged from 0-100. The composite scores consist of the total scores of the six conditions. A total of 153 participants are in their 20s (N=153) and 41 participants in their 30s (N=41). The statistical analysis used was the t-test. The t-test failed to reveal a statistically significance difference between the mean composite score for participants in their 20s (M= 82.5, SD= 4.08) compared to those in their 30s (M= 83.0, SD= 3.76), t= -.603, df=192, p= .547. The result indicated there were no measurable differences in postural stability among adults in their 2^{nd} versus 3^{rd} decade of life.

Research Question 3

"Do young adults who report engagement in routine exercise (in any given form or duration of time) have better balance than those who do not?"

The qualifying question 11, "Do you routinely engage in physical activity (e.g., treadmill, hiking, bicycling, jogging, etc)? If, so, please include the amount of time spent performing this activity each time it is performed and how often per week do you engage in this activity" assessed research question 3. In general, 69.1% of participants (n=134) reported exercise and 30.4% (n=59) reported no exercise. The t-test was used to assess if there was a statistical difference in balance for subjects who exercise compared to subjects who did not exercise. The t-test reveal a statistical difference between subjects who participated in exercise (M=83.7, SD= 3.66) and those who did not (M=80.0, SD=3.54), t= 6.667, df=191, and p<.001. According to the results, young adults who report in routine exercise (in any given form or duration of time) have better balance than those who do not.

Believing subjects who exercised have better overall postural balance; subject comparisons were made for balance in those who exercised compared to those who did not exercise. Generally, exercise had an effect on the different sensory systems used for balance. The t-test showed a statistical difference between the mean value for all three sensory systems and subjects who exercised (For details, see Table 2). Based on the above findings, exercise may improved the proprioception system which would ultimately improve overall postural control.

Other Data Analysis

Exercise variables were also compared by gender. Seventy four percent (n=40) of male subjects participated in exercise compared to 23% (n=14) who did not report exercise. Whereas, 68% (n=94) female subjects participated in exercise and 32% (n=45) stated they did not. In order to identify if a specific variable is related to exercise and balance, chi-square analysis was used to examine the relationships among the following variables: gender, BMI, age class, and waist-to-hip ratio. The result of chi-square showed no relationships between participants who exercised and gender having better balance: (χ^2= .762, df=1, P=. 383); there were relationships found between gender, BMI and balance: (χ^2 =7.622, df=2, p=. 022). The relationships with gender and BMI showed there are more overweight and obese male and normal weight female participants.

There were no relationships between age and postural balance:(χ^2 =1.822, df=1, p=. 177); and there were no relationships found between age, waist-to-hip ratio and postural balance: (χ^2 =3.885, df=2, p=. 143).

CHAPTER 6

DISCUSSION, CONCLUSION AND RECOMMENDATION

This chapter presents a discussion of the study findings, which address the research questions related to the relevant literature. Limitations, conclusions and recommendations for further research are also discussed.

Discussion and Interpretation

For the sake of clarity the discussion of the findings follows the research questions.

Research Question 1

The first research question was: "Which of the three systems (visual, vestibular, or somatosensory) used predominantly to maintain balance among adults in their 2^{nd} and 3^{rd} decade of life?"

The results showed the visual system was the predominant sensory system used among the participants. This finding supports several studies that looked at postural balance among a broad range of age groups found the primary sensory system used to maintain postural balance was the visual system (Cohen Heaton, Congdon, & Jenkins, 1996; Liaw, Chen, Pei, Leong, & Lau, 2008). Although, research studies showed younger adults may use many distinct patterns to response to environmental stimuli to maintaining balance (Ricci, Goncalves, Coimbra, & Coimbra, 2008), however, there are still gaps in research pertaining to response strategies used by young adults to maintain balance. Liaw, Chen, Pei, Leong, and Lau (2008) compared the balance characteristics among different age groups comprising of young (16-39 years old), middle-aged (40-59 years old), and elderly (60-80 years old). The result of the study showed young adults relied on vision to maintain postural control. Cohen Heaton, Congdon, & Jenkins (1996) studied the difference in the kinematics of movement between young adults and older adults, and between young and middle-aged adults. Their study also showed the reliance of vision among the younger population. In a study, looking at women between the ages of 40-80 years old it was noted they relied on their visual system to maintain balance (Choy, Brauer, & Nitz, 2003). Allum, Carpenter, Held-Ziolkowska, Adkin, Honegger, & Pierchala (2001) showed when vision is absent it had a detrimental effect on the performance for all two-legged stance task and trunk sway increased 3-fold with eyes closed. The studies above support the idea that the visual system plays a main role in postural balance; which was also supported by this study.

The importance of studying the different sensory systems used by the young population to maintain proper postural control cannot be stressed enough. The result from this study may be use as a stepping-stone for future research exploring postural balance; hence it will help establish norms for the young population. By knowing the dominant sensory system used, proper screening (i.e., yearly eye examination) must be emphasized by clinicians to their clients, so that proper health maintenance may ensue or prevent further decline of the system. If leg-strengthening exercises are included in the exercise regime it may double the effectiveness of maintaining balance.

Research Question 2

The second research question was: “Are there differences in postural stability in young adults in their 20s compared to those in their 30s?” The data showed there was no difference in postural control between young adults in their 20s versus 30s. Again, there is a lack of literature studying these particular age groups. This study’s finding may have been a result of the dissimilar size groups or the groups may have been too close to capture the differences.

Many research studies found sensory systems used for balance declines with aging (Poole, 1991; Cohen, Heaton, Congdon, & Jenkin, 1996; Merla & Spaulding, 1997; Cook & Woollacott, 2000; Liaw, Chen, Pei, Leong, & Lau, 2008; Ricci, Goncalves, Coimbra, & Coimbra, 2009) and optimal control of postural sway is achieved during late adolescence and maintained until about the age of 60 years (Liaw, Chen, Pei, Leong, & Lau, 2008). There are various studies showing the differences in balance across the age groups and differences in postural balance can be seen between the young and middle age group. Using the computerized dynamic posturography (CDP) machine with the six SOT measurements administered to a population of 107 healthy subjects between 16 and 80 years old, showed there was a statistically significant difference between the middle age and young adult groups in condition four, five, and six (Liaw et al., 2008). Cohen, Heaton, Congdon, and Jenkins (1996), showed that younger adults scored significantly higher in condition three (i.e., swayed-reference, vision with fixed support) than middle-age adults.

Overall, it is known that the sensory systems maintaining postural balance declines as one age. The integration of the visual, vestibular, and somatosensory systems is necessary to achieve good postural control. Furthermore, development and integration of these balance sensory systems starts at an earlier age and decline in older adults. Much of the thinking regarding the younger age groups are based on growth and development concepts with very little postural balance research carried out in the young adult population. Another reason why balance research in this age group is lacking is because of the inherent belief that decline does not occur until later decades, and the tools currently available may not be sensitive enough to measure subtle changes, which can occur at younger adults ages. Therefore, it is important to conduct further studies and see where the changes occur across the lifespan.

Research Question 3

"Do young adults who report engagement in routine exercise (in any given form or duration of time) have better balance than those who do not?"

The data showed a statistically significant between young adults who report exercise compared to those who did not participation in exercise. This result supported various studies showing the many health benefits in performing exercise including: improvement of postural balance and proprioception, reduction of lower extremity injuries, and prevention of sports related injury (Subasi, Gelecek, & Aksakoglu, 2008; Malliou, Gioftsidou, Beneka, & Godolias, 2004; McLeod, Armstrong, Miller, & Sauers, 2009). It is also reassuring to know that many young adults in this study are engaging in some type of exercise or physical activity program in spite of heavy study schedule.

In general, males tend to have better balance than females. This may be due to the larger muscle mass males possess (Lee & Lin, 2007). In this study, there were more female participants (n=138) versus male participants (n=54). So it is reassuring to know the results of this study indicated by performing exercise improved postural balance. Gribble, Robinson, Hertel, and Denegar (2009) investigated the effects of exercise, fatigue, and gender on performance measures on the Star Excursion Balance Test (SEBT). There were 16 physically active participants (8 men: age 22.5 $\pm$ 2.45 years, height 1.81 $\pm$ 0.11 m, weight 81.59 $\pm$ 19.76 kg and; women: age 22.5$\pm$ 2.56 years, height 1.67 $\pm$ 0.06 m, weight 60.61 $\pm$ 8.22 kg). The study indicated there are differences in gender during performance of the SEBT, with women demonstrating greater reach distances and knee flexion (Gribble, Robinson, Hertel, & Denegar, 2009). This is not a surprising finding as it is well documented that estrogen keeps women flexible (Allen, 1994). It would be interesting to test a greater number of sedentary males and compare them to female subjects who exercise because this would reflect exercise has a significant role in the maintenance of proper postural control.

This study supports the fact that strengthening the normal lines of defense while individuals are young by having them engage in some form of exercise may allow them to maintain a strong core. According to the Neuman systems model, primary prevention reduced the possibility of breaking down the normal line of defense due to physical stress (i.e., an intervention to strength the sensory systems as one ages). By strengthening the normal lines of defense (improving the sensory systems, i.e., vision, proprioception) the individual will likely adapt or overcome stressors and maintain the normal lines of defense to prevent future falls.

Limitation

The design of the study does have limitations and the results should be interpreted with caution as the data collected was a cross sectional sample. Obtaining a snapshot in time only provides information at one point in time, which can be influenced by many factors, not in the researcher's controlled. A longitudinal study would be more ideal for this type of study because it makes observations at multiple points in time, thereby increasing the chances of eliminating an error.

Another limitation in this study is the disproportionate number of those in theirs 20s (n=153) versus those in their 30s (n=41), which cannot eliminate the possibility of a type 2 error in the findings. The differences between the two groups were not captured may be due to its similarity (i.e., 20s versus 30s). Maybe, if middle-aged adults were compared to the young adults, perhaps subtle changes in balance would have been captured. There is also a disparity in the numbers of males and females; the total number of females (n=138) compared to the number of males (n=54). However, it was expected that males would have better balance; so the smaller number of males in this study is a good indicator that the result is due to the gender difference and not by chance.

Recommendations

As stated above, a longitudinal study may provide the information where balance may start to decline for the young population. To this date, only a few research studies have analyzed the effects of aging on balance in prospective longitudinal designs. In the future, it would be beneficial to follow the same subjects for a longer period of time, so that the researcher can capture where postural balance starts to decline and when reliance on one system versus another begins.

Previous research studies have shown deterioration of the postural control mechanisms during aging can start relatively early. On average, the start of postural decline can be seen as early as 40 years old and acceleration of deterioration can be seen after the age of 60 years. Recommendations to include middle age and older-age participants in balance test may help identify the pattern of balance decline.

Another recommendation is to compare balance and gender. In this study, the visual system is the main sensory system young adult use for balance; males have stronger and larger muscle mass, which probably explains the gender difference.

However, what might be interesting is the assessment of potential change in balance for the genders as postural balance declines.

Conclusion

The importance of studying postural balance among young adults cannot be stressed enough. By establishing postural sensory system norms for the young population, the normal lines of defense are strengthened. The development of evidence-based interventions geared toward the young population can be accomplished by further exploration of postural balance.

Previous research studies showed performance of physical activity have many health benefits including better proprioception leading to better balance. In this study, it is evident exercise played a role in postural balance. Furthermore, this study suggests the visual system is the dominant sensory system, therefore, proper visual screening (i.e., yearly eye exam) must be emphasized to prevent visual decline as one ages. Implementing preventive measures earlier in life may prevent falls in later years, which positively impacts health cost and ultimately improve client's well being.

APPENDIX A
TABLES

Table 1: Demographic Characteristic by Mean and Percentage

Demographic Characteristic by Mean and Percentage

Variable	Frequency	Mean	Percent
Male	54	25.17	28%
Female	140	25.41	73%
Caucasian	111	26.15	57%
Asian	44	23.86	23%
Hispanic	17	25.65	9%
African American	9	24.67	3%
Other	6	24.67	3%
Mix	6	22.33	3%

Table 2: Comparison of Sensory Systems with Participants who Exercise and who did not Exercise

Comparison of Sensory Systems with Participants who Exercise and who did not Exercise

Sensory System	Mean Scores for Exercise	Mean Scores for No Exercise	Std. Deviation for Exercise	Std. Deviation for No Exercise	t	df	p-value
Visual	.923	.873	.0484	.0796	5.354	191	<.001
Vestibular	.757	.702	.0820	.0914	4.197	191	<.001
Somatosensory	.962	.973	.0271	.0316	-2.355	191	.020

Table 4: Bonferroni Score for Senses

Bonferroni Score for Senses

Sense		Mean Difference	Std. Error	Sig.
Visual	Vestibular	3.26649	.27207	<.0001
	Somatosensory	3.73196*	.27207	<.0001
Vestibular	Visual	-3.26649	.27207	<.0001
	Somatosensory	.46546	.27207	.263
Somatosensory	Visual	-3.73196	.27207	<.0001
	Vestibular	-.46546	.27207	.263

* The mean difference is significant at the 0.05 level.

APPENDIX B
UNLV INFORMED CONSENT

UNLV
CELEBRATING FIFTY YEARS

INFORMED CONSENT

Department of School of Nursing

TITLE OF STUDY: **Age Related Decline of Postural Stability and Balance in Adults**

INVESTIGATOR(S): **Patricia T. Alpert, Sally Miller, Harvey Wallmann, & Chad Cross**

CONTACT PHONE NUMBER: **(702) 895-3810**

Purpose of the Study

You are invited to participate in a research study. The purpose of this study is to: 1. identify relationships between body measurements, balance, and vision. 2. To compare changes in balance and center of gravity (referred to as limits of stability) in individuals ages 18 to 60+.

Participants

You are being asked to participate in the study because you are a healthy individual who: (1) can walk without the use of walking aids (e.g., walkers, canes, etc.) and can stand for at least 10 minutes without assistance (2) is able to give informed consent, (3) speaks English and (4) is willing to participate.

Procedures

If you volunteer to participate in this study, you will be asked to do the following: complete a qualifying questionnaire. If you qualify for this study you will be asked to report to the Rod Lee Bigelow Health Science Building at the University of Nevada, Las Vegas for balance and limits of stability measurements on the NeuroCom Balance Master machine. The following anthropometric measurements: height, weight, body mass index (calculated from your height and weight), waist, hip, waist to hip ratio (calculated from waist and hip measurements), and leg length will also be taken. While on the NeuroCom Balance Master machine you will have to stand on a force plate for 3 trials. While your eyes are either open or closed the force plate may be stationary or may move slightly or the panoramic movable enclosure of the surround booth may be stationary or may move. You will also be asked to complete a short demographic data sheet. The measurements will take approximately 45 minutes of your time.

Benefits of Participation

There *may not* be direct benefits to you as a participant in this study. However, we hope to learn at which decade in life postural stability and balance begin to decline.

Risks of Participation

There are risks involved in all research studies. This study may include only minimal risks. You may fall while doing the balance and/or limits of stability measurements. However, the risk for injury is minimal since you are a healthy individual with no known balance disorders or functional limitations. Additionally, the NeuroCom Balance Master (the machine that will measure your balance and limits of

DEC 0 9 2009

UNLV IRB Approved DEC 0 9 2009 Expires DEC 0 8 2010

CELEBRATING FIFTY YEARS

INFORMED CONSENT

Department of School of Nursing

TITLE OF STUDY: Age Related Decline of Postural Stability and Balance in Adults

INVESTIGATOR(S): Patricia T. Alpert, Sally Miller, Harvey Wallmann, & Chad Cross

CONTACT PHONE NUMBER: (702) 895-3810

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stability) has built-in safety straps and safety detection to control any large sway or movement that you might make. The research assistant or member of the research team qualified to perform both the balance and limits of stability tests will be doing the balance and limits of stability tests and providing stand by assistance, meaning the individual doing the tests will be standing directly behind you in order to prevent you from falling.

Cost /Compensation

There *will not* be financial cost to you to participate in this study. The study will take approximately 45 *minutes* of your time. You *will not* be compensated for your time. *The University of Nevada, Las Vegas may not provide compensation or free medical care for an unanticipated injury sustained as a result of participating in this research study.*

Contact Information

If you have any questions or concerns about the study, you may contact **Dr. Patricia T. Alpert** at **(702) 895-3810.** For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact **the UNLV Office for the Protection of Research Subjects at 702-895-2794.**

Voluntary Participation

Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with the university. You are encouraged to ask questions about this study at the beginning or any time during the research study.

Confidentiality

All information gathered in this study will be kept completely confidential. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked cabinet in the principal investigator's office at UNLV for at least 3 years after completion of the study. At the end of the three year period the information gathered will be destroyed.

Participant Consent:

DEC 0 9 2009

UNLV IRB Approved DEC 0 9 2009 Expires DEC 0 8 2010

50 UNLV CELEBRATING FIFTY YEARS

INFORMED CONSENT

Department of School of Nursing

TITLE OF STUDY: Age Related Decline of Postural Stability and Balance in Adults

INVESTIGATOR(S): Patricia T. Alpert, Sally Miller, Harvey Wallmann, & Chad Cross

CONTACT PHONE NUMBER: (702) 895-3810

I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

__________________________________ ________________

Signature of Participant Date

____

Participant Name (Please Print)

Participant Note: Please do not sign this document if the Approval Stamp is missing or is expired.

3 of 3

APPENDIX C
QUALIFYING QUESTIONNAIRE

`University of Nevada Las Vegas

Qualifying Questionnaire
for the Research Study:

Age Related Decline of Postural Stability and Balance in Adults

Purpose:
The purpose of this questionnaire is to identify any pre-existing conditions that may preclude a volunteer from being a participant in this study. Please answer the following questions as honestly and completely as you can. The information obtained from this questionnaire is strictly confidential and gathered solely to determine the appropriateness of your participation in this study.

Your response to the following questions is voluntary.
Thank you for your participation.

1. What is your age? __________________

2. Have you had any ankle or knee trauma (i.e., sprained ankle or knee) requiring medical attention within the past year, including surgery? If so, please describe:
____
____
____
____

3. Do you have a history of dizziness, loss of consciousness, cardiovascular (i.e., heart) disorders, or cardiovascular insufficiencies (i.e., poor circulation)? If so, please describe:
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____
____
____
____

4. Do you have a history of inner ear disorders? If so, please describe:
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____
____
____
____

5. Do you have a history of any nervous system disorders that may affect your skin sensation? If so, please describe:
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____
____
____

6. Do you have a history of unexplained falls? If so, please describe:
____
____
____
____
____

7. Do you have a history of low back pain or hip pathology/pain? If so, please describe: ____
____
____
____
____

8. Do you have a history of any bone or joint problems? If so, please describe:
____
____
____
____
____

9. Do you have any uncorrected problems with your vision? If so, please describe: ____
____
____
____

10. Do you have any other problems or disorders not mentioned in this questionnaire that might affect your ability to control and maintain your balance and upright posture while standing? If so, please describe:
____
____
____
____
____
____

11. Do you routinely engage in physical activity (e.g., treadmill, hiking, bicycling, jogging, etc) outside of this dance class? If, so, please describe include the amount of time spent performing this activity each time it is performed and how often per week do you engage in this activity:

____

____

____

____

We thank you for your participation in completing this questionnaire. If you would like to contact us directly, please feel free to call us at 895-4765 or 895-3810.

APPENDIX D
DEMOGRAPHIC DATA SHEET

UNIVERSITY OF NEVADA, LAS VEGAS
RESEARCH: AGE RELATED DECLINE OF POSTURAL STABILITY AND BALANCE IN ADULTS

DEMOGRAPHIC DATA SHEET

Code Number: ____________

Birthday: ______________________ Age: _________

Employment Status:

Employed Full-Time:	Yes	No
Employed Part-Time:	Yes	No
Retired:	Yes	No

Student Status:

Full-Time:	☐ Yes	☐ No
Part-Time	☐ Yes	☐ No

Gender: Male ☐ Female

Ethnicity:
a. Caucasian
b. Hispanic
c. African American
d. Asian/Pacific Islander
e. Other (specify): ____________________

Number of Years of Education Completed:
a. Some high school
b. Completed high school
c. Some college
d. Completed Bachelor's Degree
e. Completed Master's Degree
f. Completed Doctorate Degree
g. Other (specify): _________________________

Marital Status:
a. Married
b. Single
c. Widowed
d. Divorced
e. Living with significant other

Income Level:

a. < $15,000/year
b. $16,000 – $24,000
c. $25,000- $50,000
d. $51,000 - $75,000
e. $76,000 - $100,000
f. > $101,000

Anthropometric Measurements

Height: __________ Weight: ____________ BMI: __________

Waist circumference: _____________ Hip: _________________

Waist to hip ratio: _______________

Leg Length: ___________________

APPENDIX E
NEUROCOM MACHINE

The Smart Balance Master
NeuroCom International, Inc

APPENDIX F
APPROVAL LETTER

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

UNLV IRB Approved DEC 09 2009 Expires DEC 08 2010

Biomedical IRB – Expedited Review
Continuing Review Approved

NOTICE TO ALL RESEARCHERS:

Please be aware that a protocol violation (e.g., failure to submit a modification for any change) of an IRB approved protocol may result in mandatory remedial education, additional audits, re-consenting subjects, researcher probation suspension of any research protocol at issue, suspension of additional existing research protocols, invalidation of all research conducted under the research protocol at issue, and further appropriate consequences as determined by the IRB and the Institutional Officer.

DATE: December 18, 2009

TO: **Dr. Patricia Alpert**, Nursing

FROM: Office for the Protection of Research Subjects

RE: Notification of IRB Action by Dr. John Mercer, Chair
Protocol Title: **Age Related Decline of Postural Stability and Balance in Adults**
Protocol #: 0711-2537

Continuing review of the protocol named above has been reviewed and approved.

This IRB action will reset your expiration date for this protocol. The protocol is approved for a period of one year from the date of IRB approval. The new expiration date for this protocol is December 8, 2010.

PLEASE NOTE:
Attached to this approval notice is the **official Informed Consent/Assent (IC/IA) Form** for this study. The IC/IA contains an official approval stamp. Only copies of this official IC/IA form may be used when obtaining consent. Please keep the original for your records.

Should there be *any* change to the protocol, it will be necessary to submit a **Modification Form** through OPRS. No changes may be made to the existing protocol until modifications have been approved by the IRB.

Should the use of human subjects described in this protocol continue beyond December 8, 2010, it would be necessary to submit a **Continuing Review Request Form** *60 days* before the expiration date.

If you have questions or require any assistance, please contact the Office for the Protection of Research Subjects at OPRSHumanSubjects@unlv.edu or call 895-2794.

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Vita
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The Role of Visual, Vestibular, and Somatosensory System in Postural Balance

Thesis Examination Committee:
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