The Effect of Cognitive Load on Stance Width of Healthy Older Adults

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THE EFFECT OF COGNITIVE LOAD ON STANCE WIDTH OF HEALTHY OLDER ADULTS

By

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THESIS

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Research has shown that narrower stance widths lead to increased postural sway. There is also evidence of increased postural sway with cognitive loading. However, no research has been done to investigate the effect of a cognitive load on stance width. The purpose of this study was to determine if a cognitive task affected the stance widths of healthy, community dwelling 65-80 year old adults. Subjects underwent six task trials (three cognitive, three non-cognitive) after which their stance width was measured. Cognitive task trials required subjects to count backwards by 7’s; non-cognitive task trials required subjects to look at a picture of a nature scene. The Greenhouse-Geisser test revealed no statistical significant difference between the stance widths for the cognitive and non-cognitive trials. This finding suggests that cognitive loading may not have an effect on stance width. Future research is needed to examine the power of cognitive loading and how it relates to stance width.
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Definition of Terms

**Angle of Orientation** – the angle created by the intersection of two lines, one line from each foot connecting the distal end of the great toe and the midpoint of the heel.

**Balance** – the ability to maintain an upright position during quiet standing.

**Base of Support (BOS)** – the length of a line perpendicular to the line of progression between the right and left foot. The two lines of progression are determined from the inked-footprint method of gait analysis.

**Center of Pressure (COP)** – the center point of the vertical projections onto a force platform at any point in time.

**Cognitive Loading** – a mental task given for the purpose of distracting one’s attention.

**Fall** – when a person’s knee(s), belly, side, bottom or back ends up on the ground or floor when he or she did not expect to.

**Functional Base of Support (FBOS)** – the proportion of the anterior-posterior (A/P) dimension of the base of support utilized during sustained maximal forward and backward leaning.

**Healthy Elderly Subject** – a person age 65 to 80 years old who is free of orthopedic or neurological conditions which may affect balance and is independent in community ambulation without an assistive device.

**Line of Progression** – the longitudinal line created by consecutive, ipsilateral foot contacts. Using the inked footprint method, the line of progression is the line connecting the reference points (the intersection of moleskin strips) of only one foot. The line of progression is a visual representation of a single stride.
Overwhelming Hazard — A hazard that could result in a fall by most young, healthy persons. An example of such a hazard is slipping on ice.

Perturbation — a sudden change in condition that displaces one’s body posture away from equilibrium. Disturbances may be mechanical, visual or somatosensory.

Postural Sway — Normal oscillating movements of the body over the feet during quiet standing.

Stance Width (SW) — the self selected distance between the feet during quiet standing. Distance measurement is determined by connecting a single point on each foot that consists of the intersection of: 1) an anterior/posterior line drawn from the most anterior portion of the foot to the midpoint of the heel and 2) a mediolateral line drawn across the widest portion of the sole of the foot.

Tandem Stance — a stance position whereby one foot is placed directly in front of the other foot with the heel of the anterior foot touching the toes of the posterior foot.

Width — the distance between the midline of the heels of the feet during quiet stance.
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CHAPTER 1

INTRODUCTION

Background

Maintaining one’s body in an upright standing position is a task that is essential to daily function. Standing balance, however, may become increasingly difficult with advancing age. Research has shown a high incidence and increased prevalence of falls among elderly populations.¹ This abundance of falls has been positively correlated to balance deficits, which also increase with age.²

Balance is defined as the ability to maintain an upright position during quiet standing.³ Currently, all of the factors that contribute to a decline in balance and an increase in falls with aging have not been fully established nor are these factors fully understood.⁴ Three important aspects that play an integral role in balance function are the sensory systems, stance width (SW) and attention to task.³

Research has shown that conditions which are more cognitively demanding, or which divert attention, may adversely affect postural stability during stance.⁵,⁶ This same research has shown that these attentional demands, when combined with normal changes of aging may further impair a person’s stability.

The sensory systems that are the major contributors to balance and are also affected by normal aging are the visual system, vestibular system and somatosensory
system. These sensory systems must detect changes in upright posture and make adjustments accordingly to maintain balance. As one ages, the acuity of these senses diminishes and balance may be compromised. Sensory input helps to detect proper SW for proficient balance. However, as the senses become diminished with age, position sense and information from the environment are not as readily detected and adjustments in posture may be delayed or absent. Under these conditions, perturbations can more easily disturb balance, resulting in falls.

Stance width is another important factor that affects balance. Stance width, as defined for this study, is the self-selected distance between one’s feet during quiet standing. Kirby et al. demonstrated a negative correlation between width of foot position and postural sway. Confirming the findings of Kirby et al., Nichols et al. stated that a narrower stance poses a greater challenge to postural stability. Shumway-Cook et al. found that the addition of a cognitive task to quiet stance degraded postural stability. A logical compensation, therefore, for diminished sensory input and/or cognitive demands may be to widen one’s stance for greater stability while standing.

Problem Statement

No known research exists that examines the effect of a cognitive task on SW. Research exists which supports the idea that a wider stance width reduces postural sway. Another body of research has shown that a cognitive task leads to greater postural sway in healthy older adults in conditions where foot position is controlled. This study attempted to link these two bodies of research and investigate the possibility that subjects naturally change their foot position during a cognitive task to maintain postural stability.
**Purpose**

The primary purpose of this study was to determine if cognitive demands affect SW in healthy older adults.

**Significance of the Problem**

The significance of this study lies in its potential to guide members of the physical therapy profession in their attempt to decrease fall risk in elderly clients. Decreased incidence of falls translates to decreased monetary costs, in terms of healthcare and lost productivity. For our clients, fewer falls mean fewer hospitalizations, enhanced safety and an improved quality of life.

Clinically, it is important for physical therapists to realize the possible effects that cognitive loading has on the older adults’ stance width, which in turn affects balance. Therapists may use this knowledge to advise elderly patients of the potentially adverse affects of mentally demanding tasks on their balance and possible compensations for these effects; hopefully preventing falls. In addition, clinicians may use cognitive tasks during treatment sessions to challenge their patients, which may enhance overall stability skills.
CHAPTER 2

REVIEW OF LITERATURE AND CONCEPTUAL FRAMEWORK

Falls among the elderly population

Approximately 30 percent of people over 65 years of age fall each year.\textsuperscript{1,11,12} Reports estimate that falls are the sixth leading cause of death among the same age group.\textsuperscript{10} Fall related injuries are of increasing concern in the elderly population. Rubenstein et al. report that 5% of fall victims sustain fractures or require hospitalization.\textsuperscript{1} Head trauma, soft-tissue damage and severe lacerations are among other serious injuries that occur in about 11% of falls.\textsuperscript{1} As many as 90% of falls not resulting in serious injury may have psychological and social consequences such as depression, social isolation and “postfall anxiety syndrome”.\textsuperscript{1,11}

Falls impose economic consequences on our society as well. Reports estimate an average cost of $11,800 per hospitalization for injuries caused by general falls among persons 65 years of age or older.\textsuperscript{12} The annual costs for acute care associated with fall-related fractures are approximately $10 billion.\textsuperscript{12} Secondary costs are also imposed on society if the person who has fallen is left unable to care for themselves or needs further medical care in the future caused by the initial fall. Furthermore, the direct cost of fall injuries dramatically increases with advancing age of the victim.\textsuperscript{10}

Age and the incidence of falls are closely related. Sattin et al. conducted a population-based survey of fire rescue reports, emergency room records, hospital
inpatient records and medical examiner investigation reports from the Dade County, Florida area.\textsuperscript{13} The issue of importance to the researchers was the number of falls occurring in the elderly population of that area, in a two-year time period. The results of their study showed an exponential increase in the number of falls with age. The lowest incidence of falls occurred in the younger population, age 65-69. Conversely, the highest incidence was reported in both males and females over the age of 85.

This data regarding falls is not surprising when one considers the balance characteristics of older adults. Perrin, Jeandel, Perrin and Bene report impairments in balance in otherwise healthy adults as young as 60 years.\textsuperscript{14} Camicioli, Panzer and Kaye compared the quantitative equilibrium scores of healthy subjects younger than 80 years, and those older than 80 years.\textsuperscript{15} These researchers found significantly worse scores in the subjects older than 80 years.\textsuperscript{15}

Other authors have supported these figures stating that the incidence of falls is relatively high in persons 60-65 years old when compared to younger subjects.\textsuperscript{1,16,17} The incidence of falls continues to rise steadily between the ages of 65 and 80 years after which, another sharp increase occurs.\textsuperscript{1,16,17}

Advancing age is not the only risk factor for falls, many other risk factors have been identified which correlate with falls. The remaining risk factors can be divided into categories such as physiological deficits, medications, pathological processes and environmental hazards.\textsuperscript{8,16,17}

Physiological changes

Physiological deficits are separated from pathological processes although the differentiation is complex. Because the elderly often have at least one pathological
process, normal age related changes are difficult to sort out. Research has shown normal age related decline in most of the major systems of the body. The vestibular, visual, musculoskeletal and somatosensory systems all play an important role in the maintenance of balance and are all subjected to the declines brought about through aging.

The vestibular system, composed of the utricle, saccule and semicircular canals, is responsible for communicating changes in head position to the brain. Johnsson and Hawkins report a 20% reduction in number of hair cells in the utricle and saccule in older adults without vestibular pathology. A 40% decline in hair cells of the semicircular canals was also reported. These age-related structural changes correspond to alterations in the responses of healthy older adults to caloric testing.

Clinically, the capacity of the aging vestibular system can be tested using a posturography force platform and the sensory organization test (SOT). The SOT examines subjects’ balance under a variety of conflicting sensory conditions. The relative contribution of the vestibular system to balance can be assessed by providing subjects’ with confusing visual and proprioceptive input. Visual input is distorted during the SOT by having subjects close their eyes or wear a visual conflict dome, an apparatus that deprives the visual system of real-world reference points. Proprioceptive input from the ankles is impaired by having subjects stand on a compliant surface. The vestibular system is relied on most heavily during the conditions in which both proprioception and vision are compromised.

Whipple et al. compared the performances of 239 healthy, elderly community dwelling adults to the performances of 34 young adults on the SOT. The healthy, elderly subjects had significantly greater sway when standing on a compliant surface with
their eyes closed or with the visual conflict dome as compared to themselves on a firm surface (p < 0.004). The elderly subjects also lost their balance more frequently than the younger subjects under those same conditions (p < 0.005).

Cohen, Heaton, Congdon and Jenkins reported similar findings in another study using the SOT. They compared the scores of asymptomatic, community dwelling adults in four different age groups on the SOT. The researchers reported results showing significant decline in overall balance scores and a change in movement strategies used to maintain balance in the older subjects. Based on their findings, Cohen et al. suggest that the portions of the vestibular system involved with balance have age-related decline throughout the lifespan and continue to decline into the ninth decade.

These two studies exemplify the contribution of the aging vestibular system to balance. Even in asymptomatic individuals, structural and neurological changes within the vestibular system have a negative impact on subjects' ability to accommodate to situations in which visual and proprioceptive information is inaccurate.

Vision is another sensory system affected by aging. Visual acuity, commonly measured by reading an eye chart, is said to decline rapidly between the seventh and ninth decades, with as much as an 80% loss by age 80. This reduction in visual acuity is due to structural changes in the eye itself and neural changes in the retina and brain. Reduced pupil size, impaired lens accommodation ability and increased opacity of the lens are all common structural changes seen in the aging eye. Loss of axons in the optic nerve and reduction in the number of ganglion cells in the retina are a few of the neural responses to aging.
The contribution of the visual system to balance is immense. Studies measuring postural sway consistently report reduced postural stability during visually comprised conditions. Stones and Kozma studied the postural control capabilities of subjects who were fully sighted, minimally sighted and blind by measuring the time subjects were able to maintain a single limb stance position. Fully sighted subjects were able to maintain the test position the longest, followed by the minimally sighted subjects. The blind subjects had the lowest times. A separate analysis was performed using only the times of the subjects who were blind from birth; the blind subjects still had the lowest times. This study is especially significant because it demonstrates the poor ability of other sensory systems to accommodate for a loss in the visual system.

Salive, Guralnik, Glynn, Christen, Wallace & Ostfeld conducted a study of 5143 older subjects to investigate the relationship of visual impairment to mobility and physical function. The results suggest those subjects with visual acuity of 20/40 or better had significantly fewer limitations in activities of daily living and reduced risk for falls.

It is well documented in the literature that gross muscle strength declines with advancing age. Several mechanisms have been proposed in an attempt to explain the reason behind the age-related declines. Winegard et al. and Payton and Poland describe a decrease in the number of muscle motor units as well as a decrease in the size of the units in the aged person. Winegard et al. performed a follow-up study that investigated ankle strength on a cohort of subjects twelve years after their own initial study. Subjects re-tested in the follow-up study ranged in age from 73 to 97 years. The researchers report strength declines in all subjects in both plantarflexors and dorsiflexors, however the degree of decline varied between these muscle groups. The researchers
acknowledge the previous work of Vandervoort and McComas who also report that ankle strength declines beginning in the 6th decade of life.\textsuperscript{30} Payton and Poland indicate overall strength decreases occur closer to age 40.\textsuperscript{29}

Direct changes in the neuromuscular system have a significant impact on muscle strength. Winegard et al. describe a progressive loss of motor neurons in the spinal cord leading to cycles of denervation and reinnervation of the motor units, thus causing successive reduction in strength of the muscle.\textsuperscript{28}

Another mechanism thought to diminish strength is the increased proportion of skeletal muscle that is replaced by fibrous connective tissue. The disproportionate ratio of muscle to connective tissue as one ages increases the stiffness of the muscle leading to decreased extensibility, strength and available joint range of motion.\textsuperscript{28,29,31}

These normal physiological changes that occur with aging all play a role in the overall decreases in muscle strength. Furthermore, Taylor describes how lifestyle can impact overall muscle strength.\textsuperscript{31} Diminished habitual activity, including intensity, duration and frequency, as one ages has been shown to negatively influence muscle strength.

Strength impairments due to non-use or the normal aging process can have a negative effect on postural stability. Whipple, Wolfson and Amerman compared ankle dorsiflexion strength in elderly fallers and elderly non-fallers.\textsuperscript{32} The researchers reported that dorsiflexion strength was significantly impaired in the fall group and suggested the inability to generate sufficient dorsiflexion torque may contribute to instability and falls.

The somatosensory system is comprised of deep senses and superficial senses. Deep senses include proprioception, deep pressure and vibration, whereas superficial
senses include light touch and temperature perception. There has been little research regarding the physiologic changes that occur to the sensory receptors during aging, and of the available research, the results are controversial. Thombury and Mistretta noted unspecific changes which occur in the morphology, number, density and location of the somatosensory receptor system. Receptors undergoing changes include Meissner corpuscles, Merkel cell neurite complexes, Ruffini endings and Pacinian corpuscles.

Kokmen, Bossemeyer and Williams have reported that complete evaluation of each of these senses with "usual" clinical examination methods is highly difficult. These researchers suggest that it is not possible to control the intensity, frequency and consistency of stimuli which is utilized to evaluate the somatic senses. Because of these evaluation difficulties, there is little research providing information about age-related declines in the somatosensory system.

The available literature focuses mainly on the deep somatosenses, proprioception (perception of joint position) and vibration. Several researchers report diminished proprioceptive responses in aged individuals. Kaplan et al. compared the proprioceptive responses of the knee joints of 29 normal women. Fifteen women were under 30 years old and fourteen women aged 60 and over. The younger age group had a greater ability to match the resting joint position of the contralateral knee joint at all times and in all positions (p < 0.05). These findings suggest that proprioceptive abilities decrease with age. Conversely, Kokmen et al. report a tendency toward age-related declines in proprioception of the toes, however they did not find the declines to be marked or significant.
Some authors conclude that proprioception is the primary sensorimotor factor contributing to balance under normal conditions (standing on a firm surface with eyes open or closed). Under more adverse conditions, such as standing on foam where sensation is reduced, vision and strength play more major roles in balance. Because of the nature of this study, intact proprioceptive sense will be important for all subjects.

Thornbury and Mistretta studied the tactile sensitivity of the pad of the index finger of 55 subjects ranging in age from 19 to 88 years. Using the Semmes-Weinstein aesthesiometer, they compared the results to detect age-related changes in light touch sensitivity. The data indicated that mean thresholds of tactile acuity increase significantly with age (p < 0.001).

It must be noted that what research that has been conducted on the various senses has been limited to single regions of the body (i.e. fingertip or knee joint). Generalizability to other areas of the body may be difficult as tactile and proprioceptive sensitivity may vary between regions.

Medications

Side effects from medications have been shown to be another major risk factor contributing to falls. Tinetti, Speechley & Ginter conducted a one-year prospective study of 336 elderly subjects that investigated the relative contribution of a number of factors on the incidence of falls. They found that of the fourteen subjects in the study taking sedatives, thirteen fell. Psychotropic agents, commonly prescribed for depression and other mood disorders are also reported as increasing the risk of falls. Nevitt et al. conducted a similar prospective study of fallers age 60 years or older. In contrast to the
findings of Rubenstein et al., the results of this study suggest that use of antidepressants was a poor indicator of recurrent falls.\textsuperscript{1}

Another factor regarding medication use that relates to increased falls is the number of different prescription medications an individual is consuming. Rubenstein et al., Tinetti et al. and Nevitt et al. all found a correlation between number of prescription medications and incidence of falls.\textsuperscript{1,12,16} These researchers report that subjects taking four or more prescription medications had a significantly greater risk for falling. Because all of these studies were correlational in nature, none of them specified a mechanism by which the number of prescription medications increases the incidence of falls.

Pathological Problems

Underlying pathological diseases and disorders have also been related to falls. Nevitt et al. and Rubenstein et al. concurred that diseases affecting the vestibular system, central nervous system and musculoskeletal system as well as metabolic disorders and cognition are frequent causes of falls.\textsuperscript{1,16} Specific afflictions include Parkinsonism, cerebrovascular disease, multiple sclerosis, arthritis, hypoglycemia and various gait disorders.

Postural hypotension is another disorder that has been linked to falls.\textsuperscript{38} Postural hypotension, also known as orthostatic hypotension is defined as a drop in systolic blood pressure greater than 20 mmHg upon standing from a recumbent position.\textsuperscript{39} The incidence of postural hypotension in people over the age of 65 has been reported as high as 20%.\textsuperscript{39} Thirteen percent of the subjects involved in a study investigating fall risk demonstrated a 10% drop in systolic blood pressure upon rising.\textsuperscript{38}
It is generally accepted that postural hypotension is the result of sluggish or unresponsive baroreceptors in the carotid sinus. It is unclear whether the reduced responsiveness of these receptors is a normal part of aging or the result of some other pathological process, such as hypertension. Symptoms of postural hypotension typically include dizziness or lightheadedness immediately following a change in position. Other symptoms that have been reported are unsteadiness, weakness and syncope.

Environmental Hazards

Environmental risk factors, both in the home and community are also at fault for the occurrence of falling. Poor lighting, uneven floor surfaces, clutter in small areas, as well as low seats are a few examples of environmental conditions which have been shown to contribute to falls. Nevitt et al. reported that, like prescription drugs, the greater the number of environmental hazards, the greater the risk for falls.

It must be noted that many of the above risk factors exist concomitantly and are infrequently found in isolation as the cause for recurrent falling. Furthermore, the risk of falling has been shown to increase with the number of risk factors present.

Effects of Stance Width on Balance

The framework of this study is developed around the consensus that SW and cognitive load each have an affect on balance. Regarding SW, Kirby et al. investigated the influence of foot position on standing balance. The researchers used a variety of stance conditions in young, healthy subjects to test the postural sway and mean center of pressure, which was calculated using a force platform. Stance positions included feet together, three varying mediolateral width conditions (15cm, 30cm, and 45cm between the long axis of the feet), several anteroposterior stance conditions (one foot ahead of the
other) and several foot angle positions (toes pointing inward or outward). The researchers found significantly more mediolateral postural sway (p < 0.01) while the subject's feet were together as opposed to the feet apart conditions. Interestingly however, their results also showed that stance width greater than 15 cm did not further reduce postural sway. Of the varying angled conditions, only the extreme toeing-in position (45°) significantly increased postural sway (p < 0.01).

Another study performed by Nichols et al. evaluated sixty-six healthy, young adults under 18 different testing conditions. Three foot positions, feet apart, feet together and tandem were tested among varying visual and platform movement conditions. Each subject was allowed to choose his or her foot position as his or her comfortable stance position. The feet-apart condition however, was maintained at a minimum of two inches of separation in order to distinguish it from the feet together condition. Postural sway by means of center of balance was assessed by the use of a force platform. The results showed the greatest amount of postural sway in the tandem foot position, with the next greatest amount of sway at the feet-together position (p < 0.01).

These studies show a relationship between foot position (stance width) and postural sway. As stance width becomes increasingly narrower, postural sway increases.

Effects of Cognitive Load on Balance

Many studies of balance as it relates to the elderly have used performance on the Mini – Mental State Exam (MMSE) as a part of exclusion criteria or as a variable of interest in age-related decline. Clinically, the MMSE is the most commonly used mental screening test. It tests memory, language and spatial ability in a simple and
straightforward manner. It is useful in the present study because it tests the ability of the subjects to answer questions appropriately and follow directions. Scores range from 0 to 30 on the MMSE; 27 and above is considered excellent and indicative of normal cognitive function. Scores in the 20 to 26 range reflect mild impairment. Age-specific norms indicate those persons between the ages of 60 and ninety years maintain MMSE scores ≥ 26. These scores are not dramatically different from younger persons whose scores range from 29 in the fifth decade to 28 in the sixth decade.

Studies of balance have used the MMSE for exclusionary purposes. Duncan et al. excluded subjects with an MMSE score < 18 in their investigation of functional reach scores in elderly male veterans. Harada et al. excluded subjects with MMSE scores ≤ 20 in their study of balance and mobility in persons living in residential care facilities.

Multiple studies have investigated the effect of cognitive load on balance. All studies discussed here utilized the dynamic posturography platform and therefore controlled stance width in the procedure. Shumway-Cook et al. tested a group of young healthy subjects, an older healthy group, and another group of older persons, this group having a history of falls. The researchers looked at postural sway with and without two different cognitive tasks, a language processing task, and a perceptual matching visual task. All three groups demonstrated degradation in postural stability with the addition of a cognitive task, however the greatest amount of sway was found in the two older groups (p < 0.05).

Maki and McIlroy tested the effect of physiological arousal and attention distraction on the postural sway of young, healthy subjects under four different task conditions. The four task conditions were, “no task,” in which subjects only stood,
"noise task," "listen task," and "math task". The noise task required subjects to listen to background white noise during the trial; this task was intended to increase arousal without affecting attention. The listen task required subjects to listen to a spoken-word recording of a book excerpt, a task that was intended to divert attention without affecting arousal. The math task was intended to affect both arousal and attention. For the math task, subjects were required to count backward from 1000 by 7's as quickly and accurately as possible.

The researchers found that subjects tended to lean slightly forward and increased the activation of the anterior tibialis muscle during the performance of the math task \( p = 0.018 \). None of the other task conditions had a significant effect on mean center of pressure readings.

A third study conducted by Stelmach et al. investigated the effect of both motor and cognitive tasks on postural sway in healthy young and old subjects. Subjects first stood on the force platform for 25 seconds to get a baseline reading of postural sway. Then another 25-second trial began in which subjects were given a combination of task conditions. The motor tasks were either an arm-swinging or hand squeezing-activity. The cognitive task (a mental arithmetic task) required subjects to listen to a recording of a person performing simple addition problems. The subjects counted the number of correct answers given by the person on the recording and then reported that number at the end of the trial. The arm-swinging task was only performed for the first seven seconds of the 25-second trial to allow researchers to measure the amount of time required to regain postural stability. All other tasks were performed throughout the 25-second trial.
When performing the arithmetic task simultaneously with the arm-swinging activity, the older subjects took a significantly longer amount of time to return to their baseline postural sway \( (p < 0.01) \). When compared to themselves, the older subjects swayed more when they had to perform the mathematical task after the arm-swinging activity rather than just standing quietly or performing the hand-squeezing task \( (p < 0.01) \).

The three previous studies strengthen the argument that the addition of cognitive tasks to a simple standing task alters the normal postural alignment in both young and older subjects. The results from both Stelmach et al. and Maki and McIlroy demonstrate the effect of a mathematical task in particular, on postural stability. Shumway-Cook, Woollacott, et al. did not use a mathematical task in their study but did use two tasks which required subjects to think and process information more than just listening.

It is important to point out that all of three of the studies discussed above required subjects to maintain their initial foot position throughout the trials. The present study allows the subjects to alter their stance position when posed with a cognitive task in order to investigate natural alterations of stance to an attention demanding activity.

Tools to Measure Stance Width

Little research has been carried out in the area of SW, and the studies that have investigated this variable employed a variety of methods, none of which are considered a “gold standard”. The research that has been performed has used terms such as “base of support” and “width” to describe different measurements of foot positions in stance and gait. As the literature is further reviewed and discussed, terms of the original authors are
preserved as well as their operational definitions. Vocabulary used is not consistent from one study to the next, however every effort has been made to alleviate confusion.

The dynamic posturography force platform is one way in which to calculate SW. This commercially produced computer-aided device can measure the location, direction and amplitude of forces applied to the platform through the subject’s feet. The force platform system gathers data regarding the subject’s center of pressure and postural sway in conditions of static standing, linear perturbations and angular perturbations. Calculations may then be made to determine the distance between the center of pressure of each foot, an indirect measurement of stance width.9

McIlroy and Maki set out to establish a standardized foot placement position for posturographic research by analyzing the preferred foot placement of 181 elderly adults and 81 younger adults during comfortable stance.46 All subjects were ambulatory and lived independently; 70% of the elderly and 57% of the younger group were female. Subjects were barefoot and asked to assume a comfortable stance. A tracing of the subject’s feet was then taken in that position. The midpoint of the heel and the distal end of the great toe were marked on the tracing, then a line connecting the great toe and the midline of the heel was drawn for each foot. These authors collected data for all subjects regarding width and angle of orientation.

Anne Shumway-Cook, a noted researcher in balance and physical therapy, described a simple, clinical measurement of stance width. The subject is asked to rise from a seated position and hold that position once in standing. The distance between the medial malleoli is measured and then compared to the measured width of the shoulders through computation of a ratio (personal communication, October 1, 1997).
The inked footprint method is a useful measurement tool for gait analysis. Using this method, ink-saturated moleskin strips are applied to the bottom of the subject’s shoe, one across the widest portion of the sole, and the second along a line approximating the second metatarsal through the midpoint of the heel. The subject is then asked to walk on a piece of paper secured to the floor, leaving inked crosses behind, indicating the placement of each foot during gait. A line of progression is then drawn connecting the point of intersection of the moleskin strips for each foot. The distance between the two lines of progression is measured and defined as the base of support. The inked footprint method has been used to report gait characteristics of a variety of patient populations and has demonstrated reliability.

One characteristic of the base of support measurement derived from the inked footprint method is quite valuable for this study. By using the intersection of the two moleskin strips as the reference point, both the length and width of the foot are taken into account. Since the majority of the sole of the foot makes contact with the floor in normal gait, it may be considered in the measurement of base of support.

Validity and Reliability

One of the largest barriers to a study of this nature is finding a valid and reliable method by which to measure stance width. The force platform system is well regarded in the physical therapy literature because it is accepted to be the most objective measure of balance. In a study that examined functional base of support over the life span, King et al. found the data obtained from the force platform device to be reproducible using a repeat testing method (ICC = 0.80). Subjects were tested two weeks and four weeks
after the initial test was given. Repeat measurements were not found to be significantly different.

McIlroy and Maki attempted to study standardized foot placement positioning by analyzing the preferred foot placement of 262 individuals ranging in age from 19 to 97 years. Their study addressed some important concerns in balance testing; however, their study still presents some concerns. While all of the subjects in the study were ambulatory and living independently, there was no indication that a general systems screen or health questionnaire was administered to ensure the health of the subjects. Persons with undetected, underlying impairments affecting balance in any way may skew the data through the compensatory stance characteristics they may adopt.

Another limitation of the McIlroy and Maki study is that they reported no formal data or testing to confirm the validity and reliability of their tracing and marking methods. These authors simply stated that they considered “marking the centre of the heel and the location of the great toe...to be the most reliable method of measuring foot placement characteristics” (p. 69).

Shumway-Cook (personal communication, October 1, 1997) described a ratio measurement between the medial malleoli and shoulder width. While this method is relatively simple to perform, no published data regarding validity and reliability or documentation of its use was found in the literature.

Boenig reported results that suggest the inked footprint method of gait analysis is both valid and reliable. In a study of thirty normal women ranging in age from 20 to 70 years, data was collected and measured on five gait factors; stride length, step length, step width (base of support), foot angle and cadence. A test-retest procedure was conducted
and reliability of the method was determined (p < 0.01). A significance level of greater than 95 percent confidence was also determined for all stride factors.

Summary

Falls in the elderly impose a large economic and psychological burden on both the elderly population and society as a whole. Many factors associated with aging, both normal and pathological contribute to poor balance and falling. These factors include normal physiological deficits, pathological processes, the use of prescription medications and environmental hazards.

Many studies have been performed investigating the variables associated with the maintenance of balance. These variables are numerous and include the width of stance and the presence of a cognitive task, both of which have been found to directly relate to balance. A narrower stance width has been positively correlated with greater postural sway. In addition, cognitive loading, such as a mathematical task has also been shown to increase sway.

Several tools have been used to measure stance width, none of which have been accepted as a "gold standard". The dynamic posturography platform is the most reliable of these methods, however it is too expensive to be used in the average physical therapy clinic. Other methods, which are less costly, have not demonstrated the same level of reliability. The inked footprint method is valuable for this study because it is relatively simple to perform and has been shown to have an acceptable level of reliability for gait analysis. The inked footprint method used for gait analysis takes into account both the length and width of each foot for the base of support measurement. Both of these
variables are important in the measurement of stance width, however modifications will
be made to this method to accommodate for the static nature of this study.

Current literature focuses only on the relationship between stance width and
postural sway or cognitive load and postural sway but does not attempt to investigate a
relationship between the two. It is intended that this study will help connect the research
regarding stance width and that of cognitive loading and how these relate to each other,
within a healthy elderly population.

**Hypothesis**

The mean stance width of healthy older adults will be greater ($\alpha = 0.05$) when
performing a cognitive task as compared to the mean stance width without a cognitive
task.
CHAPTER 3

METHODOLOGY

Study Design

This study used a quasi-experimental within-subjects design. All subjects were exposed to both treatment variables and each subject served as their own control. The within-subjects design was appropriate for this study because of its ability to account for variability among individuals. One possible disadvantage of this type of design is the potential carry-over effect that may have occurred when subjects were exposed to repeated conditions. We attempted to minimize carry-over by having subjects look at a relatively uncomplicated poster during the no-task condition.

Study Site and Subjects

A sample of convenience was recruited through fliers and informal discussions at area senior centers located in the West Michigan area. Data were collected at six senior centers and one outpatient rehabilitation facility. All facilities gave verbal or written approval until 51 eligible subjects were recruited and measured. Our sample was comprised of 31 females and 20 males, which is consistent with the male to female ratio of 3:2 in persons 65-80 years old in Michigan.52

Inclusion Criteria

Eligible subjects were healthy, community dwelling individuals 65 to 80 years old. A healthy elderly subject was defined as a male or female that lives independently and ambulates without an assistive device.
Exclusion Criteria

Prospective subjects completed the Medical History Questionnaire (Appendix A) which screened for any present or past medical problems which may impair balance. Subjects were excluded if they had a history of any diseases affecting the central or peripheral nervous system, such as Parkinson's, Meniere's or multiple sclerosis. A history of stroke, rheumatoid arthritis, lower extremity joint replacements or amputations, dizziness, fainting or vertigo also resulted in the prospective subject's exclusion. A list of specific surgical procedures for which subjects were excluded is located in Appendix B.

Subjects were also excluded if they had experienced one or more fall(s), not attributed to an overwhelming hazard, within the past year. An overwhelming hazard was defined as: a hazard that would result in a fall by most young healthy persons such as slipping on ice. Persons who used a cane, crutch or walker for ambulation were not included in this study. Use of a prosthetic or orthotic device on the lower extremity, such as an ankle foot orthosis (AFO) also resulted in exclusion. Volunteers who used four or more prescription drugs or any sedatives or psychotropic agents were excluded from this study. Prospective subjects who met all requirements on the Medical History Questionnaire and had a score on the MMSE ≥ 27 then underwent a brief health screen (Appendices B, C and D).

Equipment and Instruments

The instruments for this study were the Medical History Questionnaire (Appendix A), the MMSE (Appendix C), the Health Screen Form (Appendix D), and the Foot Tracing Method. A list of the equipment used follows:
Plinth
Snellen Eye Chart
Cotton Balls
Large Sheets of Posterboard
Nylon Stockings

Stop Watch
Standard sphygmomanometer
Stethoscope
Poster
A pen attached to a leveling device

The pen and leveling device was used for all tracing of the subjects’ feet. The leveling device served to keep the pen at a ninety-degree angle to the surface on which each subject stood. This device was created to minimize variability in the tracing technique associated with angling the pen around the soft tissue of the feet. Procedures used to ensure its reliability are outlined in the following section.

Validity and Reliability

To ensure reliability, a pilot study of ten subjects, all within the age range of 65-80 years, was performed prior to formal data collection. All ten subjects underwent the testing protocol outlined in the procedure section.

Foot tracing measurement

The first component of the pilot study required each researcher to make repeat tracings of only one of each of the subject’s feet. This procedure ensured the reliability of the tracing method, as we assume the size of one subject’s foot should not change. The use of right and left feet was randomized among subjects. The distance between the most anterior and posterior point of each foot tracing was called the length. Likewise, the distance between the most medial and lateral point of each foot tracing was the width. A comparison of both length measurements and both width measurements of each subject was made. In an attempt to limit measurement error, both researchers collaborated to measure both the length and width of each foot tracing. The correlation coefficients are
reported, \( r_L \) to describe the reliability of the length of each foot tracing and \( r_w \) to describe the reliability of the width foot tracing.

**Stance width measurement**

The second component of the pilot was used to ensure the reliability of the stance width measurements. This portion of the pilot study utilized the foot tracings of the first ten subjects to establish reliability. Each subject's foot tracing was photocopied and coded by an individual not associated with the study for identification purposes. Both researchers independently determined formal stance width measurements for all twenty tracings (two copies of ten tracings). Using the markings made at the most anterior, posterior, medial and lateral areas of each foot, lines were drawn approximating the long axis and the widest part of each foot. The intersection of the lines on each foot were the reference points from which the stance width measurement was determined for each tracing. The two values for measured stance width of each of the ten subjects were then compared.

**Figure 1. Stance Width Measurement**
**Procedure**

Informed consent (Appendix E) was obtained from each prospective subject prior to any data collection. Each subject was asked a series of interview questions about his or her medical history to screen for problems that would make him or her ineligible to participate in the study (Appendix A). Following the medical history, the MMSE was administered (Appendix C). Because the cognitive task used in this study was intended to be sufficiently demanding so that each subject's attention was diverted, it was important to test one's cognitive function before the data collection trials. If a subject did not have the mental capacity to complete the required cognitive task, we could not ensure that his or her attention would be diverted. The MMSE was used to test for cognitive ability; subjects with an MMSE score ≥ 27 were eligible.

Subjects who were eligible underwent the following brief physical screen to further check for physiological conditions that may have affected balance (Appendix D) therefore excluding them from the study. First, a visual acuity test using a Snellen eye chart was performed. The chart was posted on a wall at eye level; each person was asked to stand twenty feet away from the wall and read, with both eyes open, the lowest line they could see clearly. Normal corrective eyewear was worn during testing. Subjects scoring 20/40 or greater were included in the study.

Proprioception was then tested with the subject in a seated position, with his or her eyes closed. Both knees and both ankles were tested for accuracy of position sense. The subjects completed five trials at each joint for a total of ten trials on each lower extremity. The researcher positioned the knee or ankle and asked the subject to match the joint position with the opposite leg. Care was taken to avoid positions at the extremes of
range of motion to prevent injury and/or subjects using the sensation of muscle stretch to determine the angle of the joint. Subjects who scored at least nine out of ten correct for each lower extremity, were included in the study.

A gross strength assessment of each subject’s bilateral quadriceps femoris, hamstrings, plantarflexors and dorsiflexors was taken next. Subjects’ quadriceps femoris and dorsiflexors were tested in a seated position. Subjects who were able to extend both knees and dorsiflex both feet against gravity, through the full range of motion were eligible to participate in the study. Hamstring strength was assessed in a standing position. Subjects who were able to flex each knee to 90° with the hip in a neutral position were included. Plantar flexor strength was assessed by the subject’s ability to rise onto his or her toe while standing on one leg. Subjects unable to perform the toe raise were placed in a prone position with knees extended. Plantarflexion through the subjects’ full range of motion in this position allowed inclusion in the study.

Light touch sensation was tested by assessing key dermatomal points on the lower extremity. The L3 and S2 points were tested in standing, the remaining points (L4, L5 and S1) were tested in supine. For all positions, the subjects were asked to remove shoes and socks and close their eyes. A cotton ball was used to assess the subject’s ability to discern light touch at five specific dermatomal reference points on each lower extremity. The subject responded “cotton” or “no cotton” when the examiner asked for the subject’s response to the testing point. Subjects who received a combined score for both right and left lower extremities of nine or more correct out of ten were included in the study.

Last, each subject’s blood pressure was taken with a standard stethoscope and hand held sphygmomanometer. Readings were taken both in supine and standing. A
drop in systolic blood pressure >20 mmHg upon standing resulted in exclusion from further testing.

Eligible subjects were asked to blindly draw chips from a container holding 6 chips, three red and three white, all from a standard set of poker chips. After each chip was drawn, the researcher recorded the task condition corresponding to the color of the chip until all six chips were drawn. Red chips indicated trials with the task condition; white indicated the no-task conditions.

Subjects were asked to place nylon stockings on their feet. The nylons prevented their feet from sticking to the posterboard during testing, yet allowed the contour of the feet to be traced properly. A researcher then lead the subject to one of two stations, both of which were located in the same room. One station was designated for the cognitive task trials, the other for the no-task trials. Both stations had a large piece of posterboard fixed to the floor with tape. After each tracing, the posterboard was removed and replaced with a new piece of posterboard, for a total of six pieces per subject.

A researcher then read the following directions before each of the trials with no cognitive task:

"Please step onto the large piece of paper on the floor in front of you. (Pause) Assume a natural, comfortable stance. You will stand here for thirty seconds, please do not speak but feel free to shift your position if necessary. At the end of the thirty seconds, I will say 'Stop'. At that time, please hold your position while I collect the necessary data. Again, you may shift your position as needed until I say 'Stop'. Do you have any questions?"
For the no-task condition, a poster of a nature scene was on the wall in front of the subject. We assumed that the subjects would naturally focus on the poster, therefore no instructions regarding the poster were given. This was done in an attempt to remove any carryover from the cognitive task of a previous trial, as we did not want to introduce an entirely new task.

Before each trial with a cognitive task, the following directions were read to the subject:

“Please step onto the large piece of paper on the floor in front of you. (Pause) Assume a natural, comfortable stance. Please count backwards, in your head from 1000 by 7’s (2\textsuperscript{nd} trial began at 250, 3\textsuperscript{rd} trial began at 125). You will stand here for thirty seconds, please do not speak but feel free to shift your position if necessary. At the end of the thirty seconds, I will say ‘Stop’. At that time, please hold your position while I collect the necessary data. I will then ask you for the number on which you ended to test for its correctness. Again, you may shift your position as needed until I say ‘Stop’. Do you have any questions?” Any questions that the subject had were then answered.

Once the subject was standing on the paper and the directions were read, the researcher began to monitor the time with a stopwatch. In addition to monitoring the time, the researcher stood near the subject, but not on the paper, in case the subject lost his/her balance. After the thirty seconds, the researcher said, “Stop. Please hold your position.” The researcher then asked for the number on which the subject ended and that number was recorded. Next the researcher traced around the most anterior, posterior, medial and lateral areas of the subject’s feet using the tracing device. When the tracing was complete the subject was asked to step off of the paper while the researcher set up
for the next trial. A chair was made available for rest periods between trials if the subjects felt it was needed. The researcher began the next trial at the appropriate station based upon the order of chips drawn initially.

All trials under the same task condition were performed exactly the same, with one exception. For the cognitive task trials, the number from which the subject began counting backwards was changed with each trial ($1^{st} = 1000, 2^{nd} = 250, 3^{rd} = 125$). This was done in an effort to minimize the subject remembering the order of numbers from a previous trial and ensure maximal cognitive loading. The goal of the cognitive task trial was to sufficiently divert the subjects' attention; if the subject remembered the order of the numbers from previous trials, that goal might not have been met.

If a participant lost their balance or fell during a measurement trial, or moved their feet after the “stop” command was given, the subject was asked to step off the data collection paper and a new trial was performed. Any such incidences were recorded in the space at the bottom of the Data Collection Form (Appendix F). Participants who acquired more than two failed attempts during a single measurement trial were excluded from the study due to possible balance difficulties not detected in the initial screening.

Formal stance width measurements were performed after all 306 foot tracings were complete (6 tracings per subject). Again, the researcher with the highest reliability completed all measurements.

Figure 1 (pg. 26) denotes the method in which intersecting lines were drawn to produce a single point on each foot whereby the stance width was measured. Using a transparent meter stick, the researcher found the most anterior and posterior portions of the foot tracings and drew a single line connecting the two points. Similarly, the most
medial and lateral points were connected. The intersection of the two lines became the single reference point from which the stance width measurement was determined. Another line was then drawn from point to point and the researcher measured the distance in centimeters to determine stance width.
Chapter 4

Results/Data Analysis

The purpose of the study was to determine if cognitive demands affect stance width in healthy older adults. The hypothesis was: The mean stance width of healthy older adults will be greater ($\alpha = 0.05$) when performing a cognitive task as compared to the mean stance width without a cognitive task.

Pilot Study

A pilot of ten subjects all within the age range of 65-80 years was performed prior to the data collection to assess reliability of the tracing technique. A value of $r \geq 0.90$ for each intraclass correlation coefficient was considered an acceptable level of reliability. Intraclass correlation coefficient values of $r_L = 0.998$ and $r_w = 0.992$ were obtained by the researcher who performed all of the foot tracings.

Reliability of stance width measurements was assessed using the tracings of the first ten subjects after all subjects completed the testing protocol. A value of $r \geq 0.90$ for the intraclass correlation coefficient was considered an acceptable level of reliability. The researcher with the higher Intraclass correlation coefficient ($r = .999$) completed all stance width measurements. Details describing pilot study procedures may be found in Chapter 3.
**Subject Characteristics**

Twenty-one males and 31 females volunteered for the study. One male was excluded due to failure to complete the MMSE bringing the total eligible subjects to 51. Variables considered for each subject included gender, age and six stance width measurements. The inclusion criteria for this study required that subject be at least 65 years of age but not older than 80 years. The mean age was 72.6 years (SD = 4.8 years). A summary of the distribution of males and females, their mean ages and mean stance widths are provided in Table 1.

**Table 1.**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean Age (SD)</th>
<th>Mean Cog. SW (SD)</th>
<th>Mean NonCog. SW (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Subjects</td>
<td>51</td>
<td>72.6 (4.8)</td>
<td>20.9 (5.5)</td>
<td>20.7 (5.7)</td>
</tr>
<tr>
<td>Males</td>
<td>20</td>
<td>73.5 (4.9)</td>
<td>24.1 (4.4)</td>
<td>24.2 (4.2)</td>
</tr>
<tr>
<td>Females</td>
<td>31</td>
<td>72 (4.8)</td>
<td>18.8 (5.2)</td>
<td>18.5 (5.5)</td>
</tr>
</tbody>
</table>

*Cog = Cognitive, NonCog = Non-Cognitive, SW = Stance Width, SD = Standard Deviation*

**Statistical Analysis**

Stance width data were analyzed using the Greenhouse–Geisser test, a form of the two-way Repeated Measures Analysis of Variance. The Greenhouse–Geisser uses corrected degrees of freedom when a study fails to meet the assumption of sphericity. This statistical measure was used because each subject was measured on multiple trials and he or she served as his/her own control as well as being exposed to all levels of the treatment (cognitive task/no task). This analysis allowed individual variability to be removed from the data so the effect of the task condition could be seen more clearly. The accepted level of significance for the analyzed data was $\alpha = 0.05$. 
To assess the effect of the task condition on stance width, the mean cognitive stance width for each subject was compared to his or her own mean non-cognitive stance width. The mean stance width for all subjects with the cognitive task condition was 20.9 cm (SD = 5.5 cm), with a range of 8.43 cm to 31.20 cm. The mean stance width for all subjects with the non-cognitive task condition was 20.7 cm (SD = 5.7 cm), with a range of 9.60 cm to 32.17 cm. Figure 2 illustrates the similarity of stance widths for cognitive and non-cognitive trials for all subjects. The box length represents the interquartile range which contains the middle-most values; the line within the box represents the median value for that task condition. The whiskers are the lines that extend from the box to the highest and lowest values.

Figure 2.
Table 2 represents the results of the two-way Repeated Measures Analysis of Variance. Results of the effect of trial repetition, task condition, and the interaction between trial repetition and task on stance width are reported.

Table 2.

ANOVA Summary Table

<table>
<thead>
<tr>
<th>Source</th>
<th>Df</th>
<th>Mean Square</th>
<th>F Test</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial Repetition (TR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects*TR</td>
<td>50</td>
<td>1.576</td>
<td>7.363</td>
<td>0.839</td>
</tr>
<tr>
<td>Error</td>
<td>300</td>
<td>78.789</td>
<td>8.776</td>
<td>0.411</td>
</tr>
<tr>
<td>Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects*Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>1</td>
<td>1.118</td>
<td>4.323</td>
<td>0.259</td>
</tr>
<tr>
<td>TR*Task</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Subjects<em>TR</em>Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>1</td>
<td>1.662</td>
<td>2.113</td>
<td>0.471</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>83.108</td>
<td>4.483</td>
<td>0.590</td>
</tr>
</tbody>
</table>

Discussion of Statistics

When the effect of trial repetition on subjects' stance width was examined, the effect was found to have no statistical significance ($F_{1,576,50} = 0.839, P = 0.411$). This finding suggests that there was no learning effect taking place over the six trials.

The effect of task condition, the main research question for this study, was also found to be statistically non-significant ($F_{1,50} = 0.259, P = 0.613$). The data analysis suggests that subjects' stance width did not statistically change (i.e. widen or narrow) as a function of task condition. This finding is in agreement with the graphic representation in Figure 2, which shows minimal differences in stance width between the two task conditions.
Since there was no significant effect of trial repetition or task condition on stance width, we cannot rule out the possibility that there was an interaction of these two variables. A final analysis which examined the effect of both trial repetition and task on stance width also showed a lack of statistical significance ($F_{1.662.50} = 0.471, P = 0.590$). This suggests that there was no interaction effect between the variables.

A post hoc analysis was conducted on the effects of age and gender on stance width. The Pearson Correlation Coefficient was used to determine if a correlation existed between age and stance widths in each of the task conditions. The analysis revealed a mild correlation between age and stance width during the non-cognitive trials, however this correlation was not significant ($r = 0.226, P = 0.110$). A slightly higher correlation was found between age and stance widths during the cognitive trials, this correlation was found to be significant ($r = 0.295, P = 0.035$). These findings suggest that with increasing age, people tend to widen their stance; this difference may be compounded by the performance of a cognitive task.

The one-tailed t-test was used to assess the effect of gender on stance width. When male and female stance widths were compared during the non-cognitive trials, male stance width was significantly greater than females ($t_{49} = -3.939, P < 0.001$). During the cognitive task trials, male stance width again was significantly greater than females ($t_{49} = -3.738, P < 0.001$). This suggests that the men in this study had a wider stance than the females regardless of task condition.
CHAPTER 5
DISCUSSION AND IMPLICATIONS

Much research has been conducted on the subject of balance and falls in the elderly population. The researchers performing this study were interested in the potential effects of cognitively demanding tasks and foot position on balance. Foot position, or in this study, stance width has been shown to directly impact postural sway in healthy persons. In addition, the performance of cognitive tasks has also been correlated with increased sway. The purpose of the study was to determine if cognitive demands affect stance width in healthy older adults. The hypothesis was: The mean stance width of healthy older adults will be greater ($\alpha = 0.05$) when performing a cognitive task as compared to the mean stance width without a cognitive task.

Discussion of Findings

Three independent variables were assessed to determine their effect on stance width. The first variable, trial repetition was examined to determine if there were any effects related to learning or fatigue on the part of the subjects. In essence, we wanted to be sure that there was little to no variance in stance widths during the same task condition trials. Significant differences between the cognitive task trials would suggest that a learning or fatigue effect may have occurred.

The Repeated Measures Analysis of Variance (ANOVA) revealed that trial repetition had no significant effect on subjects’ stance widths. This finding was
expected as methods were in place in the procedure to prevent a learning effect or fatigue. Subjects were asked to begin counting backwards from different numbers for each of the cognitive task trials. This was done to prevent the subjects from remembering the order from previous cognitive task trials. To prevent fatigue, subjects were allowed breaks between each of the trials.

This study set out to determine if the performance of a cognitive task altered the stance widths of healthy older adults. The second variable assessed looked at the effect of task (cognitive or non-cognitive) on stance width. During cognitive task trials subjects counted backwards, by sevens from 1,000, 250, or 125, depending on the trial. The non-cognitive task condition involved subjects standing in front of a picture of a nature scene. As determined by the data analysis, the subjects in this study did not consciously or unconsciously significantly widen their stance when performing a cognitive task versus a non-cognitive task. This finding did not support the hypothesis.

We propose several explanations for this finding. First, since there was no significant effect of time or task on stance width, it was possible that there was an interaction of these two variables. The data analysis included an investigation of the interaction term (Trial Repetition*Task). This effect, however, was not found to be significant.

Second, despite possible increased postural sway while performing a cognitive task, the subjects in this study did not naturally accommodate by widening their stance. Since postural sway was not examined in this study, we cannot be certain that these subjects displayed increased postural sway during the cognitive task trials. Therefore, a widened stance may not have been warranted for these subjects.
Also, the researchers noted that few subjects altered their stance during the thirty-second trials. It is possible that subjects’ may have known that their stance was being studied, therefore causing them to hesitate to alter their stance during either task condition. To help prevent this, precautions were taken by avoiding the use of the terms “feet” or “stance” in response to subjects’ questions about the study. However, subjects were probably aware that foot placement was a factor after the first foot tracing.

In addition, the poster board on which subjects stood, as well as the nylon stockings worn for the data collection may have influenced their stance in some way. These unusual conditions as well as the inherent novelty of the situation may have caused subjects to stand in an unnatural way.

The subjects selected for this study had to meet rigorous inclusion and exclusion criteria. Absence of chronic disease, recent falls or disorders which might affect balance were key characteristics of the sample. Shumway-Cook et al. found that while older adults without a history of falls demonstrated decreased postural stability when compared to healthy young persons when performing a cognitive task, they did not perform as poorly as older adults with a falling history. Due to their high functional status the volunteers in this study may not have experienced enough degradation in postural stability while performing the cognitive task to warrant an adjustment in their stance widths.

A final possibility is that the tasks chosen for the study did not meet the intended goal. That is, the cognitive task may have been so difficult that subjects gave up and did not perform the task during the trials and simply guessed at a final number. Conversely,
the non-cognitive task may have been interpreted by the subjects to be more challenging than planned and thought processes were elicited.

The post hoc analysis revealed a mild positive correlation between age and stance width for both task conditions. The correlation was found to be non-significant for the non-cognitive task condition, but was significant for the cognitive task condition. This was an interesting finding, however because correlation does not indicate causation, further research is needed to more fully evaluate this relationship.

The t-test analyzed the effect of gender on stance width. Males were found to have a greater stance width than females under both task conditions. This finding may be attributed to anatomical differences between the sexes. Future studies are needed to determine if anthropometric measures contribute to a persons stand width.

**Clinical Implications**

Due to the lack of significant findings relating cognitive loading and stance width, it does not appear that the performance of cognitive tasks during static stance should be of primary concern for physical therapists treating healthy older adults. Greater research is needed to expand the clinical significance of these findings as the healthy older adult is not a typical candidate for physical therapy.

**Limitations**

One of the limitations of this study is the method by which stance width was measured. It is a hybrid of two methods, the inked footprint method of gait analysis and the stance width measurement using preferred foot placement proposed by Maki and McIlroy (1997). Of the two however, only the inked footprint method has been shown to
be reliable. It was intended that the procedures used to guarantee reliability in the pilot study would minimize this limitation.

Although reliability of the technique was established, the issue of validity remained a primary concern. Since no formal analysis was conducted to establish validity, we cannot be sure that the procedures in place measured what they were intended. Subtle variations in stance width may have occurred that this method was unable to detect. In addition, this method may not be the best way of determining stance width.

This study required subjects to perform cognitive tasks in a static position, whereas most activities of daily living are dynamic in nature. Therefore the results of this study cannot be generalized to most daily activities.

A final limitation is created by the use of convenient sampling. Conclusions drawn from this study are not applicable to populations outside of the sample itself.

**Suggestions for Future Research**

There is a need for further research in the area of stance width as it relates to the performance of mentally demanding tasks. The methods utilized in this study to determine stance width were a hybrid of two previously established methods. This newer method employed unique procedures that have not yet been determined to be valid or reliable. Research to determine the validity and reliability of these methods should be the next step.

Future studies would do well to expand the investigation of other confounding variables that may influence stance width such as gender and age. A fifteen-year range as used for the subjects in this study, is quite large when dealing with the elderly. Dramatic
health changes can occur during this time period; investigating smaller age ranges is suggested.

This study focused on healthy older subjects, yet previous researchers have shown that fallers demonstrate the greatest postural sway when performing cognitive tasks. An interesting study would replicate these procedures using a sample with a history of falls.

Conclusions

Kirby et al. and Nichols et al. suggested that narrower stance widths lead to greater postural sway in healthy subjects. Shumway-Cook et al. and Stelmach et al. determined that cognitive loading increased postural sway in groups of healthy young, healthy older individuals, and older individuals with a history of falls. No current literature shows a relationship between cognitive loading and stance width. This study attempted to investigate a possible relationship between these two variables.

While there are a multitude of factors influencing one’s stance width, the results of this study led to the conclusion that in a sample of healthy older adults, performance of a cognitive task may not be a determinant of stance width. Further research is needed to establish stance width and the factors affecting stance width as clinical indicators of postural stability.
References


Appendix A

Medical History Questionnaire
Medical History Questionnaire

The following is a list of questions to assess your general health. Please answer as completely and honestly as you can. All responses will be kept confidential.

1. What is your current age: _______ years

2. Do you live in your own home? NO____ YES____

3. Do you receive assistance from anyone for cooking, bathing or dressing? NO____ YES____

4. Are you currently taking any prescription medications? NO____ YES____
   If yes, please list below:

<table>
<thead>
<tr>
<th>NAME</th>
<th>HOW OFTEN</th>
<th>REASON FOR TAKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Do you have, or have you ever had any of the following:
   a. Parkinson's Disease or any other neurological disorder NO____ YES____
   b. Stroke NO____ YES____
   c. Rheumatoid Arthritis NO____ YES____
   d. Dizziness/Fainting/Vertigo NO____ YES____
   e. Surgery (explain below) NO____ YES____
   f. Amputation (of the lower extremity) NO____ YES____
   g. Hip, knee or ankle joint replacement NO____ YES____
   h. Fractures of the lower extremity within the last year NO____ YES____

   Explanation for above:
6. Have you fallen in the past year? (A "fall" is defined as: when a person's knee(s), belly, side, bottom or back ends up on the ground or floor when he or she did not expect to.) NO___ YES___

5. Do you use an assistive device such as a cane? NO___ YES___

6. Do you use a brace such as an AFO on your leg or foot? NO___ YES___
Appendix B

Exclusion Criteria
Procedures for Subject Screening

All eligible subjects must fall under the definition of “healthy elderly subject” as stated in the definition of terms for this study. Further investigation of subject eligibility will be based upon exclusion criteria listed on the Medical History Questionnaire (Appendix B) and the Health Screen Form (Appendix C). Listed below are exclusion criteria for the Medical History Questionnaire and instructions for each factor that will be screened using the Health Screen Form.

Medical History Questionnaire

Age
Subjects must be 65 to 80 years old.

Living Conditions
Subjects must be living in their own home, not part of an extended care or assisted living facility.

Activities of Daily Living
Subjects must be independent in cooking, bathing and dressing.

Medications
Subjects must not take more than three prescription medications or be taking any psychotropics or sedatives. See examples of commonly prescribed psychotropics and sedatives below:

Sedatives:
Alprazolam (Xanax)
Phenobarbitol (Barbita, Solfoton)
Estazolam (ProSom)
Oxazepam (Valium)
Triazolam (Halcion)
Lorazepam (Ativan)
Psychotropics:
Fluoxetine HCl  (Prozac)
Amitriptyline HCl  (Elavil)
Amoxapine  (Asendin)
Paroxetine  (Paxil)
Imipramine  (Janimine, Tofranil)
Sertraline HCl  (Zoloft)

Disorders/Diagnoses/Surgeries:
"Yes" responses to letters a, b, c, d, f, g, h, will all result in exclusion.
Surgical exclusions (Letter e), within the last year:
- Arthroscopic procedures of the lower extremity
- Bunionectomy
- Ligamentous/Tendon/Meniscal surgeries in the lower extremities
- Arterial bypass in the lower extremity
- Removal of vein in the lower extremity
- Grafting or surgical drainage of wound on the lower extremity

Falls
A "Yes" response reporting a fall will be followed with questioning from the researcher, regarding the conditions of the fall. Subjects who have fallen, in conditions other than an overwhelming hazard within the last year will be excluded.

Fall – when a person’s knee(s), belly, side, bottom or back ends up on the ground or floor when he or she did not expect to.

Overwhelming hazard – a hazard that would result in a fall by most young, healthy persons, such as slipping on ice.

Assistive Device
Any “Yes” response to this question will result in exclusion.

Lower Extremity Brace
Any foot/knee brace or device worn on the lower extremity, other than a shoe insert will result in exclusion.
Health Screening Procedures

Vision
1) The Snellen Eye Chart will be fixed to the wall, the subject will stand 20 feet away.
2) Each subject will wear his or her normal, corrective eyewear used for distance vision.
3) The subject will be asked to read the lowest line on the chart visible using both eyes.
4) The subject will be included if they can read, with greater than 50% accuracy the line corresponding to 20/40 vision.

Proprioception
1) After explaining the testing procedure to the subject, he/she will be seated on plinth, blindfolded with shoes and socks removed.
2) The researcher will begin testing on the right knee by placing the knee at five random angles. Subject will respond by matching the left knee to the given angle.
3) Researcher will then test right ankle using five random positions of plantarflexion and dorsiflexion.
4) Researcher will judge correctness by visual interpretation. Subjects must score at least nine out of ten matches correctly per LE to be included.
5) The same procedure will be performed on the left knee and ankle.

Strength
1) Strength testing will begin with the subject seated.
2) For all muscles tested, each subject’s ability to move the extremity through their full range of motion against gravity will be sufficient strength for inclusion.
3) Bilateral quadriceps strength will be assessed by having the subject extend each knee in turn through his/her full range of motion.
4) The subject will raise each foot, while still in a seated position, to test dorsiflexor strength.
5) Hamstring strength will be tested in a standing position. The subject will flex each knee to 90° with the hip in a neutral position.
6) Plantar flexor strength will also be assessed in a standing position. A subject who is able to rise onto toes while standing on one leg will be included. Both lower extremities will be tested.
7) If the subject is unable to perform the toe raise, he/she will be positioned prone and asked to plantar flex his/her ankle with the knee extended. Subjects unable to perform this movement will be excluded.
Sensation
1) Five specific dermatomal points will be assessed on each LE.
2) Using a cotton ball, each dermatome will be tested three times.
3) The researcher will randomly alternate between touching the dermatomal point and not touching the point.
4) Subjects response will be “cotton” or “no cotton” and must answer correctly two out of three times for each point to be included.
5) Dermatomal points to be tested in standing:
   - L3 - Medial femoral condyle
   - S2 - Popliteal fossa
6) Place gait belt around subject’s waistline and position the subject in supine on plinth.
7) Dermatomal points to be tested in supine:
   - L4 - Medial malleolus
   - L5 - Dorsum of foot at third MTP joint
   - S1 - Lateral heel

Blood Pressure
1) Subject will begin in a supine position.
2) Place blood pressure cuff around subject’s right arm above the elbow.
3) Record blood pressure in supine position.
4) Subject will swiftly rise to a standing position.
5) Record blood pressure in standing within 1 minute of position change.
6) Subjects with a drop in systolic blood pressure greater than 20 mmHg will be excluded.
Appendix C

Mini-Mental State Exam
### Mini-Mental State Exam

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Maximum Score</th>
<th>Score</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the (year) (season) (date) (day) (month)?</td>
<td>5</td>
<td></td>
<td>Ask for the date. Then proceed to ask other parts of the question. One point for each correct segment of the question.</td>
</tr>
<tr>
<td>Where are we: (state) (county) (town) (hospital)</td>
<td>5</td>
<td></td>
<td>Ask for the facility then proceed to parts of the question. One point for each correct segment of the question.</td>
</tr>
<tr>
<td>Regionation</td>
<td>3</td>
<td></td>
<td>Name the objects slowly, one second for each. Ask her to repeat. Score by the number she is able to recall. Take time here for her to learn the series of objects, up to 6 trials, to use later for the memory test.</td>
</tr>
<tr>
<td>Attention and Calculation</td>
<td>5</td>
<td></td>
<td>Score the total number correct. (93, 85, 79, 72, 65)</td>
</tr>
<tr>
<td>Count backwards by 7s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start with 100. Step after 5 calculations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternated Question</td>
<td>5</td>
<td></td>
<td>Score the number of letter in correct order. (diw = 5, dloew = 3)</td>
</tr>
<tr>
<td>Spell the word “world” backwards.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recall</td>
<td>3</td>
<td></td>
<td>Score one point for each correct answer (bed, apple, shoe)</td>
</tr>
<tr>
<td>Ask for the three objects used in question 2 to be repeated.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Naming: Name this object: (watch, pencil)</td>
<td>2</td>
<td></td>
<td>Hold the object. Ask patient to name it. Score one point for each correct answer.</td>
</tr>
<tr>
<td>2. Repetition: Repeat the following - “No ifs, ands or buts.”</td>
<td>1</td>
<td></td>
<td>Allow one trial only. Score one point for correct answer. Use a blank sheet of paper.</td>
</tr>
<tr>
<td>3. Follow a 3-stage command:</td>
<td>3</td>
<td></td>
<td>Score one point for each part correctly executed.</td>
</tr>
<tr>
<td>“Take the paper in your right hand, fold it in half, and put it on the floor.”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Language</th>
<th>Maximum Score</th>
<th>Score</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Reading: Read</td>
<td>1</td>
<td></td>
<td>Instruction should be printed on a page. Allow patient to read it. Score by a correct response.</td>
</tr>
<tr>
<td>the following:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Close your eyes.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Writing: Write</td>
<td>1</td>
<td></td>
<td>Provide paper and pencil. Allow patient to write any sentence. It must contain a noun, verb, and be sensible.</td>
</tr>
<tr>
<td>a sentence.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Copying: Copy</td>
<td>1</td>
<td></td>
<td>All 10 angles must be present. Figures must intersect. Tremor and rotation are ignored.</td>
</tr>
<tr>
<td>this design.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Total Score      |       | Maximum 30: Test is not timed.                                                       |

Appendix D

Health Screen Form
Health Screen Form

1. **Vision:**
   
   Score: _____

2. **Proprioception:**

   Right Knee Score: _____  
   Left Knee Score: _____  
   Right Ankle Score: _____  
   Left Ankle Score: _____

3. **Strength:**

   Seated:
   - Right Quads: Able____ Unable____
   - Right DF: Able____ Unable____
   - Left Quads: Able____ Unable____
   - Left DF: Able____ Unable____

   Standing:
   - Right HS: Able____ Unable____
   - Right PF: Able____ Unable____
   - Left HS: Able____ Unable____
   - Left PF: Able____ Unable____

4. **Sensation:** (Record number correct out of three.)

   Standing:
   - L3 – Medial femoral condyle  
     Left: ___  Right: ___
   - S2 – Popliteal fossa  
     Left: ___  Right: ___

   Supine:
   - L4 – Medial malleolus  
     Left: ___  Right: ___
   - L5 – Dorsum of the foot, 3rd MTP  
     Left: ___  Right: ___
   - S1 – Lateral heel  
     Left: ___  Right: ___

5. **Blood Pressure:**

   **Supine**  
   **Standing**

   BP: ___  ___
Appendix E

Informed Consent
INFORMED CONSENT

THE EFFECT OF COGNITIVE LOAD ON STANCE WIDTH
OF HEALTHY OLDER ADULTS

I have been informed that this study will investigate the effects of a mental task on factors related to balance. I have been chosen to participate in this study because I am between the ages of sixty-five and eighty years and have no significant health problems. This study will help physical therapists and other health professionals understand balance problems in people my age.

I understand that I will be one of 50-60 subjects that will be asked to stand with nylon stockings on their feet on individual sheets of paper for 30 seconds for a total of 6 trials. For some of the trials I will be asked to perform a series of mathematical problems in my head. At the conclusion of each trial, marks will be made on the paper around my feet.

In addition to these trials I will be asked a series of questions about my health and activity level. I also understand that a screen of my blood pressure, vision, sensation and strength will be performed to ensure that I fit the researchers’ definition of “healthy”. My participation in the study will take approximately 1 hour.

I understand that I may experience some pain or discomfort as a result of my participation in this study, specifically the strength screen, but the discomfort is expected to be minimal. There is also a risk that during the testing I may lose my balance. A researcher will be close by to catch me, should I lose my balance.

I understand that my participation in this study will help facilitate research regarding balance in people my age and I will receive a free general health screen.

I understand that all information gathered, including names and personal information, will be kept confidential. All data will be coded so that identification of individual participants will not be possible.

I understand that I may ask questions about the study at any time. Susan Brown (249-3221) and Amy Thackery (538-1257) are available to answer my questions or address concerns. I understand that I will be informed of any significant new findings discovered through the course of this study, which might influence my continued participation. If I wish to contact someone other than the researchers to discuss a research-related issue, or any other concern, I may contact:

Ms. Jolene Bennett
Thesis Chairperson
P.T. Dept., GVSU
391-7788

Robert Henderson
Human Subjects Review Board
GVSU
895-2195
I understand that my participation is voluntary and that I may refuse to participate or may withdraw consent and discontinue participation at any time. I also understand that Susan Brown or Amy Thackery may terminate my participation in this study at any time after they have explained the reasons for doing so.

I have explained to ____________________________ the purpose of the research, the procedures required, and the possible risks and benefits to the best of my ability.

Investigator ____________________________ Date

I confirm that Susan Brown and/or Amy Thackery have explained to me the purpose of the research, the study procedures that I will undergo, and the possible risks/discomforts, as well as the benefits that I may experience. I have read and I understand this consent form. Therefore, I agree to give my consent to participate as a subject in this research project.

Subject ____________________________ Date

Witness to Signature ____________________________ Date

I am interested in receiving a summary of the study results. NO YES (Please furnish name and mailing address if YES.)

Name: ____________________________

Street: ____________________________

City, State, Zip ____________________________

Please mail a copy of this consent form to my above address. NO YES
Appendix F

Data Collection Form
Data Collection Form

Subject Number: ______
Date: __________
Data Site: ________

Gender: M F

Subject Age: ______

Stance width #1 ________ cm
No Task
Task

Stance width #2 ________ cm
No Task
Task

Stance width #3 ________ cm
No Task
Task

Stance width #4 ________ cm
No Task
Task

Stance width #5 ________ cm
No Task
Task

Stance width #6 ________ cm
No Task
Task

Cognitive Task Responses:

Trial #1 ______
Trial #2 ______
Trial #3 ______

Notes: