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The Effect of Upper Extremity Immobilization Following Surgical Rotator Cuff Repair on Balance in Elderly Individuals

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by

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THE EFFECTS OF UPPER EXTREMITY IMMOBILIZATION FOLLOWING SURGICAL ROTATOR CUFF REPAIR ON BALANCE IN ELDERLY INDIVIDUALS

ABSTRACT

The purpose of this study was to determine if a relationship exists between upper extremity immobilization following surgical rotator cuff repair and balance in elderly individuals. Twenty-eight healthy volunteers (nine with rotator cuff repair, nineteen without) aged 53 to 74 participated in the study. Balance was measured using the Berg Balance Measure, Modified Berg Balance Measure, Functional Reach Test, and force plate analysis. Results were analyzed using t-tests for paired and independent samples, Mann Whitney U (Wilcoxon Rank Sum W) tests and Wilcoxon Matched-Pairs Signed-Ranks tests. Significant differences were found between the post-rotator cuff surgery and control groups for performance on the Berg (p=0.0125) and Modified Berg (p=0.019, p=0.0120), as well as between the sling and no-sling block for two measures of posterior maximal lean (p=0.0249, p=0.0179). Results suggest that long and short term immobilization have some effect on balance. A need for balance training may exist in this population.

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* *

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Chapter One
Introduction

Approximately one-third of the elderly living in the community and one-half living in nursing homes fall every year (Cutson, 1994). According to the National Safety Council, falls are the leading cause of unintentional death injury in those 75 years of age or older and is the second leading cause of death in those aged 65 to 74 (National Safety Council, 1995). Though a majority of falls in the elderly do not result in serious injury, medical attention is often needed for fall related injuries (Cutson, 1994; Commodore, 1995). Falls may result in hip fractures which are a major medical problem of the elderly and a factor associated with chronic disabilities, complications leading to hospitalization, and sometimes death (Barangan, 1990; Perlin, 1992). Each year $75 billion to $100 billion is spent on direct and indirect costs of falls in the United States (Urton, 1991). With the percentage of persons over age 65 rising in the United States from 12.8% in 1994 to a projected 16.2% in 2020 (U. S. Bureau of the Census, 1995). The incidence and health care costs of falls in the elderly can be expected to increase as well.

Since an expected increase of falls may accompany the rising elderly population, associated risk factors must be identified to help prevent these falls. An increased incidence of falls has been associated with a decrease in balance (Lewis, 1996). A variety of factors have been found to affect a person's balance. The literature has focused on and emphasized the effects of vision, proprioception, vibration sense, strength, and the vestibular system on balance in individuals (Brocklehurst, Robertson, & James-Groom, 1982; Era & Heikkinen, 1985; Gehlsen & Whaley, 1990; Iverson, Gossman, Shaddeau, & Turner, 1990; Lord, Clark, & Webster, 1991). Researchers have suggested that the visual, proprioceptive, and vestibular systems work together to allow a person to control balance (Anacker & DiFabio, 1992; Chandler, Duncan, & Studenski, 1990).

Many of the body systems that contribute to balance decline functionally as one ages. Deficits in the proprioceptive, visual, vestibular, and muscular systems have been found with increasing age (Duncan, Chandler, Studenski, Hughes & Prescott, 1993;

Iverson, et al., 1990; Poole, 1991; Stelmach and Worringham, 1985; Woollacott, Shumway-Cook, & Nashner, 1982). Balance, as measured by postural sway, has also been found to decrease with age (Brocklehurst, et al., 1982; Overstall, Exton-Smith, Imms, and Johnson, 1977).

Increasing age is also thought to be a contributing factor to the tearing of the shoulder's rotator cuff (Craig, 1994). Rotator cuff tears most often occur, and appear to be the most common cause of shoulder pain, in people aged 40 and older (Craig, 1994; Wittert, 1986). Surgery to correct rotator cuff lesions range from arthroscopically assisted repair to open repair (Baker & Liu, 1995). These surgeries are performed to decrease pain and improve function (Post, 1990). Post-operatively, the duration of immobilization and positioning of the upper extremity is dependent upon the repair procedure performed (Simon & Hill, 1989). The extremity may be immobilized for two to eight weeks and can be positioned in abduction with a splint, an abduction pillow, or at the patient's side with a sling (Baker & Liu, 1995; Gore, Murrary, Sepic, & Gardner, 1986; Watson, 1985).

Though this surgical procedure is relatively common in the elderly, no literature was found evaluating the effect of upper extremity immobilization on balance/postural control in the elderly or any other age group. However, at least three factors may explain a possible relationship between upper extremity immobilization and balance. First, the immobilization could cause an alteration in body scheme, a variable involved in postural control (Gurfinkel, Levik, Popov, Smetanin, & Shlikov, 1988). The second possible effect of immobilization on the upper extremity is shortening of the latissimus dorsi muscle which has its insertion on the humerus and one of its origins on the pelvis (Kendall, McCreary, & Provance, 1993, p. 279). Since the hip is involved in balance strategies, an alteration of the latissimus dorsi muscle may affect balance (Shumway-Cook & Woollacott, 1995, p. 212). Third, a lack of arm swing, which is part of the normal gait cycle, may result from joint stiffness or muscle shortening due to upper extremity immobilization and affect balance during gait (Norkin & Levangie, 1992, p. 480-481).

Statement of the Problem

Research is lacking concerning the effects of immobilization of the upper extremity on balance in the elderly population.

Purpose of the Study

The purpose of this study is to attempt to show that long-term upper extremity immobilization following rotator cuff repair will decrease balance as measured by postural sway; static leans anterior, posterior, left, and right; the Berg Balance Measure; the Modified Berg Balance measure; and the Functional Reach test in persons age 60 to 74 as compared to normal persons of the same age group. This study will also attempt to show that temporary immobilization, through the application of a sling, will also decrease balance in both normal and post-rotator cuff repair subjects as measured by postural sway and static leans anterior, posterior, left and right.

Significance of the Study

Physical therapists treat elderly patients who have undergone rotator cuff repair. Results of this study will assist therapists in determining if patients who have undergone long or short periods of immobilization should be tested for possible deficits of balance. Information gathered from testing will help the therapist identify the appropriateness for balance re-education in this population. Through education and treatment, falls may be prevented. This will result in decreased morbidity and health care costs in this population.

Chapter Two
Literature Review

Definition of Balance and Postural Control

Balance is an intricate and dynamic process in which an individual maintains his/her body weight over his/her base of support through constant adjustments of muscle activity and joint position (Iverson, et al., 1990). Postural control is the ability to maintain a body position against one or more forces which threaten the body's disequilibrium or sense of orientation in space (Norkin & Levangie, 1992). Balance is a necessary component of postural control, and is achieved through various strategies.

Balance Strategies and Righting Reflexes

Healthy human adults employ automatic postural responses in order to maintain balance and postural control. These automatic postural responses are proactive and stereotypic movement patterns which are dependent upon environmental conditions and accurate sensory information. The "ankle strategy" is used when the individual experiences small, slow horizontal displacements on firm surfaces longer than the feet. The individual will reposition his/her body mass by exerting torques against the surface and swaying as an inverted pendulum above the ankle. There is little motion about the knee and hip with this strategy. The "hip strategy" is used to regain equilibrium in situations when the individual must respond to large, fast displacements or if the support surface is shorter than the feet. An individual will then add trunk rotation through active hip motions resulting in horizontal shear forces on the support surface. Immediately following changes of surface width or when reaching the outer limits of their stability, an individual may use a combination of the hip and ankle strategy. If the ankle or hip strategy are inadequate, the individual will resort to a stepping or stumbling strategy to maintain his/her center of mass over his/her base of support (Horak & Nashner, 1986; Horak, Nashner, & Diener, 1990).

Righting reactions are another way the human organism preserves balance. These include labyrinthine, optical, body on head, and landau righting reactions. By aligning the head and trunk or orienting the head in a normal functional position to the ground, the body is able to assume the normal standing posture. Righting reactions help maintain balance as the individual changes position through head control (Crutchfield & Barnes, 1993, p. 213).

Factors Affecting Balance

Duncan, et al. (1993) and Dornan, Fernie and Holliday (1978) describe sensory, effector, and central processing components as the three physiological components of balance. The sensory components include somatosensation, vision, and vestibular function. Range of motion (ROM) and muscle strength are the effector components of balance. The sequencing of muscle responses following postural perturbation are accomplished by the central processing component of postural control.

Dornan, et. al. (1978) also describe the sensory component of normal static balance as a combination of vision, proprioception, and vestibular mechanisms. When one component is impaired, the other two must compensate if equilibrium is to be maintained. Duncan, et al. (1993) describe redundant functioning of these sensory components as necessary to carry out normal activity. When declines of functioning in any one of these sensory components occur, the ability to compensate and maintain balance and postural control diminish.

Several studies describe proprioception as the key sensory component of balance and postural control. Anacker and DiFabio (1992) studied how conflicting ankle somatosensation and visual inputs affect standing balance in 47 elders with a recent history of falls. From the data gathered in their study, these authors concluded that proprioception is the primary modality used to maintain balance. Integration of proprioceptive input with vestibular and visual input provides a means of adaptation to changing environmental conditions in which proprioceptive input may be inadequate. In a study by Lord, Clark, and Webster (1991), the authors determined proprioception to contribute 56.3% to postural stability, vision 21.3%, and vestibular input 22.4%. These analyses revealed sensation in the lower limbs to be the main factor contributing to balance under normal conditions with vision playing a major role under adverse conditions. Doman, et al. (1978) add that vision is very important to postural stability when proprioceptive information is unreliable or unavailable. Cohen (1994) states that vestibular input also becomes increasingly important as proprioceptive input decreases.

Horak, et al. (1990) determined the effect of somatosensory and vestibular loss on postural strategies. Although postural responses were neither delayed nor disorganized with lack of vestibular and somatosensory input, the type of postural response selected was altered. While a loss of somatosensation increased the use of hip strategy for postural correction, a loss of vestibular input resulted in a lack of hip strategy. This suggests that vestibular input plays an important role in achieving hip strategy for postural control (Horak, et al., 1990).

ROM and muscle strength are also important effector factors of postural control. An individual may have perfect sensation and central processing, but without adequate strength and ROM, postural strategies cannot be carried out. Gehlsen and Whaley (1990) studied the effects of decreased strength and flexibility of elderly fallers. These authors suggest that flexibility of the hip and ankle may be related to falls when extreme joint excursion situations are required. Since a decline in flexibility decreases both stability and mobility, normal postural strategies may be ineffective. This study also supported a study by Whipple, Wolfson, and Amerman (1987) stating that peak torque and power were decreased in knee flexors, knee extensors, ankle dorsiflexors, and ankle plantarflexors in nursing home residents with a history of falls. These authors also reported that ankle strength, particularly in the dorsiflexors, appears to be especially important in maintaining balance. Research by Lord, et al. (1991) also showed that reduced ankle dorsiflexor and quadricep strength is associated with decreased postural stability. As with vision, they found that strength becomes increasingly important under adverse conditions involving reduced sensation. Anacker and DiFabio (1992) speculate that decreased lower limb strength, along with an increase in activation threshold for joint proprioceptors, may predispose the ankle to excessive displacements on challenging surfaces. In their study regarding effector factors of falls, Studenski, Duncan, and Chandler (1991) also indicated muscle strength and ankle ROM are reduced in fallers.

Pathology can also affect balance. Orthopedic disorders affecting ROM, muscle strength, or structural integrity may alter postural responses. Individuals with arthritis or recent joint replacement may have inadequate postural support to maintain balance due to pain. According to Lamb, Miller, and Hernandez (1987), degenerative joint disease, osteoporosis, cervical spondylosis, and foot deformities may cause changes in gait or posture and contribute to falls. Pathology or disease which changes a person's center of mass may cause imbalance until the body makes appropriate adaptations. Likewise, neurologic disorders affecting sensory, effector, or central processing components of balance may also contribute to postural instability. Perlin (1992) reports that Parkinson's disease, stroke, seizure, dementia, and transient ischemic attack increase the incidence of falls. Lamb, et al. (1987) add peripheral neuropathy, cataracts, and glaucoma to this list. As neurologic disease affects vision, vestibular function, or proprioception, the redundancy of sensory information decreases and balance is impaired.

Several studies cite certain pharmacologic agents to be associated with falls. Campbell, Reinken, Allan, and Martinez (1981) state that psychotropic drugs are receiving attention as contributing to impaired balance in the elderly. Lamb, et al. (1987) stated that psychotropics, hypoglycemics, diuretics, ethacrynic acid, and furosemide cause dizziness which affects balance and may lead to falls. Antihypertensives can also lower blood pressure enough to cause hypotension and contribute to falls. Overstall, et al. (1977) state that night sedatives, antihypertensives, diuretics, phenothiazines, and benzodiazepines are likely to increase postural sway. Increases in postural sway are associated with an increased tendency to fall in the elderly population (Overstall, et al., 1977; Fernie, Gryfe, Holliday, & Llewllyn, 1982). The study by Overstall, et al. (1977), however, showed no difference in the amount of sway between males and female who do and do not receive these drugs. Likewise, a study by Brocklehurst, et al. (1982) examined the relationship between falls and sway. They found that sedative type drugs did not relate to falls or sway. Dosage of drugs examined in this study was not considered, however, and these authors hypothesize that high doses of such medications do cause impaired stability.

It is possible that distortions of body scheme can lead to postural instability and decreased balance. O'Sullivan and Schmitz (1994) defined body scheme as a

> postural model of the body, including the relationship of body parts to each other and the relationship of the body to the environment. Body awareness is derived from the integration of tactile, proprioceptive, and interoceptive sensations in addition to the individuals subjective feelings about the body (p. 617).

The normal functions of the body scheme, as stated by Gurfinkel, et al., (1988), are:

> perception of the borders between the body and extrapersonal space; knowledge of the body dimensions, lengths of the body segments and the sequence of their linkage; their mass inertia properties; formation of a stationary reference system common for the body and the external space; a proper adjustment of the levels of the muscle activity required to maintain a given posture; and postural adaptations to predictable disturbances (p. 191).

These authors state that "implementation of these functions requires adequate sensory input" (p. 191). Changes in vision, vestibular function, and proprioception that occur with aging may ultimately cause distortions of body scheme since these age-related changes alter sensory input. Further decreases of sensory input, as with immobilization, may continue to alter body scheme. This may ultimately cause a decrease in postural control impacting one's ability to maintain balance.

Changes in Balance with Age

Many age associated changes in components of balance for the elderly are considered to be normal. These changes, which contribute to a decrease in balance, may help explain the prevalence of falls in this population. Lamb, et al. (1987) state that changes in vision and decreases in proprioception and vestibular function are normal aging changes. These authors also report a decrease in muscle mass and tone in the elderly which contributes to decreases in strength and coordination.

Vision.

In a study by Lord, Clark, and Webster (1991), 95 residents of a hostel for the aged were tested to determine the effect of age on visual acuity and contrast sensitivity. These authors report a prevalence of poor vision in this population with visual acuity and contrast sensitivity declining markedly with age. A clinical examination revealed that those elders with a visual disorder such as cataracts or retinopathy had poorer vision than those without disorders, but the difference was insignificant. This suggests a decline in vision, even in the absence of pathology, is normal as one ages. This study also showed an association between age and poor visual acuity as well as between age and contrast sensitivity while subjects stood on foam. The foam simulated situations of reduced peripheral sensation and forced subjects to rely on visual and vestibular inputs. Without appropriate vision to aid in making compensations in this scenario, it became difficult for the individuals to balance as indicated by an increased postural sway while the subject stood on foam. Practical applications can be drawn from these findings. While walking on foam-like surfaces, such as thick carpet, grass, or uneven surfaces, peripheral sensation is reduced. Without adequate vision to compensate for this loss of sensation, postural stability may be decreased thereby increasing the risk of falling.

Poole (1991) also describes a decline in vision with age. Not only does the lens of the eye become less transparent with age, but it also cannot accommodate to bring near objects into focus. This author states that "older adults require more illumination and have reduced dark adaptation, depth perception, color discrimination, and peripheral vision" (p. 59). Again, these changes may lead to an increased incidence of falls due to lack of sensory input.

Vestibular System.

Lamb, et. al. (1987) states that vestibular function decreases with age. Rosenhall (1973) has shown a 40 percent loss of sensory cells within the vestibular system in individuals beyond 70 years old. Rosenhall and Rubin (1975) also report a progressive decrease in the number of sensory cells and nerve fibers of the peripheral vestibular system in adults older than 40 years. The loss of sensory cells may impair vestibular sensitivity in the aged decreasing postural stability. This is especially true when either vision or proprioception are impaired and unable to compensate for the missing vestibular information regarding body position in space.

Proprioception.

Literature strongly supports decreased proprioception as the main factor in balance and falls. It is inconclusive, however, about the degree to which proprioceptive changes occur naturally with age. Poole (1991) states that mechanical receptors, which are responsive to touch, vibration, and changes in joint position, demonstrate a noticeable loss in sensitivity with age. Rowe and Besdine (1982, p. 394) further states that "normal aging is associated with decreased sensitivity of the mechanoreceptors to changes in orientation of the head on the neck." This may decrease the effectiveness of the elderly persons' righting reactions which, through head control, help maintain balance as an individual changes position (Crutchfield & Barnes, 1993, p. 213). Peripheral neuropathy is also common among elderly persons affecting proprioception (Cassel, Cohen, Larson, Meier, Resnick, Rubenstein, Sorensen, 1997, p. 789)

ROM and Flexibility.

ROM and flexibility decline with age. Lamy (1980, p. 52) states that aging affects collagen and elastin, the major components of connective tissue. As a person ages, collagen becomes more crystalline in orientation and loses water content, which increases it's tensile strength and stiffness (Lamy, 1980, p. 52). This causes muscles, skin, and tendons to be less flexible and mobile (Lewis, 1996, p. 150). Lewis (1996, p. 150) further states that the spine becomes less flexible with age secondary to collagen changes in the annulus fibrosis and decreased water content of the nucleus pulposus. Disk size decreases with these changes leading to a more inflexible spine.

A study by Bergstrom, Aniansson, Bjelle, Grimby, Lundgren-Lindquist & Svanborg (1995) examined the functional consequences of joint impairment at age 79. These authors found restricted ROM of separate joints in one-fifth to two-thirds of all individuals in their study. However, 50 percent of these individuals managed their own house-keeping and two-thirds of these people did not use an ambulation device despite their ROM limitations. These authors concluded that disability, as a direct cause of joint impairment, is not very frequent in the elderly even at the age of 79. However, decreased ROM that occurs with age could have a major impact on balance. If an individual does not have adequate ROM at the ankles, knees, or hips, postural strategies can not be carried out to maintain balance.

Strength.

It is generally agreed upon that muscle strength decreases with age. Although many of the muscular changes associated with aging are due to disuse and can be prevented, literature supports a decrease in muscle mass to be a true age-related change (Scully & Barnes, 1989). Scully and Barnes (1989) state

> Muscle mass decreases with age as a result of fiber atrophy, particularly among type II Fibers, and probably as a result of fiber loss. Other changes within skeletal muscle may include disorganization of the myofibril, infiltration of fat and connective tissue, evidence of denervation, and alterations of the neuromuscular junction and sarcoplasmic reticulum.

> Electrophysiological studies indicate that fewer motor units function in older persons, and that nerve conduction velocity tends to decrease (p. 100).

These authors state that "alterations in the nervous system, circulation, endocrine system, and nutrition frequently occur with aging...making muscle less efficient and perhaps contributes to cell death" (p. 101). Lewis (1996, p. 155) states that the number of motor units also decline with age, decreasing coordination and speed of muscle contraction. Grob (1983, p. 329) notes that the age at which muscle changes begin to occur is highly variable.

Such physiologic changes in the muscle and its components as described above, along with disuse, can lead to major deficits of strength in the elderly. Lewis (1996, p. 156) states that a decrease in strength occurs especially in antigravity muscles such as quadriceps femoris, hip extensors, and ankle dorsiflexors with disuse. Commonly used in daily activity, these muscles begin to atrophy as the older person, in many cases, no longer performs strenuous activities which help preserve strength in these muscles (Lewis, 1996, p. 156). A strength decline in these muscles may render the hip and ankle strategies used to maintain an upright posture ineffective.

Central Processing.

Not only is muscle strength affected by aging, Woollacott and Shumway-Cook (1990) report that the response of muscles to platform translations differs between older and younger adults. These authors describe an increase in latency of distal muscle responses, reversals of the normal distal-to-proximal sequence of muscle contractions, and a larger incidence of short-latency spinal monosynaptic reflexes with platform rotations with the older population. Woolacott, Zederbaur-Hylton, and Marvin (1989) report a greater coactivation of agonist and antagonist muscles about the joints of the older adult. These changes may affect an elderly person's ability to employ proper postural responses to maintain balance.

Age related changes in the components necessary to maintain balance as mentioned above put the elderly individual at a high risk for falls. The redundancy of sensory inputs allows the body to make postural compensations despite impairments of the various senses. At a certain point, unique to each individual, there ceases to be enough redundant information to maintain balance. This may result in a fall. Lack of muscle strength, limitations in ROM, and inaccurate central processing capabilities alone or in combination with other deficits may further decrease balance. It is important, then, that the elderly population is educated about expected age related changes and taught compensation methods as a preventative treatment for falls.

Measures of Balance

Many useful tools in measuring balance have been cited in the literature. Among these tools are the Visual Push test, Postural Stress Test (PST), center of pressure excursion (COPE), Functional Reach test (FR), the Berg Balance Measure, postural sway as measured by the Wright Ataxiameter and force plates, and limits of stability as measured biomechanically.

The visual push test is used as an indication of the body's ability to respond to an unexpected displacement and avoid falls during movement (Ring, Matthews, Nayak, & Isaacs, 1988). As the subject stands upright on a force platform, visual surroundings projected on a screen create a sensation of self movement. Sway path is measured as the subject stands on a solid or foam platform. Ring, Matthews, Nayak, & Isaacs (1988) found sway path with and without the subject standing on foam to significantly increase with age. These authors determined that in the assessment of balance function, the visual push method is a safe and acceptable method of measuring balance in the young and old. These authors state that this method

> simulates the conditions in which falls might occur in elderly people during normal activity. It is sufficiently sensitive to detect symptomless subjects who might fall if they were provided with inaccurate or conflicting visual or proprioceptive information (p. 259).

Ring, Nayak, & Isaacs (1988) also have demonstrated that significant differences exist between older people who have and have not fallen using the visual push test.

The PST also can determine individuals at risk for falls. Using a pulley-weight system, a reproducible, destabilizing force is delivered to the subject at waist level. Subject responses to the force are videotaped and evaluated using a nine level grading scale (Wolfson, Whipple, Amerman, & Kleinberg, 1986). Wolfson, et al. conclude that the PST is predictive of individuals with a propensity to fall and may be useful for studying balance response longitudinally.

The COPE is a test in which the subject stands on a force plate platform while his/her center of pressure is recorded as he leans forward, backward, and to each side (Murray, Seireg, & Sepic, 1975). In comparison to younger subjects, elderly individuals do not approach the edges of their base of support. Their avoidance of the outer limits of their support base is thought to be a protective compensation for decreased postural control mechanisms (Lee & Deming, 1988). COPE, then, is a useful measure of determining postural control and balance in the elderly.

Similar to COPE, FR was also designed as a measure of the margins of stability. FR is defined by Duncan, Studenski, Chandler, & Prescott, (1992) as

> the maximal distance one can reach forward beyond arms length while maintaining a fixed base of support in the standing position. FR is measured using a yardstick secured to the wall at the height of the acromion (p. 93).

FR has been shown to be sensitive to clinically significant changes in balance with patients in a rehabilitation program. In addition, test-retest reliability, inter-observer reliability, and criterion validity has been demonstrated (Duncan, Weiner, Chandler, & Studenski, 1990; Weiner, Bongiorni, Studenski, Duncan, & Kochersberger, 1993). Wiener, Duncan, Chandler, & Studenski (1992) also found FR to be a reliable, clinically accessible balance tool for the elderly demonstrating criterion and concurrent validity regarding physical frailty.

The Berg Balance Measure is another measure of balance that has been developed recently. This measure was designed to be appropriate for geriatric patients. It was created using the input of nurses, physicians, physical therapists, occupational therapists, and geriatric patients. The measure evaluates a subject's performance on 14 items common in daily life. The items focus on the subject's ability to maintain various postures, change positions, and maintain balance while the subject's center of mass is moved within his/her base of support. The intraclass correlation coefficients measuring the inter-rater and intra-rater reliability for the measure as a whole were found to be .98 and .99 respectively. Also, the measure was found to have a Cronbach's Alpha (measuring internal consistency) of .96 which indicates that it is measuring one concept and that the total measure is providing more information on balance than on any single item (Berg, Wood-Dauphinée, Williams, & Gayton, 1989; Berg, Maki, Williams, Holliday, Wood-Dauphinée, 1992). This measure of balance, therefore, is an excellent measure of balance in the clinical setting.

Postural sway, as measured by the Wright Ataxiameter and force plates, may also serve as a useful measure of balance in predicting those at risk for falls (Brocklehurst, et al., 1982; Overstall, et al., 1977; Maki, Holliday, & Topper, 1994). The link between postural sway and fall risk was described by Overstall, et al. (1977). These researchers found that postural sway was significantly increased in people who fell due to a loss of balance. In addition, Maki, et al. (1994) stated that spontaneous sway measurements were the best variable for prediction of falls when compared to induced sway measurements. According to Maki, et al. (1994), examination of postural sway is thought to "reflect primarily the integrity of the corrective posture control mechanisms" (p. M81). These authors elaborate by mentioning that possibly spontaneous sway predicts falls by an indirect association, for example "heightened postural activity during unperturbed stance may act as a marker of deterioration in the neural and sensorimotor substrates that serve the balance recovery mechanisms" (p. M82). Postural sway can therefore be considered a valid measurement used to predict falls.

The theoretical limits of stability (LOS) cone provides a measure of posture stability in a dynamic sense. The cone is described as one with its apex projecting upward from the feet. The area within the cone represents the region in which one's center of gravity (COG) can be moved safely without need for external support or taking a step. Common activities of daily living require movement of the COG within the LOS in both lateral and anterior-posterior directions (Hamman, Mekjavic, Mallinson, & Longridge, 1992). Therefore, quantifying an individual's LOS may measure his/her balance abilities in a more dynamic and functional sense.

The Rotator Cuff

Anatomy and Physiology.

The rotator cuff of the shoulder consists of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles. This musculotendinous cuff blends with the articular capsule of the glenohumeral joint. Individually, the muscles each contribute to various shoulder movements. Together, the cuff muscles protect and give dynamic stability to the shoulder joint by keeping the humeral head in the scapula's glenoid cavity (Moore, 1992; Norkin & Levangie, 1992). In addition, the cuff provides a watertight compartment, which may play a role in the nutrition of the glenohumeral articular surfaces (Craig, 1994). In short, regular function of the shoulder is greatly dependent on a normal rotator cuff mechanism (Post, 1990).

Incidence and Mechanisms of Tears.

Rotator cuff tears commonly occur in those aged 45 to 65 and appear to be the most common cause of shoulder pain in patients older than 40 years old (Craig, 1994; Wittert, 1986). The main cause of cuff tears are trauma, such as falling on an outstretched arm, and degeneration (Bateman, 1963; Post, 1990). Several human tissues tend to degenerate with age (Yost & Schmoll, 1992). Craig (1994) mentions that normal aging is believed to be a contributor to rotator cuff tears. Wittert (1986) notes that a relatively minor trauma to the shoulder of a patient with a degenerated rotator cuff may result in a tear.

Though the clinical signs and symptoms of rotator cuff tears may vary, typical presentation of a tear includes weakness with shoulder abduction and pain with overhead activities (Snyder & Kapp, 1992).

Treatment of Tears

Treatment of rotator cuff tears may include conservative measures and/or surgical repair (Wittert, 1986). Most physicians recommend non-operative management for cuff tears initially and suggest surgery be used as a secondary treatment (Baker & Liu, 1995). Of patients selected for surgery, there is a debate as to whether immediate surgery or a six week to three month delayed surgery is best (Simon & Hill, 1989). However, Gore, et al. (1986) found that surgical repair done either early or delayed both resulted in satisfactory outcome. According to the literature, the goals of surgical repair are to accomplish one or a combination of the following: to improve strength, decrease pain, and improve function (Baker & Liu, 1995; Gore, et al., 1986; Post, 1990). Surgical techniques may vary from surgeon to surgeon (Simon & Hill, 1989). Craig (1994) states that with a full thickness tear of the rotator cuff,

> tendon repair is accompanied by an anterior acromioplasty to decompress the rotator cuff and increase the space for the repaired tendon to pass. Usually small and medium-sized tears are repaired by tendon-to-tendon and tendon-to-bone techniques. Larger tendon tears are difficult to repair. A number of muscle transfers, grafts, and synthetic implants have been advocated for adjunctive treatment in larger tears (p. 391).

Baker and Liu (1995) grouped surgical procedures into open and arthroscopic-assisted repairs. They concluded that the arthroscopic-assisted repair was as effective as the open repair. They also reported that the arthroscopic-assisted repair offered several advantages including preservation of the deltoid attachment, shorter hospital stay, treatment and inspection of other shoulder joint conditions, and earlier return to full activity.

Post-operative upper extremity immobilization positioning, type, and duration vary in the literature. Simon and Hill (1989) report that immobilization duration varies from two to eight weeks, and arm position varies from resting at the side in a sling to a full airplane, or abduction, splint. Baker and Liu (1995) report use of a shoulder immobilizer and abduction pillow for three weeks followed by a sling for protective immobilization. Snyder and Kapp (1992) described a lightweight abduction shoulder brace which allows for free movement of the elbow, wrist, and hand. The duration of use of this brace was not given. Gore, et al. (1986) stated 81% of patients in their study had their upper extremity immobilized at the side for four to six weeks, while those with "long" tears were immobilized with a shoulder spica cast or metal splint in abduction for about six weeks. Hawkins, et al. (1985) reported 90% of their subjects used a post-operational sling, while 10% used and abduction brace for six weeks secondary to excessive tension in the rotator cuff tendons when the arm was fully adducted. Watson (1985) reported that his subjects were immobilized in abduction for five weeks, yet he concluded that immobilization in abduction gives no advantage over resting the arm in adduction. Furthermore, he stated that after five weeks, "splinted shoulders are stiff with winging of the scapula on movement" (p. 623). Therefore, according to the literature, there is not a consensus on protocol for post-operative rotator cuff repair immobilization.

Though each patient case has a different prognosis following rotator cuff repair (Post, 1990), a review of the literature has shown that most patients gain overall positive results from the surgery. Most patients report marked pain relief and an increase in shoulder function (Gore, et al., 1986; Hawkins, et al., 1985; Paulos & Kody, 1994; Post, Silver, & Singh, 1983). More specifically, patients who have smaller tears repaired will likely have better functional and strength increases post-operatively as compared to patients with larger tears (Gore, et al., 1986; Hawkins, et al., 1985). However, two studies disagreed as to whether strength increased following rotator cuff repair in most patients (Hawkins, et al., 1985; Post, et al., 1983). Nevertheless, Post, et al. (1983) mentioned that a carefully supervised post-operative rehabilitation program is essential for optimal patient recovery.

Post-Surgical Rehabilitation

Utilization of physical therapy after rotator cuff repair surgery was common in the literature. Typically, passive ROM and Codman pendulum exercises are initiated with patients at several days to four weeks after surgery. Active-assisted and active ROM exercises were reported to follow passive ROM exercises at about three to six weeks post-operation, respectively. These exercises are followed by resisted exercise at about six to eight weeks post-surgery (Baker & Liu, 1995; Gore, et al., 1986; Hawkins, et al., 1985; Paulos & Kody, 1994; Simon & Hill, 1989; Snyder & Kapp, 1992). Simon and Hill (1989) explained that early physical therapy rehabilitation includes modalities to relieve pain and control inflammation. These authors also report that later stages of rehabilitation include modalities used to increase tissue extensibility, stretching techniques to maintain extensibility of muscle and the joint capsule, and shoulder girdle strengthening. They identify the most important aspects of rehabilitation are the identification and modification of activities which inflame rotator cuff tendons.

In conclusion, an intact and operational rotator cuff is essential for normal shoulder function. This anatomical structure is subject to damage by way of trauma and/or degeneration, and is injured more often in older adults. Surgical repair of a torn cuff is an option for treatment that often results in significantly positive results in terms of increasing function and decreasing pain in the shoulder. Typically following surgery, the involved shoulder is immobilized by one or more of the devices described above for a variable period of time, usually less than eight weeks. Physical therapy follow-up begins around the first week after surgery and consists of a typical progression from passive to resistive exercises for the shoulder. However, a review of the literature has not identified physical therapy evaluation or treatment aimed at possible balance deficits in this population.

Immobilization

As mentioned earlier, the literature described that immobilization of the shoulder follows surgical repair of a rotator cuff. The literature also shows that the shoulder is subject to several changes that result from immobilization. More specifically, immobilization alters the properties of the joint capsule and related periarticular components, as well as muscles involved with shoulder motion.

Akeson (1987) noted that with immobilization there is fibrofatty proliferation, intra-articular adhesions, as well as changes in tendons, ligaments, and joint capsule. This, in effect, causes ligamentous weakening and joint contractures. Videman (1987) furthers the description by stating that immobilization involves an "adaptation" of connective tissue that leads to shortening of capsular tissues. This produces increased tension in periarticular tissues. The effect of the immobilization on each capsular component may vary, since ligaments differ from each other biochemically and histologically as dictated by their specific function (Harwood & Amiel, 1992). This shrinking of joint tissue clinically presents in a reduction of joint ROM (Appell, 1990). Therefore, following removal of the rotator cuff immobilization device, the patient may have decreased shoulder ROM as compared to the pre-operative range capability.

Immobilization also affects the involved muscles. After review of the literature concerning muscular atrophy following immobilization, Appell (1990) concluded that muscle metabolism, function, and structure are all severely impaired following immobilization. Gioux and Petit (1993) stated that immobilization induces both muscle atrophy and impairments of muscle contraction. Muscle atrophy is accompanied by functional impairment of the involved joint (Appell, 1990). Gioux and Petit (1993) also mentioned that changes in atrophy depend on the duration of immobilization and on the length at which the muscle was fixed. Several animal experiments have shown that immobilization of muscles in a lengthened position delays the development of disuse atrophy or may even produce a transient hypertrophy (Appell, 1990; Williams & Goldspink, 1978). In addition, immobilization of skeletal muscle produces an increase in passive muscle stiffness, which has been attributed to quantitative changes in connective tissue (Williams & Goldspink, 1978). Immobilization has also been found to be associated with a decrease in maximum twitch and tetanic tension, as well as gross strength loss in skeletal muscles (Appell, 1990). The greatest changes in strength loss occur during the first days after immobilization, followed by a decrease in rate of loss as disuse continues (Appell, 1990).

In reviewing the literature concerning immobilization effects, attention is justified concerning the results of immobilizing the shoulder following rotator cuff repair. Most likely, the patient's shoulder ROM will be negatively affected during the immobilization period. Also, all muscles associated with the glenohumeral joint may atrophy, become passively stiff, lose strength output capacity, and be functionally impaired.

These above complications may have an effect on balance. First, the alteration in ROM may affect the patient's body scheme which has been shown to be involved with postural control. Second, the increased stiffness, decreased strength, and functional impairment of the latissimus dorsi muscle may affect hip strategies essential control.

Upper Extremity Immobilization and Balance

The nature of this study is to determine if there is any relationship between upper extremity immobilization post rotator cuff repair and balance in the elderly. In examining the literature, there have been no studies addressing this or similar topics. Because the elderly population have many factors which contribute to decreases in their balance and may face rotator cuff repair followed by immobilization, a study examining the relationship between these two variables is warranted. Upon reviewing the literature described above, several speculations can be drawn as to the nature of a relationship between upper extremity immobilization and balance.

First, the stepping or stumbling strategy used to maintain balance when hip or ankle strategies are inadequate may involve upper extremity motion. Decreases in upper extremity ROM and strength may render upper extremity involvement in this strategy insufficient. As mentioned previously, immobilization has been shown to affect ROM and strength. Therefore, immobilizing the upper extremity may negatively affect one's ability to maintain balance.

Second, as stated by Kendall, McCreary, and Provance (1993, pg. 279), the latissimus dorsi muscle has it's origins from the spinous processes of vertebrae T6 to T12, ribs 9 to 12, the lumbar and sacral vertebrae and the posterior third of the external lip of the iliac crest through the lumbar fascia, and a slip from the inferior angle of the scapula. This muscle then inserts on the intertubercular groove of the humerus. When the origin is fixed, this muscle medially rotates, extends, and adducts the glenohumeral joint. It also serves to depress the shoulder girdle and assist lateral flexion of the trunk. When its insertion is fixed, it functions to tilt the pelvis laterally and anteriorly. Bilateral action of this muscle aides in hyperextension of the spine and anterior tilting of the pelvis. Depending on its relation to axes of motion during activity, it may also aid in flexion of the spine. In view of this, alteration of this muscle may affect shoulder, trunk, and pelvic mechanics. Immobilization has been shown to alter structural and physiological properties of muscle causing decreases in strength and flexibility. Because the latissimus dorsi muscle acts on the shoulder and the pelvis, alterations in this muscle may directly affect hip and stepping strategies of balance.

Third, body scheme may be impaired following immobilization. While immobilized, the upper extremity may not receive it's usual amount of sensory input. This change in input can cause alterations in body scheme. As stated earlier, a main function of body scheme is to adjust the levels of muscle activity necessary to maintain a given posture as well as make necessary postural adaptations essential to counteract predictable disturbances. A change in body scheme may therefore affect one's ability to maintain postures necessary for adequate balance. Upper extremity immobilization, then, may cause changes in body scheme and may ultimately affect balance.

In conclusion, a review of the literature shows that there are many age associated changes involving the physiological components of balance which may contribute to the increased incidence of falls in the elderly. Since the elderly are already at a disadvantage in regards to balance, prevention of other factors leading to possible balance deficits is crucial. This study, therefore, is needed to investigate if upper extremity immobilization is a possible contributing factor of balance deficits in the elderly.

Null Hypothesis

1. Berg Balance Measure, Modified Berg Balance Measure, and Functional Reach scores will be statistically the same for the post-rotator cuff repair subjects and control subjects.

2. The application of a sling will not significantly alter measures of static sway, anterior lean, posterior lean, or lateral leans in either the post-rotator cuff repair subjects or normal subjects from measures taken without the sling.

3. There will be no significant difference in static sway, anterior lean, posterior lean, or lateral leans between post-rotator cuff repair subjects or control subjects.

Chapter Three
Methodology

Research Design

This research study is quasi-experimental post-test only in design. Functional and high technology balance measures were taken. The Berg Balance Measure, Modified Berg Balance Measure, and Functional Reach test were used to determine the functional balance of the subjects. Postural sway in standing, as well as performance of anterior lean, posterior lean, and lateral leans, were measured using force plates as a more sensitive tool to measure balance. There were two groups of subjects studied. The first group consisted of normal, healthy elderly; the second group consisted of healthy elderly who had recently undergone rotator cuff surgical repair. Group one provided normative data with which group two was compared. Both groups were a sample of convenience.

Subjects

Volunteer subjects for the normal, healthy group were recruited from area senior centers by way of written and verbal communication. Subjects were given brochures (Appendix A) or a brief verbal description by the researchers regarding the study. Interested individuals were scheduled for an appointment time for screening and data collection. Volunteers were instructed to bring a list of their medications and comfortable clothing, including shorts or a loose fitting skirt to this session. Volunteers were included in the study providing they were not excluded from the study according to the criteria described in Appendix B.

Subjects for the rotator cuff repair group were recruited from local Grand Rapids and Holland area physicians and physical therapists. Area physicians and physical therapists were contacted in regards to details of the study and brochures (Appendix A) were left at their facilities to distribute to prospective subjects. Interested individuals contacted the researchers and scheduled an appointment time for screening and data collection. Volunteers were included in the study if they had undergone surgical rotator cuff repair within the past twelve months and were subsequently immobilized for a period of three weeks or more. Volunteers were included in the study according to the criteria listed in Appendix B. The balance test scores of this subject group were then compared to the normative subjects.

Instrumentation

The following items were used in this study: AMTI force plates and accompanying software; a video camera; tape to mark and measure foot position on the force plates; a tape measure; the Berg Balance Measure; a stop watch; a stool; one chair with and one chair without armrests; a shoe; a yard stick; an eye screening chart; a goniometer; a gait belt and safety harness to ensure safety of subjects; and an arm sling. A standard goniometer was used to ensure adequate ROM in the shoulders, hips, knees and ankles.

The Berg/Modified Berg Balance Measure (Appendix C) and the Functional Reach Test were used to determine the functional balance of the subjects in each group. Force plates were used to measure subjects' static sway and maximal sway with static leans with and without a sling.

Procedure

Screening Procedure

Upon arriving at the site of data collection, the subjects were given the opportunity to ask questions regarding the study before completing a consent form (Appendix D). They then completed a medical history questionnaire (Appendix E) with the assistance of a physical therapist and were assigned a subject number to ensure anonymity. Provided they were not excluded from the study according to the exclusion criteria, they continued with the screening process. A licensed physical therapist was available on site to perform all screening tasks and supervise data collection. Screening results were recorded on a prepared form (Appendix F).

ROM measurements were taken using a goniometer for shoulder flexion, hip flexion/extension, knee flexion/extension, and ankle dorsiflexion according to the protocol (Appendix G). These measurements were of active ROM. Gross vision was assessed as a part of the vestibular screen. The vestibular screen included three tests: Range of Motion, Pursuit, and Vestibular-Ocular Reflex. See Appendix G for testing protocol. Proprioception of the distal lower extremity was measured according to the metatarsal phalangeal joint of the great toe. See Appendix G for testing procedure. Sensation of the lower extremity was screened according to the International Standards for Neurological and Functional Classification of Spinal Cord Injury, Revised 1992. Testing was done with a disposable safety pin for sharp/dull sensation and a cotton ball for light touch sensation. See Appendix G for testing procedure.

Provided subjects successfully met all screening criteria, they were included in the study. Subject height and weight were measured and recorded. Subject's blood pressure (left arm) and heart rate (radial pulse right arm) were also measured and recorded.

Berg Balance Measure

The examiner clearly and audibly read the instructions for the test to the subject. If needed, the subject was allowed to question the examiner or ask for demonstration to ensure that the subject understood what was being requested. The examiner scored the subject's performance as indicated by the Berg Balance Measure form. Instructions and scoring criteria are listed in Appendix C. Following the Berg, data was collected regarding one legged stance and tandem stance of the leg opposite of that tested by the Berg. This was considered the modified Berg Balance Measure.

Functional Reach Test

The Functional Reach test was also given to the subjects. They were instructed to reach with their dominant arm as far as they could three separate times as described by Duncan, et al. (1992). A yard stick was attached to the wall at the height of the subject's acromion process and values in centimeters were recorded by the examiner for each reach at the bottom of the Berg and Modified Berg Balance Measure.

Force Plates

Following the Berg Balance Measure, Modified Berg Balance Measure, Functional Reach Test, and a five minute break, the subject removed his/her shoes. The examiner gave a brief overview of the force plates and procedures that the subject would follow. The subject was allowed to ask questions at this time. See Appendix H for full procedure and details regarding force plate data collection.

The safety harness was then placed on the subject. The subject stood on the force plates with feet positioned at a comfortable stance width. Marker tape was applied to the force plates to mark this position. Right and left foot measurements were taken at this time and included: foot length, anterior/posterior base of support, maximum bilateral lateral proximal spacing, maximal bilateral lateral distal spacing, and angle of lateral foot to y-axis of force plate. The safety harness was then connected to the overhead cables. The video camera was turned on and the video of the experiment started. The video camera was in operation during all force plate data collection. The force plate data input was zeroed. The subject was instructed to stand relaxed with his/her arms comfortably at his/her side. The subject was instructed to look straight ahead and focus on the poster in front of him/her and instructed to keep his/her eyes focused on the poster during the experimental measurement periods. The experimenter then made sure subject and instrumentation were ready for data collection. Although subjects were instructed to perform each task for 20 seconds, only the middle 10 seconds of performance was recorded.

Static Sway:

When the data collection system and data officer were ready, the data collection period began. This marked time zero minutes. When the experimenter was informed by the data officer that data collection had begun, the experimenter instructed the subject to stand quietly for 20 seconds. The experimenter informed the subject when 20 seconds was over. Following a 30 second rest period this sequence of commands was repeated two more times.

Sway with Static Lean:

The subjects were then asked to lean anteriorly, posteriorly, to the left, and to the right as far as possible. The subject performed each lean in a predetermined random order a total of three times.

Anterior Lean: The subject was told what he/she would be doing and was reminded to bend at the ankles and not at the hip while leaning. After thirty seconds of rest, the experimenter instructed the data officer to begin data collection. Upon confirmation that data collection had begun, the experimenter instructed the subject to keep his/her eyes focused on the poster, lean forward as far as possible without taking a step keeping some part of each foot in contact with the force plate and within the marker tape at all times. The subject was instructed to hold this position until the end of the data collection period of 20 seconds.

Posterior Lean: The subject was told what he/she would be doing and was reminded to bend at the ankles and not at the hip while leaning. After thirty seconds of rest, the experimenter instructed the data officer to begin data collection. Upon confirmation that data collection had begun, the experimenter instructed the subject to keep his/her eyes focused on the poster, lean backward as far as possible without taking a step keeping some part of each foot in contact with the force plate and within the marker tape at all times. The subject was instructed to hold this position until the end of the data collection period of 20 seconds.

Lateral Lean Right: The subject was told what he/she would be doing and was reminded to bend at the ankles and not at the hip while leaning. After one minute of rest, the experimenter instructed the data officer to begin data collection. Upon confirmation that data collection had begun, the experimenter instructed the subject to keep his/her eyes focused on the poster, lean right as far as possible without taking a step keeping some part of each foot in contact with the force plate and within the marker tape at all times. The subject was instructed to hold this position until the end of the data collection period of 20 seconds.

Lateral Lean Left: The subject was told what he/she would be doing and reminded to bend at the ankles and not at the hip. After one minute of rest, the experimenter instructed the data officer to begin data collection. Upon confirmation that data collection had begun, the experimenter instructed the subject to keep his/her eyes focused on the poster, lean to the left as far as possible without taking a step keeping some part of each foot in contact with the force plate and within the marker tape at all times. The subject was instructed to hold this position until the end of the data collection period of 20 seconds.

Following the static leans, the safety harness was unhooked and removed. The subject was given a five minute break. During this break, the subject was instructed to sit and offered a complimentary beverage and snack.

Following the break, a shoulder sling was applied to each subjects' dominant arm. The sling was applied so that the shoulder was in adduction with the elbow at 90° flexion. The safety harness was then reconnected and the subject was told to stand on the force plates within the previously tape-marked boundaries. The subject was instructed in each task as previously stated. The testing procedure was repeated as previously described, beginning with the static sway task and finishing with the static leans (in a different random order).

Upon completing the tasks with the sling in position, the safety harness was disconnected and removed from the subject. The subject put his/her shoes and socks back on and was thanked for his/her participation in the study. After it was determined that the subject had fully recovered from the measurement process, he/she was allowed to leave.

Data Analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) for Windows version 6.1. A significance level of $p<0.05$ was chosen for this study. Groups were defined as either control or post-surgical rotator cuff repair subjects. Blocks were defined in all of the subjects, both control and post-surgical rotator cuff repair, as either a sling worn or not worn. Parametric and nonparametric tests were used in this study because non-normal distributions were present in some cases. Small sample sizes made it difficult to detect distributions in the group. Differences between post-surgical rotator cuff repair and control groups in performance on the Berg Balance Measure, Modified Berg Balance Measure, Functional Reach Test, and force plate tasks were analyzed by parametric and nonparametric tests. Differences between sling and no sling blocks on force plate performance were analyzed using parametric and non-parametric tests. Interaction between subject groups and subject blocks performance on force plates was analyzed with parametric and nonparametric tests. Tests were conducted separately secondary to the repeated measures design considerations of this study.

Chapter Four
Results

Subjects

Twenty-eight healthy elderly volunteer subjects participated in this study. The subjects were recruited from the greater Grand Rapids/Holland area. Nineteen subjects served as control group subjects and nine, who had recently undergone surgical rotator cuff repair, served as post-rotator cuff surgical repair subjects. All subjects met the inclusion criteria required for participation in the study.

Subjects were between the ages of 54 and 74, with a mean age of 64.8. Those subjects in the control group were between the ages of 61 and 74, with a mean age of 68.9. Subjects in the post-rotator cuff surgical repair group were between the ages of 53 and 71 with a mean age of 63.7. Seventeen males and ten females participated in this study.

Data Analysis

Data was analyzed using parametric and nonparametric tests. Parametric analysis included t-tests for independent samples and t-tests for paired samples. Nonparametric analysis included Mann-Whitney U (Wilcoxon Rank Sum W) Test for independent samples and Wilcoxon Matched-Pairs Signed-Ranks Test for paired samples. A significance level of <0.05 was chosen for this study.

Tables 1 and 2 illustrate subject performance on the Berg Balance Measure, Modified Berg Balance Measure, Average Functional Reach, and Best Functional Reach. Table 1 displays p-values from t-test for Independent Samples analyses, as well as group means, for differences between groups on each clinical measure of balance. The only statistically significant difference between group performance was on the Modified Berg Balance Measure, where the post-surgical rotator cuff repair group performed poorer than the control group ($p=0.019$). Table 2 displays Mann-Whitney U (Wilcoxon Rank Sum W) Test analysis, as well as group mean ranks, for differences between groups on each clinical measure of balance. With this analysis, the post-rotator cuff surgical repair group performed significantly poorer on both the Berg Balance Measure and the Modified Berg Balance Measure (p=0.0125 and p=0.0120 respectively).

Table 1

Group Effects--Parametric
t-tests for Independent Samples

	Berg Balance Measure	Modified Berg Balance Measure	Average Functional Reach Test (cm)	Best Functional Reach Test (cm)
Mean value for control group	55.4737	63.1579	36.4737	37.3684
Mean value for rotator cuff group	54.5714	61.4286	32.0000	33.5000
p-value	0.054	0.019	0.180	0.257

Table 2

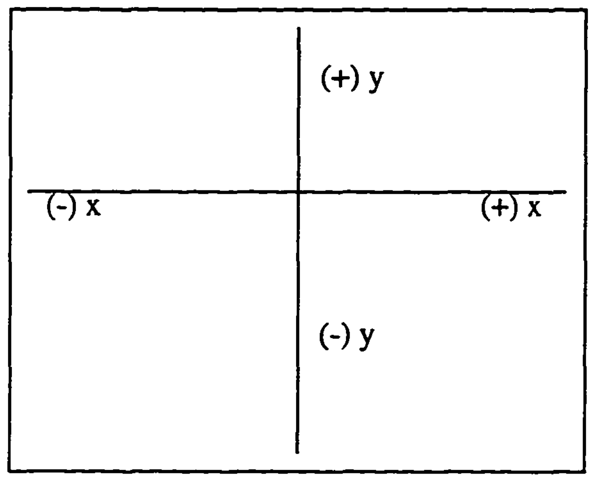
Group Effects--Non-Parametric
Mann-Whitney U - Wilcoxon Rank Sum W Test

	Berg Balance Measure	Modified Berg Balance Measure	Average Functional Reach Test	Best Functional Reach Test
Mean rank for control group	15.53	15.63	15.74	15.55
Mean rank for rotator cuff group	8.00	7.71	9.88	10.31
p-value	0.0125	0.0120	0.0791	0.1166

Tables 3 through 8 illustrate mean values and statistical analysis of subjects' performance on force plate tasks. Each table displays analysis of performance of subjects in the x- and y-directions for the task of postural sway. Performance in the y-direction was analyzed for anterior and posterior maximal leans, whereas performance in the x-direction was analyzed for lateral leans. Figure 1 defines positive and negative directions for the x and y axes. The coordinates (0,0) represent the subjects' original center of pressure. Each subject stood facing into the positive-y direction for each task.

Figure 1

Directions used in force plate analysis



Tables 3 through 8 show mean performance values over the three trials for each of the following defined variables. Mean x and mean y are defined as the mean position of the center of pressure over all trials in the x- and y-directions respectively. High x and high y are defined as the maximal location of the center of pressure achieved in all trials in the x- and y-direction respectively. Standard deviation in the x-direction and standard deviation in the y-direction are defined as the average statistical standard deviation of the location of the center of pressure over time in the x- and y- directions respectively.

The mean values listed in tables 3 through 8 were quantified in the following way. Y-values were defined as an excursion of center of pressure (COP) in the anterior-posterior direction. Anterior excursion was defined as positive y, whereas posterior excursion was defined as negative y. The y-values quantify the COP excursion as a percentage of each subject's footlength. X-values were defined as an excursion of COP in the lateral directions. Right lateral excursion was defined as positive x, whereas left lateral excursion was defined as negative x. The x-values quantify the COP excursion as a percentage of each subjects maximal stance width.

Table 3 illustrates a parametric analysis of the difference between control and post-rotator cuff surgical repair groups on force plate performance. T-tests for independent samples were performed to analyze the data. No significant difference was shown to exist between the two groups for any of the variables.

Table 3

Group Effects--Parametric t-tests for Independent Samples

	Postural Sway	Lateral Lean Right	Lateral Lean Left	Anterior Lean	Posterior Lean
Mean x	cg=0.1614 eg=-0.1204 p=0.366	cg=27.2316 eg=29.9852 p=0.317	cg=-27.5877 eg=-32.3167 p=0.070	Not Applicable	Not Applicable
Mean y	cg=0.4386 eg=0.9444 p=0.519	Not Applicable	Not Applicable	cg=24.8061 eg=26.5352 p=0.660	cg=-13.9430 eg=-16.3556 p=0.338
High x	cg=2.5447 eg=1.5278 p=0.085	cg=32.5509 eg=34.2630 p=0.504	cg=-33.1614 eg=-37.1241 p=0.121	Not Applicable	Not Applicable
High y	cg=5.1614 eg=4.2556 p=0.424	Not Applicable	Not Applicable	cg=31.6886 eg=32.3000 p=0.880	cg=-20.6482 eg=-22.5037 p=0.465
Std. Dev. in x-direction	cg=0.8982 eg=0.6019 p=0.066	cg=2.2719 eg=1.8000 p=0.067	cg=2.2982 eg=2.0519 p=0.467	Not Applicable	Not Applicable
Std. Dev. in y-direction	cg=1.9132 eg=1.5463 p=0.267	Not Applicable	Not Applicable	cg=2.9807 eg=2.5074 p=0.198	cg=2.7535 eg=2.6204 p=0.627

*Values are (cg=sample mean control group, eg=sample mean post-rotator cuff group, & p=p-value)

Table 4 shows a parametric analysis of the difference between sling and no-sling blocks on force plate performance. Since each subject received both sling and no-sling, t-tests for paired samples were performed to analyze the data. The only significant finding between the groups was found to be with the posterior lean task. The no-sling group performed better on the variables high y and mean y for the posterior lean (p=0.012, p=0.023).

Table 4

Block Effects--Parametric t-tests for Paired Samples

	Postural Sway	**Lateral Lean Right**	**Lateral Lean Left**	**Anterior Lean**	**Posterior Lean**
Mean x	s=0.1702 ns=-0.0286 p=0.440	s=27.8476 ns=28.3857 p=0.487	s=-29.4833 ns=-28.7321 p=0.256	Not Applicable	Not Applicable
Mean y	s=0.5024 ns=0.7000 p=0.619	Not Applicable	Not Applicable	s=26.4857 ns=24.2381 p=0.099	s=-13.8298 ns=-15.6071 p=0.023
High x	s=2.2690 ns=2.1667 p=0.776	s=32.8119 ns=33.3905 p=0.481	s=-34.4524 ns=-34.4179 p=0.957	Not Applicable	Not Applicable
High y	s=4.5667 ns=5.1738 p=0.313	Not Applicable	Not Applicable	s=32.8310 ns=30.9393 p=0.108	s=-20.1464 ns=-22.3429 p=0.012
Std. Dev. in x-direction	s=0.8012 ns=0.8048 p=0.971	s=2.0321 ns=2.2083 p=0.197	s=2.0476 ns=2.3905 p=0.081	Not Applicable	Not Applicable
Std. Dev. in y-direction	s=1.7548 ns=1.8357 p=0.638	Not Applicable	Not Applicable	s=2.8667 ns=2.7905 p=0.729	s=2.6167 ns=2.8048 p=0.136

*Values are (s=with sling, ns=without sling, & p=p-value)

Table 5 displays the results of a non-parametric analysis of the difference between control and post-rotator cuff surgical repair groups on force plate performance. Mann Whitney U (Wilcoxon Rank Sum W) Tests were used to analyze the data. No statistically significant differences were shown to exist between the two groups for any of the variables.

Table 5

Group Effects--Nonparametric
Mann-Whitney U - Wilcoxon Rank Sum W Test

	Postural Sway	Lateral Lean Right	Lateral Lean Left	Anterior Lean	Posterior Lean
Mean x	cg=15.58 eg=12.22 p=0.3131	cg=13.76 eg=16.06 p=0.4910	cg=16.26 eg=10.78 p=0.0994	Not Applicable	Not Applicable
Mean y	cg=13.82 eg=15.94 p=0.5224	Not Applicable	Not Applicable	cg=14.11 eg=15.33 p=0.7122	cg=15.42 eg=12.56 p=0.3893
Mean x	cg=15.58 eg=12.22 p=0.3131	cg=13.76 eg=16.06 p=0.4910	cg=16.26 eg=10.78 p=0.0994	Not Applicable	Not Applicable
Mean y	cg=13.82 eg=15.94 p=0.5224	Not Applicable	Not Applicable	cg=14.11 eg=15.33 p=0.7122	cg=15.42 eg=12.56 p=0.3893
High x	cg=15.63 eg=12.11 p=0.2904	cg=14.26 eg=15.00 p=0.8248	cg=16.26 eg=10.78 p=0.0994	Not Applicable	Not Applicable
High y	cg=14.74 eg=14.00 p=0.8248	Not Applicable	Not Applicable	cg=14.47 eg=14.56 p=0.9804	cg=14.95 eg=13.56 p=0.6759
Std. Dev. in x-direction	cg=15.21 eg=13.00 p=0.5064	cg=15.84 eg=11.67 p=0.2095	cg=15.05 eg=13.33 p=0.6054	Not Applicable	Not Applicable
Std. Dev. in y-direction	cg=15.58 eg=12.22 p=0.3129	Not Applicable	Not Applicable	cg=15.79 eg=11.78 p=0.2281	cg=14.82 eg=13.83 p=0.7678

*Values are (cg=sample mean control group, eg=sample mean post-rotator cuff group, & p=p-value)

Table 6 illustrates the results of a non-parametric analysis of the difference between sling and no-sling blocks on force plate performance. Wilcoxon matched-pairs signed-ranks tests were used to determine if differences existed. The results showed that the no-sling group performed better than the sling group in terms of the variables high y and mean y in the posterior direction (p=0.0179, p=0.0249). No other significant differences were found with this analysis.

Table 6

Block Effects--Nonparametric
Wilcoxon Matched-Pairs Signed-Ranks Test

	Postural Sway	Lateral Lean Right	Lateral Lean Left	Anterior Lean	Posterior Lean
Mean x	s=16.35 ns=12.90 p=0.8287	s=13.36 ns=15.64 p=0.7156	s=14.05 ns=14.79 p=0.2694	Not Applicable	Not Applicable
Mean y	s=14.50 ns=14.50 p=0.5090	Not Applicable	Not Applicable	s=15.19 ns=13.25 p=0.1084	s=15.07 ns=13.06 p=0.0249
High x	s=16.63 ns=11.90 p=0.8008	s=12.93 ns=16.31 p=0.8376	s=14.73 ns=14.23 p=0.6819	Not Applicable	Not Applicable
High y	s=11.60 ns=17.00 p=0.7186	Not Applicable	Not Applicable	s=14.78 ns=14.00 p=0.1514	s=17.06 ns=9.90 p=0.0179
Std. Dev. in x-direction	s=10.97 ns=19.42 p=0.2158	s=15.10 ns=13.35 p=0.3613	s=10.35 ns=15.47 p=0.0675	Not Applicable	Not Applicable
Std. Dev. in y-direction	s=15.29 ns=13.71 p=0.8022	Not Applicable	Not Applicable	s=17.35 ns=12.03 p=0.7096	s=12.86 ns=15.56 p=0.1614

*Values are (s=with sling, ns=without sling, & p=p-value)

The previous tables assumed no significant interactions. Tables 7 and 8 show the results of parametric t-tests for independent samples and Mann-Whitney U - Wilcoxon Rank Sum W Tests which evaluated possible interactions between the control/post-rotator cuff surgical repair groups and the sling/no-sling blocks. Neither group of statistical tests revealed any significant interactions between the groups and blocks.

Table 7

Group-Block Interaction--Parametric t-tests for Independent Samples

	Postural Sway	Lateral Lean Right	Lateral Lean Left	Anterior Lean	Posterior Lean
Mean x	cg=0.3965 eg=-0.2185 p=0.265	cg=-1.1053 eg=0.6593 p=0.289	cg=-1.1123 eg=0.0111 p=0.321	Not Applicable	Not Applicable
Mean y	cg=-0.4105 eg=0.2519 p=0.441	Not Applicable	Not Applicable	cg=1.9246 eg=2.9296 p=0.728	cg=1.8193 eg=1.6889 p=0.936
High x	cg=0.0965 eg=0.1148 p=0.981	cg=-1.2982 eg=0.9407 p=0.202	cg=-0.2105 eg=0.3370 p=0.696	Not Applicable	Not Applicable
High y	cg=-1.0281 eg=0.2815 p=0.309	Not Applicable	Not Applicable	cg=1.4228 eg=2.8815 p=0.559	cg=2.2298 eg=2.1259 p=0.954
Std. Dev. in x-direction	cg=-0.0211 eg=0.0333 p=0.801	cg=-0.2491 eg=-0.0222 p=0.437	cg=-0.4632 eg=-0.0889 p=0.366	Not Applicable	Not Applicable
Std. Dev. in y-direction	cg=-0.1526 eg=0.0704 p=0.550	Not Applicable	Not Applicable	cg=0.1018 eg=0.0222 p=0.868	cg=-0.2298 eg=-0.1000 p=0.548

*Values are (cg=sample mean control group, eg=sample mean post-rotator cuff surgical repair group, & p=p-value)

Table 8

Group-Block Interaction--Nonparametric
Mann-Whitney U - Wilcoxon Rank Sum W Test

	Postural Sway	Lateral Lean Right	Lateral Lean Left	Anterior Lean	Posterior Lean
Mean x	cg=15.55 eg=12.28 p=0.3251	cg=13.53 eg=16.56 p=0.3627	cg=13.68 eg=16.22 p=0.4458	Not Applicable	Not Applicable
Mean y	cg=13.47 eg=16.67 p=0.3374	Not Applicable	Not Applicable	cg=13.21 eg=17.22 p=0.2281	cg=14.47 eg=14.56 p=0.9804
High x	cg=15.16 eg=13.11 p=0.5385	cg=13.39 eg=16.83 p=0.3015	cg=14.55 eg=14.39 p=0.9608	Not Applicable	Not Applicable
High y	cg=13.68 eg=16.22 p=0.4458	Not Applicable	Not Applicable	cg=13.34 eg=16.94 p=0.2791	cg=14.53 eg=14.44 p=0.9804
Std. Dev. in x-direction	cg=14.53 eg=14.44 p=0.9803	cg=13.89 eg=15.78 p=0.5712	cg=13.71 eg=16.17 p=0.4602	Not Applicable	Not Applicable
Std. Dev. in y-direction	cg=14.45 eg=14.61 p=0.9607	Not Applicable	Not Applicable	cg=14.18 eg=15.17 p=0.7677	cg=14.26 eg=15.00 p=0.8247

*Values are (cg=sample mean control group, eg=sample mean post-rotator cuff surgical repair group, & p=p-value)

Chapter Five
Discussion and Implications

Results Within Theoretical Framework.

Parametric and nonparametric analyses were used because normal distributions could not be determined from the small sample sizes of this study. The first null hypothesis stated that "The Berg Balance Measure, Modified Berg Balance Measure, and Functional Reach scores will be statistically the same for the post-rotator cuff repair subjects and normal subjects." This appeared true when data was analyzed parametrically using t-tests for independent samples for the Berg Balance Measure and Average and Best Functional Reach Tests. However, the Modified Berg Balance Measure demonstrated that the scores for the post-rotator cuff repair group were significantly less (p=0.019) than the control group when the data was analyzed using this same test. Non-parametric analyses demonstrated that the post-rotator cuff repair group scored significantly less on both the Berg Balance Measure (p=0.0125) and Modified Berg Balance Measure (p=0.0120) using the Mann-Whitney U (Wilcoxon Rank Sum W) Test rejecting this null hypothesis at a 95 percent confidence level. The null hypothesis was not rejected for the Functional Reach test when analyzed by this nonparametric measure.

The second null hypothesis stated that "The application of a sling will not significantly alter measures of static sway, anterior lean, posterior lean, or lateral leans in neither the post-rotator cuff repair subjects or normal subjects from measures taken without the sling." This hypothesis was not rejected as analyzed parametrically and nonparametrically for the anterior and lateral leans. Parametric and nonparametric analysis demonstrated this hypothesis to be false for the mean and high-y measurements of posterior leans. The mean and highest posterior lean were significantly greater for the non-sling block compared to the sling block.

The third null hypothesis stated that "There will be no significant difference in static sway, anterior lean, posterior lean, or lateral leans between post-rotator cuff repair subjects or normal subjects." This hypothesis appeared to be true regardless of whether the data was analyzed parametrically or nonparametrically.

Review of Findings.

Since there was not a significant difference in the static sway, anterior lean, posterior lean, or lateral leans between subjects without a sling, it is reasonable to suggest that sling immobilization has no long-term effects on balance in individuals who have been immobilized for a period of at least three weeks. The application of a sling, however, to both the control and experimental groups did display a significant difference in these subjects' ability to lean posteriorly. This suggests that the application of a sling may limit the cone of stability for an individual. A limitation in these subjects cone of stability could cause a decrease in their ability without stepping to recover from perturbations of balance.

The Berg Balance Measure and Modified Berg Balance Measure demonstrated significant differences of balance between the control and experimental groups. Since the two main differences between these testing measures were that the Modified Berg Balance Measure required subjects to perform tandem and one-legged stance tasks bilaterally whereas the Berg Balance Measure only tests subjects unilaterally on these tasks, one might suggest that these tasks are useful as quick screens of balance for patients who have undergone immobilization. Again, the results of the clinical portion of this study indicate that subtle differences of balance between those who have and have not undergone immobilization following rotator cuff repair might exist since the post-rotator cuff repair group scored lower on both tests.

Results Compared to Literature.

Because research has not been previously done regarding upper extremity immobilization and balance, other studies are not available to which this study can be compared. Literature does describe the Functional Reach Test as a reliable, clinically accessible balance evaluation tool for frail elderly and has been proven to have criterion and concurrent validity (Weiner, et al., 1992). It is possible that because the subject group in this study was considered to be healthy, the Functional Reach Test was not a sensitive enough tool to pick up balance deficits in this group. Also, the sample size may not have been large enough to demonstrate a difference between the two groups. The Berg Balance Measure, however, is more comprehensive in its testing. This balance measure examines the subject's performance on 14 items commonly used in daily life which require them to maintain their balance while assuming various postures and changing their position within their base of support. Inter-rater reliability, intra-rater reliability, and the Cronbach's alpha of this balance measure is quite high measuring .98, .99, and .96 respectively. The Berg Balance Measure, along with it's modified version, appeared to be a significant measure of possible high-level balance deficits in this study.

Overstall, et al. (1977) found that postural sway was significantly increased in people who fell due to a loss of balance. Numerous other authors state that postural sway, as measured by the Wright Ataxiameter and force plates, serve as a useful measure of balance in predicting falls (Brocklehurst, et al., 1982; Overstall, et al., 1977; Maki, Holliday, & Topper, 1994). Although these studies support postural sway as a useful measure of balance, this measure did not indicate a significant difference of balance between the experimental and control groups. This implies one of three things. First, even though the Berg Balance Measure results indicated some deficits of balance, actual balance deficits may not have existed. Second, postural sway, in this case, may not be a good measure of balance. Finally, clinical measures of balance and force plate analysis might evaluate different aspects of balance. This final possibility may not be a strong one since Berg, et al. (1992) found that performance on the Berg Balance Measure was moderately correlated with force plate analysis for both amplitude and speed of postural sway.

Hamman, et al. (1992) described postural stability in terms of a limits of stability cone. This study used maximal leans as a measure of subjects' limits of stability. In the present study, anterior and lateral leans did not demonstrate differences between the groups or blocks. Differences did exist between the block in the posterior lean task, which demonstrates that a relationship may exist between sling immobilization and balance. This would support the use of limits of stability in a posterior direction as an indicator of postural stability as described by Hamman, et al. (1992).

Limitations of the Study.

Several limitations exist in this study. First, the evaluator who performed the screening procedure and clinical measures of balance was not blind to which subjects were in the control group and which subjects were in the experimental group. This may have biased the evaluator in determining the scores of the Functional Reach Test and Berg/Modified Berg Balance Measures although strict instructions were given to quantify scores with these tests. Along with this, the evaluator mistakenly did not collect data regarding the clinical measures of balance on two of the post-rotator cuff repair subjects. This decreased the sample size for the clinical measures of balance.

Limitations regarding the sample size and characteristics must also be noted. The size of the post-surgical rotator cuff repair group (n=9 for technologically based balance measures, n=7 for clinical balance measures) was small compared to the size of the control group (n=19). Neither group was randomized, but instead was a sample of convenience. The age span was large within the control and experimental groups ranging from 53 to 74. Because vision, proprioception, vestibular function, and strength have all been shown to decline with age, this large age range might lead one to believe that the subjects who are older in age already had greater balance deficits than those who were younger. Significant results, then, may not be related to sling immobilization, but instead to the declines of the components of balance. Also, within these subject groups, medications and activity level were not controlled. Both of these factors may have influenced balance.

Another limitation is that force plate balance analysis was relatively static in nature. Dynamic activities, such as bending down to pick up an object, would have been a much more functional measure to determine how deficits of balance affected daily activities. This study did attempt to address more functional aspects of balance via the Functional Reach test, Berg Balance Measure, and Modified Berg Balance Measure, and the Modified Berg Balance Measure, which demonstrated significant differences between the control and post-surgical rotator cuff groups. The Modified Berg Balance Measure, however, has not been proven valid or reliable. Evaluation of this balance measure could be an area of future study.

Statistically, the study would have been better in design if subjects in the control group had been randomly placed into two separate groups--one of which would perform all balance measures with a sling and the other would perform all balance measures without a sling. The experimental group would be structured in the same way. With a design such as this, statistical measures could have been performed comparing groups with and without a sling instead of comparing blocks separately from groups.

Strengths of the Study.

This study also has many strengths. Foremost, minimal research has been done regarding upper extremity immobilization and balance. Also, this study used both clinical and technologically based measures to evaluate balance. A study by Thapa, Gideon, Fought, Kormicki, and Ray (1994) also sought to correlate technologically based and clinically based balance measures. These researchers found no correlation between these two groups of balance measures with nursing home residents. Despite the study by Thapa, et al. (1994), other researchers should be encouraged to add clinical balance measures to their studies, along with force plate analysis and other technologically based balance measures, to create more clinically applicable information for the use of therapists.

Although the sample size for the experimental group was small, the control group was quite large. Both groups were considered to be healthy according to the extensive screening procedure in this study. Because falls are a major problem in the elderly population, any study which may determine unknown factors causing falls is important.

This study looked at an area minimally researched before and has displayed some evidence that immobilization, even if short-term, may be related to balance.

Conclusions.

This study displayed that subjects who had undergone rotator cuff repair and subsequent immobilization scored significantly lower on the Berg Balance Measure and Modified Berg Balance Measure. This study also displayed that both the control and experimental groups leaned farther posteriorly with a sling placed on their dominant upper extremity. This could imply a decrease in their cone of stability with an immobilization device in place.

Although this study had limitations, it was very important in addressing an area not investigated before in the literature. Further studies are justified to explore the influence that the upper extremity has on balance. The statistical design described above in which two control groups--one with and one without a sling--and two post-rotator cuff surgical repair groups designed the same would be a definite improvement on this study. Likewise, a larger experimental group would be helpful. A narrower span of ages would also make following studies more valid.

References

Akeson, W. H., Amiel, D., Abel, M. F., Garfin, S. R., Woo, S. L. (1987). Effects of immobilization on joints. Clinical Orthopaedics and Related Research, 219, 28-37.

American Spinal Injury Association. (1992). International standards of neurological and functional classification of spinal cord injury (4th ed.) [Brochure]. Chicago, IL.

Anacker, S. L., & DiFabio, R. P. (1992). Influence of sensory inputs on standing balance in community-dwelling elders with a recent history of falling. Physical Therapy, 72, 575-581.

Appell, H. (1990). Muscular atrophy following immobilization: A review. Sports Medicine, 10, 42-58.

Baker, C. L., & Liu, S. H. (1995). Comparison of open and arthroscopically assisted rotator cuff repairs. The American Journal of Sports Medicine, 23, 99-104.

Barangan, J. D. (1990). Factors that influence recovery from hip fracture during hospitalization. Orthopaedic Nursing, 9, 19-29.

Bateman, J. E. (1963). The diagnosis and treatment of ruptures of the rotator cuff. Surgical Clinics of North America, 43, 1523-1530.

Berg, K. O., Maki, B. E., Williams, J. I., Holliday, P. J., & Wood-Dauphinee, S. L. (1992). Clinical and laboratory measures of postural balance in an elderly population. Archives of Physical Medicine and Rehabilitation, 73, 1073-1080.

Berg, K., Wood-Dauphinée, S., Williams, J. I., & Gayton, D. (1989). Measuring balance in the elderly: Preliminary development of an instrument. Physiotherapy Canada, 41, 304-311.

Bergstrom, G., Aniansson, A., Bjelle, A, Grimby, G., Lundgren-Lindquist, B., & Svanborg, A. (1985). Functional consequences of joint impairment at age 79. Scandinavian Journal of Rehabilitative Medicine, 17, 183-190.

Brocklehurst, J. C., Robertson, D., & James-Groom, P. (1982). Clinical correlates of sway: Sensory modalities. Age and Ageing, 11, 1-10.

Campbell, A. J., Reinken, J., Allan, B. C., & Martinez, G. S. (1981). Falls in old age: A study of frequency and related clinical factors. Age and Ageing, 10, 264-270.

Cassel, C. K., Cohen, H. J., Larson, E. B., Meier, D. E., Resnick, N. M., Rubenstein, L. Z., & Sorenson, L. B. (1997). Geriatric medicine. New York: Springer-Verlag.

Chandler, J. M., Duncan, P. W., & Studenski, S. A. (1990). Balance performance on the postural stress test: Comparison of young adults, healthy elderly, and fallers. Physical Therapy, 70, 410-415.

Cohen, H. (1994). Vestibular rehabilitation improves daily life function. The American Journal of Occupational Therapy, 48, 919-925.

Commodore, D. I. (1995). Falls in the elderly population: A look at incidence, risks, healthcare costs, and preventative strategies. Rehabilitation Nursing, 20, 84-89.

Craig, E. V. (1994). The shoulder and arm. In S. L. Weinstein, & J. A. Buckwalter (Eds.), Turek's orthopedics: Principles and their application (5th ed.) (pp. 359-399). Philadelphia: J. B. Lippincott Company.

Crutchfield, C. A. & Barnes, M. R. (1993). Motor control and motor learning in rehabilitation. Atlanta: Stokesville Publishing Co.

Cutson, T. M. (1994). Falls in the elderly. American Family Physician, 49, 149-156.

Dornan, J., Fernie, G. R., & Holliday, P. J. (1978). Visual input: Its importance in the control of postural sway. Archives of Physical and Medical Rehabilitation, 59, 586-591.

Duncan, P. W., Chandler, J., Studenski, S., Hughes, M., & Prescott, B. (1993). How do physiological components of balance affect mobility in elderly men?. Archives of Physical and Medical Rehabilitation, 74, 1343-1349.

Duncan P. W., Studenski S., Chandler J., & Prescott B. (1992). Functional reach: predictive validity in a sample of elderly male veterans. Journal of Gerontology, 47, M93-98.

Duncan P.W., Weiner D. K., Chandler J., & Studenski S. (1990). Functional reach: a new clinical measure of balance. Journal of Gerontology, 45, M192-7.

Era, P., & Heikkinen, E. (1985). Postural sway during standing and unexpected disturbance of balance in random samples of men of different ages. Journal of Gerontology,40, 287-295.

Fernie, G. R., Gryfe, C. I., Holliday, P. J., & Llewellyn, A. (1982). The relationship of postural sway in standing to the incidence of falls in geriatric subjects. Age and Ageing, 11, 11-16.

Gehlsen, G. M., & Whaley, M. H. (1990). Falls in the elderly: Part II, balance, strength, and flexibility. Archives of Physical and Medical Rehabilitation, 71, 739-741.

Gioux, M. & Petit, J. (1993). Effects of immobilizing the cat peroneus longus muscle on the activity of its own spindles. Journal of Applied Physiology, 75, 2629-2635.

Gore, D. R., Murray, M. P., Sepic, S. B., & Gardner, G. M. (1986). Shoulder-muscle strength and range of motion following surgical repair of full-thickness rotator-cuff tears. The Journal of Bone and Joint Surgery, 64-A, 266-272.

Grob, W. (1983). Clinical aspects of aging. (2nd ed.). Baltimore: Williams & Williams.

Gurfinkel, V. S., Levik, Y. S., Popov, K. E., Smetanin, B. N., & Shlikov, V. U. (1988). Body scheme in the control of postural activity. Stance and motion: Facts and concepts. New York: Plenum Press.

Hamman, R. G., Mekajavic, I., Mallinson, A. I., & Longridge, N. S. (1992). Training effects during repeated therapy sessions of balance training using visual feedback. Archives of Physical Medicine and Rehabilitation, 73, 738-744.

Harwood, F. L., & Amiel, D. (1992). Differential metabolic responses of periarticular ligaments and tendon to joint immobilization. Journal of Applied Physiology, 72, 1687-1691.

Hawkins, R. J., Misamore, G. W., & Hobeika, P. E. (1985). Surgery for full-thickness rotator-cuff tears. The Journal of Bone and Joint Surgery, 67-A, 1349-1355.

Horak, F. B., Nashner, L. M. (1986). Central programming of postural movements: Adaption to altered support surface configurations. Journal of Neurophysiology, 55, 1369-1381.

Horak, F. B., Nashner, L. M., & Diener, H. C. (1990). Postural strategies associated with somatosensory and vestibular loss. Experimental Brain Research, 82, 167-177.

Iverson, B. D., Gossman, M. R., Shaddeau, S. A., & Turner, M. E., Jr. (1990). Balance performance, force production, and activity levels in noninstitutionalized men 60 to 90 years of age. Physical Therapy, 70, 348-355.

Kendall, F. P., McCreary, E. K., & Provance, P.G. (1993). Muscle testing and function (4th ed.). Baltimore, Williams & Wilkins.

Lamy, P. P. (1980). Prescribing for the elderly. Littleton: PSG Publishing Company, Inc.

Lamb, K., Miller, J., & Hernandez, M. (1987). Falls in the elderly: Causes and prevention. Orthopaedic Nursing, 6, 45-49.

Lee, W. A. & Deming, L. R. (1988). Age-related changes in the size of the effective support base during standing. Physical Therapy, 68, 859.

Lewis, C. B. (1996). Aging: The health care challenge (3rd ed.). Philadelphia: F. A. Davis Co.

Lord, S. R., Clark, R. D., & Webster, I. W. (1991). Postural stability and associated physiological factors in a population of aged persons. Journal of Gerontology, 46, M69-M76.

Lord, S. R., Clark, R. D., & Webster, I. W. (1991). Visual acuity and contrast sensitivity in relation to falls in an elderly population. Age and Ageing, 20, 175-181.

Maki, B. E., Holliday, P. J., & Topper, A. K. (1994). A prospective study of postural balance and risk of falling in an ambulatory and independent elderly population. Journal of Gerontology, 49, M72-M84.

Manchester, D., Woollacott, M. H., Zederbauer-Hylton, N., & Marin, O. (1989). Visual, vestibular and somatosensory contributions to balance control in the older adult. Journal of Gerontology, 44, 118-127.

Moore, K. L. (1992). Clinically oriented anatomy (3rd ed.). Baltimore: Williams & Wilkins.

Murray, M. P., Seireg, A. A., & Sepic, S. B. (1975). Normal postural stability and steadiness: Quantitative assessment. Journal of Bone and Joint Surgery, 57A, 510-6.

National Safety Council (1995). Accident Facts. Itasca, IL: National Safety Council.

Norkin, C. C. & Levangie, P. K. (1992). Joint structure and function: A comprehensive analysis (2nd ed.). Philadelphia: F. A. Davis Co.

O'Sullivan, S. B. & Schmitz, T. J. (1994). Physical rehabilitation assessement and treatment (3rd ed.). Philadelphia: F. A. Davis Co.

Overstall, P. W., Exton-Smith, A. N., Imms, F.J., & Johnson, A. L. (1977). Falls in the elderly related to postural imbalance. British Medical Journal, 1, 261-264.

Paulos, L. E., & Kody, M. H. (1994). Arthroscopically enhanced "miniapproach" to rotator cuff repair. The American Journal of Sports Medicine, 22, 19-25.

Perlin, E. (1992). Preventing falls in the elderly: A practical approach to a common problem. Postgraduate Medicine, 91, 237-244.

Poole, J. L. (1991). Age related changes in sensory system dynamics related to balance. Physical & Occupational Therapy in Geriatrics, 10, 55-66.

Post, M. (1990). Complications of rotator cuff surgery. Clinical Orthopaedics and Related Research, 254, 97-104.

Post, M., Silver, R., & Singh, M. (1983). Rotator cuff tear: Diagnosis and treatment. Clinical Orthopaedics and Related Research, 173, 78-91.

Ring, C., Matthews R., Nayak U. S. L., Isaacs, B. (1988). Visual push: A sensitive measure of dynamic balance in man. Archives of Physical and Mediacal Rehabilitation, 69, 256-260.

Ring, C., Nayak, U. S. L., Isaacs, B. (1988). Balance function in elderly people who have and who have not fallen. Archives of Physical and Medical Rehabilitation, 69, 261-264.

Ring, C., Nayak, U. S. L., & Isaacs, B. (1989). The effect of visual deprivation and proprioceptive change on postural sway in healthy adults. Journal of the American Geriatrics Society, 37, 745-749.

Rosenhall, U. (1973). Degenerative changes in the aging human vestibular geriatric neuroepithelia. Acta Otolaryngologia, 76, 208-20.

Rosenhall, U. & Rubin, W. (1975). Degenerative changes in the human vestibular sensory epithelia. Acta Otolaryngologia, 79, 67-80.

Rowe, J. W., & Besdine, R. W. (1982). Health and disease in old age. Boston: Little, Brown and Company.

Scully, R. M., & Barnes, M. R. (1989). Physical therapy. Philadelphia: J. B. Lippincott Company.

Shumway-Cook, A., & Woollacott, M. H. (1995). Motor control: Theory and practical applications. Baltimore: Williams & Wilkins.

Simon, E. R., & Hill, J. A. (1989). Rotator cuff injuries: An update. The Journal of Orthopaedic and Sports Physical Therapy, 10, 394-398.

Snyder, S. J., & Kapp, K. (1992). Arthroscopic evaluation and treatment of rotator cuff pathology. AORN Journal, 56, 225-241.

Stelmach, G. E., & Worringham, C. J. (1985). Sensorimotor deficits related to postural stability: Implications for falling in the elderly. Clinics in Geriatric Medicine, 1, 679-694.

Studenski, S., Duncan, P.W., & Chandler, J. (1991). Postural responses and effector factors in persons with unexplained falls: Results and methodologic issues. Journal of the American Geriatrics Society,39, 229-234.

Thapa, P. B., Gideon, P., Fought, R. L., Kormicki, M., & Ray, W. A. (1994). Compaison of clinical and biomechanical measures of balance and mobility in elderly nursing home residents. Journal of the American Geriatrics Society, 42, 493-500.

Urton, M. M. (1991). A community home inspection approach to preventing falls among the elderly. Public Health Reports, 106, 192-195.

U. S. Bureau of the Census. (1995). Statistical abstract of the United States: 1995 (115th ed.). Washington, D. C.

Videman, T. (1987). Connective tissue and immobilization: Key factors in musculoskeletal degeneration?. Clinical Orthopaedics and Related Research, 221, 26-32.

Watson, M. (1985). Major ruptures of the rotator cuff: The results of surgical repair in 89 patients. The Journal of Bone and Joint Surgery, 67-B, 618-624.

Weiner D. K., Bongiorni D. R., Studenski S. A., Duncan P. W., & Kochersberger G. G. (1993). Does functional reach improve with rehabilitation? Archives of Physical Medicine and Rehabilitation, 74, 796-800.

Weiner D., Duncan P.W., Chandler J., & Studenski, S.A. (1991). Functional reach: A marker of physical frailty. Journal of the American Geriatrics Society, 40, 203-207.

Whipple, R. H., Wolfson, L. I., & Amerman, P. M. (1987) The relationship of knee and ankle weakness to falls in nursing home residents. Journal of the American Geriatric Society, 35, 13-20.

Williams, P. E., & Goldspink, G. (1978). Changes in sarcomere length and physiological properties in immobilized muscle. Journal of Anatomy, 127, 459-468.

Wittert, D. D. (1986). Rotator cuff tears. Orthopaedic Nursing, 5, 17-25.

Wolfson L. I., Whipple P. T., Amerman P., & Kleinberg A. (1986). Stressing the postural response: A quantitative method for testing balance. Journal of the American Geriatrics Society, 34, 845-850.

Woollacott, M. H. & Shumway-Cook, A. (1990). Changes in posture control across the lifespan--A systems approach. Physical Therapy, 70, 799-807.

Woollacott, M. H., Shumway-Cook, A., & Nashner, L. (1982). Postural reflexes and aging. In J. A. Mortimer (Ed.), The aging motor system (pp. 98-119). New York: Praeger.

Yost, J. G., & Schmoll, D. W. (1993). Shoulder disorders: An orthopedic perspective. In C. B. Lewis & K. A. Knortz, Orthopedic assessment and treatment of the geriatric patient (pp. 101-111) St. Louis, MO: Mosby-Year Book, Inc.

Appendix A

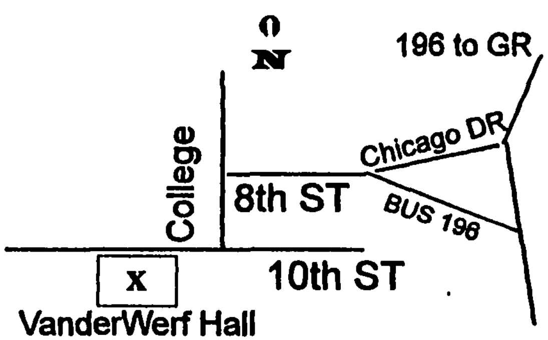
See brochure on following page.

Where:

Hope College Biomechanics Research Laboratory; Holland, Michigan

Directions to Research Lab at Hope College from Grand Rapids:

- Take 196 to: Chicago DR West or Business 196.
- Chicago Drive and Business 196 will merge into one road and will lead into 8th ST.
- 8th ST will lead into downtown Holland. Continue on 8th ST until College ST.
- Turn LEFT (go south) on College. Go 2 blocks until 10th ST
- At 10th ST, turn RIGHT (go west). VanderWerf Hall will be on your left.
- Parking is available in front of the building.
- Enter far west door (at loading dock) and follow signs from that point.



Researchers:

Carl Luchies, PhD: Director of Hope College Biomechanics Research Laboratory

Jolene Bennett, MA, PT, OCS, ATC: Research Coordinator/ Clinical Specialist Butterworth Physical Therapy, Faculty Grand Valley State University Department of Physical Therapy

Becky Schneider/Ed Gagne: Graduate students Grand Valley State University Program of Physical Therapy

Carol Polockko/Sarah Caril/Matt DeBoer/Joe Zupanic: undergraduate engineer students in summer research program.

We Need YOU for Balance Research

Hope College
Biomechanics Research Lab

Grand Valley State University
Department of Physical Therapy

We need you for balance research!

What:

Research study investigating the effects that upper extremity injury has on balance.

Why:

According to the National Safety Council, falls are the leading cause of death in those individuals over 65 years of age. Though a majority of falls in the elderly do not result in serious injury, medical attention is often needed for fall related injuries. Your participation in this study will help expand what we know about balance thus providing information to be used to prevent falls.

Who:

Two different groups of participants are needed for this research:

❶ Healthy adults age 60-74
❷ Healthy adults age 60-74 who have recently undergone rotator cuff surgery.

What:

What qualifies me for the study?

❶ Age 60-74.
❷ Live independently.
❸ Walk without assistance of canes, crutches, etc.
❹ No medical history of neurological or balance disorders such as Parkinson's, MS or Meniere's disease.
❺ No hip or knee total joint replacements.

What:

What to bring/wear:

❶ List of medications
❷ Comfortable clothes including shorts or loose fitting skirt.

When:

Testing times are set at your convenience during the month of July.

What:

What are the benefits to participants?

❶ Free evaluation of your current balance status.
❷ Help the medical community to increase knowledge about balance.
❸ Research participants will be paid $8.00/hr. including travel time.

Contact Person: Jolene Bennett at 616/243-8053. M-F 8 am - 5 pm

Appendix B

Subjects will be excluded from this study if they:

1. are not between the ages of 50 and 75 years
2. do not ambulate independently without an assistive device
3. do not live independently

Subjects will not be included in this study if they have a history of:

1. Parkinson's Disease
2. Cerebral Vascular Accident
3. Multiple Sclerosis
4. other neuromuscular disease
5. Total Hip or Knee Replacement
6. Rheumatoid Arthritis
7. other orthopedic disorder
8. Post-Polio Syndrome
9. head injury or concussion
10. Alzheimer's Disease
11. difficulty with memory
12. neuropathy in lower extremity
13. Spinal Cord Injury
14. nerve root impingement
15. amputation
16. Meniere's Disease
17. acoustic neuroma
18. acute or chronic Otitis Media
19. taking ototoxic drugs
20. abnormal balance or coordination
21. experienced vertigo or syncope
22. had lower extremity surgery in the past two years
23. vestibular dysfunction

Subjects will not be included in this study if they do not have:

1. neutral ankle dorsiflexion
2. hip flexion to 90 degrees
3. hip extension to 0 degrees
4. knee flexion to 90 degrees
5. knee extension to 0 to -5 degrees
6. shoulder flexion to 90 degrees
7. adequate vision as tested by the vestibular screen with or without corrective lenses
8. intact proprioception
9. intact sharp/dull and light touch sensation
10. manual muscle strength testing score of three or greater

Appendix C

Berg Balance Measure

PARTICIPANT #: ____

1. SITTING TO STANDING
INSTRUCTIONS: **Please stand up. Try not to use your hands for support.**
( )4 able to stand without using hands and stabilize independently
( )3 able to stand independently using hands
( )2 able to stand using hands after several tries
( )1 needs minimal aid to stand or to stabilize
( )0 needs moderate or maximal assist to stand

2. STANDING UNSUPPORTED
INSTRUCTIONS: **Please stand for two minutes without holding.**
( )4 able to stand safely 2 minutes
( )3 able to stand 2 minutes with supervision
( )2 able to stand 30 seconds unsupported
( )1 needs several tries to stand 30 seconds unsupported
( )0 unable to stand 30 seconds unassisted

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

3. SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: **Please sit with arms folded for 2 minutes.**
( )4 able to sit safely and securely 2 minutes
( )3 able to sit 2 minutes under supervision
( )2 able to sit 30 seconds
( )1 able to sit 10 seconds

4. STANDING TO SITTING
INSTRUCTIONS: **Please sit down.**
( )4 sits safely with minimal use of hands
( )3 controls descent by using hands
( )2 uses back of legs against chair to control descent
( )1 sits independently but has uncontrolled descent
( )0 needs assistance to sit

5. TRANSFERS
INSTRUCTIONS: **Arrange chair(s) for a pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.**
( )4 able to transfer safely with minor use of hands
( )3 able to transfer safely with definite need of hands
( )2 able to transfer with verbal cueing and/or supervision
( )1 needs one person to assist
( )0 needs two people to assist or supervise to be safe

6. STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: **Please close your eyes and stand still for 10 seconds.**
( )4 able to stand 10 seconds safely
( )3 able to stand 10 seconds with supervision
( )2 able to stand 3 seconds
( )1 unable to keep eyes closed 3 seconds but stands safely
( )0 needs help to keep from falling

7. STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: **Place your feet together and stand without holding.**
( )4 able to place feet together independently and stand 1 minute safely
( )3 able to place feet together independently and stand for 1 minute with supervision
( )2 able to place feet together independently but unable to hold for 30 seconds
( )1 needs help to attain position but able to stand 15 seconds feet together
( )0 needs help to attain position and unable to hold for 15 seconds

8. REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: **Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the finger reaches while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)**
( )4 can reach forward confidently 25 cm (10 inches)
( )3 can reach forward 12 cm safely (5 inches)
( )2 can reach forward 5 cm safely (2 inches)
( )1 reaches forward but needs supervision
( )0 loses balance while trying/requires external support

9. PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: **Pick up the shoe/slipper which is placed in front of your feet.**
( )4 able to pick up slipper safely and easily
( )3 able to pick up slipper but needs supervision
( )2 unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
( )1 unable to pick up and needs supervision while trying
( )0 unable to try/needs assist to keep from losing balance or falling

10. TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: **Turn to look directly behind you over toward left shoulder. Repeat to right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.**
( )4 looks behind from both sides and weight shifts well
( )3 looks behind one side only other side shows less weight shift
( )2 turns sideways only but maintains balance
( )1 needs supervision when turning
( )0 needs assist to keep from losing balance or falling

11. TURN 360 DEGREES
INSTRUCTIONS: **Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.**
( )4 able to turn 360 degrees safely in 4 seconds or less
( )3 able to turn 360 degrees safely one side only 4 seconds or less
( )2 able to turn 360 degrees safely but slowly
( )1 needs close supervision or verbal cueing
( )0 needs maintenance while turning

12. PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: **Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.**
( )4 able to stand independently and safely and complete 8 steps in 20 seconds
( )3 able to stand independently and complete 8 steps > 20 seconds
( )2 able to complete 4 steps without aid with supervision
( )1 able to complete >2 steps needs minimal assist
( )0 needs assistance to keep from falling/unable to try

13. STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) **Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width).**

Right. ( )4 able to place foot tandem independently and hold 30 seconds
( )3 able to place foot ahead of other independently and hold 30 seconds
( )2 able to take small step independently and hold 30 seconds
( )1 needs help to step but can hold 15 seconds
( )0 loses balance while stepping or standing

Left. ( )4 able to place foot tandem independently and hold 30 seconds
( )3 able to place foot ahead of other independently and hold 30 seconds
( )2 able to take small step independently and hold 30 seconds
( )1 needs help to step but can hold 15 seconds
( )0 loses balance while stepping or standing

14. STANDING ON ONE LEG
INSTRUCTIONS: **Stand on one leg as long as you can without holding.**

Right. ( )4 able to lift leg independently and hold > 10 seconds
( )3 able to lift leg independently and hold 5-10 seconds
( )2 able to lift leg independently and hold = or > 3 seconds
( )1 tries to lift leg unable to hold 3 seconds but remains standing independently
( )0 unable to try or needs assist to prevent fall

Left. ( )4 able to lift leg independently and hold > 10 seconds
( )3 able to lift leg independently and hold 5-10 seconds
( )2 able to lift leg independently and hold = or > 3 seconds
( )1 tries to lift leg unable to hold 3 seconds but remains standing independently
( )0 unable to try or needs assist to prevent fall

(Taken from: Lewis, C. B., & McNerney, T. (1994). The functional tool box: Clinical measures of functional outcomes "the functional outcomes tool box". (pp. II--E--5-II--E--10). Washington, DC: Learn Publications.)

* NOTE: Two additional tasks are listed above (one in item 13 and one in item 14) as an addition to the Berg Balance Measure to comprise the Modified Berg Balance Measure. The Berg Balance Measure present in the source listed above does not include these two additional tasks. The scores for the two additional tasks were added to the Berg Balance Measure score to obtain the Modified Berg Balance Measure score for each subject.

Appendix D

Consent Form

I understand that this is a study regarding the effect of upper extremity immobilization on balance. Knowledge gained from this study will aid physical therapists and physicians in determining if balance assessment and training is necessary following immobilization of the upper extremity.

I also understand that:

1. I have been selected to participate in this study because I am currently healthy, am between the ages of 60 and 75, and am without known balance problems.

2. I will be asked to answer questions asked by the interviewer regarding my medical history; the flexibility of my shoulders and legs will be measured; I will be asked to follow objects with my eyes and shake my head back and forth to test my vision and balance organs of my inner ear; I will be asked to describe the position of my big toe as the examiner moves it while I lay down; I will be asked to describe if a light pin prick on my legs feels sharp or dull; and I will be asked to describe how a cotton ball feels on the skin of my leg.

3. I will be asked to do things such as sit, stand, reach, turn in a circle, and step onto a small stool as part of a functional balance test. I will be asked to do some of these tests on one leg or with my eyes closed.

4. I will be asked to stand on force plates and lean as far forward and to the side as much as I safely can with and without my arm in a sling.

5. I may withdraw from the experiment at any time for any reason I see fit without penalty or loss of benefits to which I may otherwise be entitled.

6. all information obtained at any time during this study will used for the sole purpose of research and my name will be kept confidential at all times. I will be assigned a participant number in order to keep my name confidential.

7. although the possibility exists that I may fall during this study, every attempt will be made to ensure my safety.

8. there will be no direct benefit to me for participating in this study aside from monetary compensation. and that the knowledge gained by the investigators may be of help in the identification of risk factors related to poor balance and falls.

9. I may request and obtain a summary of study results.

10. I will receive payment of $8.00/hour for my participation in this study even if I choose to withdraw from this study.

11. I may contact Edward Gagné at (616) 791-6579 or Rebecca Schneider at (616) 459-2772 if I have any questions.

12. I may also contact Paul Huizenga (616) 895-2472, head of the Human Research Review Committee at Grand Valley State University, if I have further questions regarding my rights as a research subject.

I acknowledge that:

"I have been given the opportunity to ask questions regarding this study and that these questions have been answered to my satisfaction."

"information collected during this study may be released to scientific literature and I give my authorization for the researchers to release such information."

"I acknowledge that I have read and understand the above information, and that I agree to participate in this study."

______________________ ______________________
Witness Participant's Signature

______________________ ______________________
Date Date

____ check here if you would like a copy of the results of this study

Appendix E

Medical History Questionnaire

Participant #: _______

Age: _______ Birthdate: _______________ Sex: M F
(circle one)

Please answer the following questions concerning your medical history.

1. Are you able to walk safely more than 500 feet in community settings without the assistance of another person?

   ___Yes ___No

2. Are you able to live and function safely in your residence without the assistance of another person?

   ___Yes ___No

3. Have you had any surgical procedures in the past two years? If yes, please list the procedures below.

   ___Yes ___No

   ____

   ____

4. Have you undergone a total hip replacement and/or total knee replacement? If yes, please list which procedure below.

   ___Yes ___No

   ____

5. Have you been hospitalized or had a significant illness in the past year? If yes, please list below.

   ___Yes ___No

   ____

   ____

6. Are you currently taking any medications? If so, please list below.

   ____

   ____

____

____

7. Do you regularly exercise? If so, what is the type of exercise? How many sessions/week and for how many minutes?

___Yes ___No

____

____

____

8. In case of emergency, whom should be contacted?

Name: ______________________

Relationship: __________________

Telephone Number: _____________

9. Do you have a history of any of the following conditions?

___ Asthma
___ COPD (Chronic Obstructive Pulmonary Disease)
___ Hypertension
___ Heart Murmur
___ Myocardial Infarction (Heart Attack)
___ Congestive Heart Failure
___ Angina
___ Heart Arrythmia
___ PVD--arterial or venous or both
___ Diabetes Mellitus
___ Endocrine/Thyroid Dysfunction
___ Cancer/Leukemia/Lymphoma
___ Anemia
___ Osteoarthritis
___ Rheumatoid Arthritis
___ Gout/Pseudogout
___ Osteoporosis
___ Muscle Disease
___ Cerebral Vascular Accident (Stroke) or Transient Ischemic Attack
___ Epilepsy
___ Seizures
___ Parkinson's Disease
___ Polio/Post-Polio Syndrome
___ Head Injury

___ Alzheimer's Disease
___ Headaches
___ Neuropathy
___ Spinal Cord Injury or Impingement
___ Neck Injury
___ Encephalitis/Meningitis
___ Automobile Accidents
___ Fractures/Significant Sprains
___ Amputations
___ Foot Problems
___ Gastrointestinal Problems
___ Meniere's
___ Acoustic Neuroma
___ Ear Surgery
___ Acute/Chronic Otitis Media
___ Ototoxic drugs
___ Ear damage/Tinnitus/Aural Fullness
___ Hearing Aide

10. Do you have any problems with any of the following?

___ Vision
___ Falls
___ Balance/Coordination
___ Driving/Night Driving
___ Vertigo
___ Syncope
___ Lightheadedness
___ Memory
___ Weakness
___ Numbness/Tingling/Burning Pain
___ Muscle/Joint Stiffness (pain, swelling, warmth, redness)
shoulder
elbow
wrist
fingers
back
hip
knee
ankle
foot
toes
___ Shortness of Breath
___ Dyspnea on Exertion
___ Chest Pain
___ Claudication
___ Edema

11.	Hand Dominance (which hand do you write with?)	Right	Left
	Leg Dominance (which leg would you kick a soccer ball with?)	Right	Left

12. Do you wear corrective lenses? yes no

13. Height (cm) _______ Weight (kg) _______

Pulse _______ Blood Pressure Supine _______
Standing _______

Appendix F

Participant #: ____

Participant Screen

Range of Motion:

	Right	Left
Shoulder Flexion (90°)	____	____
Hip Flexion (90°)	____	____
Hip Extension (0°)	____	____
Knee Flexion (90°)	____	____
Knee Extension (0-5°)	____	____
Ankle Dorsiflexion (neutral)	____	____

Vestibular/Gross Vision:

Range of Motion (can follow H pattern)	____	____
Pursuit (can fixate; no hesitation with crossing midline; no nystagmus; no jumpy/jerky movements; no head/body compensatory movements)	intact	not intact
Vestibular-Ocular Reflex (no dizziness or nausea; able to read eye chart)	intact	not intact
Depth Perception	normal	abnormal

Proprioception:
(able to accurately describe position of the metatarsal phalangeal joint)

up	_____	_____	down
up	_____	_____	up
down	_____	_____	down
up	_____	_____	down
down	_____	_____	up

Sensation:

0=absent
1=impaired (partial/altered sensation; hyperaesthesia)
2=normal
NT=not testable

	sharp/dull right	left	light touch right	left
L2	_____	_____	_____	_____
L3	_____	_____	_____	_____
L4	_____	_____	_____	_____
L5	_____	_____	_____	_____
S1	_____	_____	_____	_____
S2	_____	_____	_____	_____

Muscle Strength:
(must score 3/5)

	Right	Left
Shoulder ABductors	_____	_____
Shoulder ADductors	_____	_____
Biceps	_____	_____
Triceps	_____	_____
Wrist Flexors	_____	_____
Wrist Extensors	_____	_____

	Right	Left
Grip	_____	_____
Intrinsics	_____	_____
Hip Flexors	_____	_____

	Right	Left
Hip Extensors	_____	_____
Hip ABductors	_____	_____
Hip ADductors	_____	_____
Knee Extensors	_____	_____
Knee Flexors	_____	_____
Ankle Dorsiflexors	_____	_____
Ankle Plantarflexors	_____	_____

Reflexes:
(+ or -)

Biceps	_____	_____
Triceps	_____	_____
Patellar	_____	_____
Achilles	_____	_____
Babinski	_____	_____
Vibration	_____	_____

Cerebellar Screen:
(+ or -)

Finger-Nose	_____	_____
Heel-Shin	_____	_____
RAM--Hands	_____	_____
RAM--Feet	_____	_____

Muscle Tone: (+ or -)	Right	Left
Cogwheeling	_____	_____
Pronator Drift	_____	_____

	Right	Left
Spasticity	_____	_____
Romberg	_____	_____

Cranial Nerves
(+ or -)

Facial Nerve	_____	_____

Appendix G

Participant Screening Protocol

RANGE OF MOTION

Shoulder Flexion

Position:
--Supine with knees flexed
--Shoulder 0 degrees abduction, adduction, and rotation
--Forearm 0 degrees supination and pronation with palm facing body

Stabilization:
--Stabilize scapula to prevent elevation, posterior tilting, and upward rotation of scapula
--Stabilize thorax to prevent extension of scapula

Goniometer Alignment:
--Fulcrum of goniometer centered close to acromion process
--Proximal arm aligned with mid-axillary line of thorax
--Distal arm aligned with lateral midline of humerus using lateral epicondyle of humerus for reference

Hip Flexion

Position:
--Supine with hip in 0 degrees abduction, adduction, and rotation
--Knee extended initially, but knee flexion is allowed as range of hip flexion is completed

Stabilization:
--Stabilize pelvis to prevent posterior tilting or rotation

Goniometer Alignment:
--Fulcrum centered over lateral aspect of hip using greater trochanter of femur for reference
--Proximal arm aligned with lateral midline of pelvis
--Distal arm aligned with lateral midline of femur using lateral epicondyle for reference

Hip Extension

Position:
--Prone with hip in 0 degrees of abduction, adduction, and rotation
--Knee extended
--Pillow under abdomen for comfort if needed; no pillow under head

Stabilization:
--Stabilize pelvis to prevent anterior tilting or rotation

Goniometer Alignment:
--Fulcrum centered over lateral aspect of hip using greater trochanter of femur for reference
--Proximal arm aligned with lateral midline of pelvis
--Distal arm aligned with lateral midline of femur using lateral epicondyle for reference

Knee Flexion and Extension

Position:
--Prone with hip in 0 degrees of abduction, adduction, flexion, extension, and rotation
--Foot over edge of supporting surface

Alternative position for measuring knee flexion if rectus femoris muscle appears to limit range of knee flexion: Supine. Hip initially in 0 degrees of flexion, extension, abduction, and adduction. Hip allowed to flex as knee flexes.

Stabilization:
--Stabilize femur to prevent rotation, flexion, or extension of hip

Goniometer Alignment:
--Fulcrum centered over lateral epicondyle of femur
--Proximal arm aligned with lateral midline of femur using greater trochanter for reference
--Distal arm aligned with lateral midline of fibula using lateral malleolus for reference

Ankle Dorsiflexion

Position:
--Supine with knee flexed at least 30 degrees
--Foot positioned in 0 degrees of inversion and eversion

Stabilization:
--Stabilize tibia and fibula to prevent knee motion and hip rotation

Goniometer Alignment:
--Fulcrum centered over lateral aspect of lateral malleolus
--Proximal arm aligned with lateral midline of fibula using head of fibula for reference
--Distal arm aligned parallel to lateral aspect of fifth metatarsal

VESTIBULAR/GROSS VISION

Range of Motion

--Examiner and subject sit facing each other; subjects head is in midline.
--Left eye of subject is covered with an eye patch
--Subject instructed to "Sit still".
--Examiner places his/her finger 10-12 inches in front of subject's eyes and slowly traces a large "H" pattern in the air to include the extremes of all directions.
--Eye patch removed from left eye and place over right eye.
--Examiner places his/her finger 10-12 inches in front of subject's eyes and slowly traces a large "H" pattern in the air to include the extremes of all directions.
--Eye patch removed from right eye and subject; subject sits facing evaluator with neither eye concealed.
--Subject considered normal if he/she can visually follow entire "H" pattern.

Pursuit

--Examiner and subject sit 18-20 inches apart facing each other; subject's head is in midline.
--Subject instructed to "Sit still".
--Examiner's finger is held 12-16 inches from the patient's eye and moved slowly through a horizontal figure "8" pattern.
--Subject is instructed to "Follow my finger with your eyes, but don't move your head".
--Loss of fixation on the target, hesitation when crossing midline, nystagmus, jumpy/jerky movement, or compensatory head or body movement deems the subject abnormal.

Vestibular-Ocular Reflex

--Subject sits 20 feet away from an eye chart.
--Subject is instructed to "Turn your head to the left and right at a medium to fast speed while reading the eye chart".
--Dizziness or nausea will warrant discontinuation of the test.
--Subject then instructed to "Tilt your head up and down at a medium to fast speed while reading the eye chart".
--Dizziness or nausea will warrant discontinuation of the test
--Inability to read the eye chart, nausea, or dizziness will deem the subject abnormal.

PROPRIOCEPTION

--Subject long sits on mat with eyes open
--Examiner moves subjects' great toe at the metatarsal phalangeal joint to an "up toward your head" position and instructs subject that "This is up".
--Examiner moves subjects great toe at the metatarsal phalangeal joint to a "down toward the floor" position and instructs subject that "This is down".
--This is repeated a few times to ensure subject comprehension
--Subject then lies in supine and his/her eyes are covered.
--Examiner moves the subjects left great toe asking "Is your toe up or down" in the following sequence: up, up, down, up, down. Responses are recorded.
--Examiner then moves the subjects right great toe asking "Is your toe up or down" in the following sequence: down, up, down, down, up. Responses are recorded.
--Subject must provide 100% of the correct responses to be considered normal.

SENSATION

Sharp/Dull Sensation

--Subject will short sit facing examiner with lower extremities exposed.
--Examiner will demonstrate sharp and dull with a disposable safety pin on subjects forearm.
--Subject will be blindfolded.
--Examiner will touch each key dermatome point three times varying sharp/dull sequence and ask subject "Is this sharp or dull?" Examiner will record responses for each dermatome point.
--Dermatome points will be tested on the right and left lower extremities in the following order: L2--mid anterior thigh, L3--medial femoral condyle, L4--medial malleolus, L5--dorsum of foot at the third metatarsal phalangeal joint, S1--lateral heel, and S2--popliteal fossa in the midline.
--Subject will identify the presence or absence of a cotton ball touching their skin at each dermatome point.
--Subject must respond correctly 100% of the time to be considered normal.

Light Touch

--Subject will sit facing examiner with lower extremities exposed.
--Examiner will demonstrate light touch with a cotton ball on the subjects forearm.
--Subject will be blindfolded.
--Examiner will touch/not touch each dermatome point three times varying touch/not touch sequence and ask subject "Cotton or no cotton?" Examiner will record responses for each dermatome point.
--Dermatome points will be tested on the right and left lower extremities in the following order: L2--mid anterior thigh, L3--medial femoral condyle, L4--medial malleolus, L5--dorsum of foot at the third metatarsal joint, S1--lateral heel, and S2--popliteal fossa in the midline.
--Light touch will be graded according to the following scale: 0=absent, 1=impaired (partial or altered sensation, including hyperaesthesia), 2=normal, and NT=not testable.
--The subject must achieve a score of 2 on all dermatome points to be considered normal.

Appendix H

General Instructions

"We will have scheduled breaks, but we can take additional breaks at any time."

"You will not be asked to do anything that you are not comfortable doing."

"You may quit at any time during the experiment if you feel the need to."

"We will do a few practice trials until you feel comfortable with the procedure."

Static Sway

"Please place your feet in the area outlined with the tape."

"The first task is to simply stand still for 20 seconds."

"You will be asked to keep your eyes focused on the poster in front of you and to stand comfortably still with your arms comfortably at your side."

"I will now demonstrate this task for you."

DEMONSTRATE THE TASK FOR THE SUBJECT

"You are now allowed to practice this task and ask any questions."

ALLOW PRACTICE AND ANSWER QUESTIONS

"Are you ready to begin?"

WHEN SUBJECT IS READY, INFORM THE DATA OFFICER(S)

"We are ready to begin the task. When I say 'Focus on the poster', please focus your eyes on the poster in front of you and stand comfortably still with your arms comfortably at your side."

WHEN CUE IS GIVEN FROM DATA OFFICER(S), . . .

"Focus on the poster."

ONCE 20 SECOND DATA COLLECTION PERIOD IS OVER, . . .

"And relax. We are going to perform this task two more times. If you have any questions, please ask them at this time. If you have no questions, we will perform the task again in about 10-15 seconds."

AFTER QUESTIONS HAVE BEEN ANSWERED OR AFTER THIRTY SECONDS REST PERIOD, . . .

"Are you ready to begin?"

WHEN SUBJECT IS READY, INFORM THE DATA OFFICER(S)

WHEN CUE IS GIVEN FROM DATA OFFICER(S), . . .

"Focus on the poster."

ONCE 20 SECOND DATA COLLECTION PERIOD IS OVER, . . .

"And relax."

AFTER THIRTY SECONDS PERIOD, . . .

"Are you ready to begin?"

WHEN SUBJECT IS READY, INFORM THE DATA OFFICER(S)

WHEN CUE IS GIVEN FROM DATA OFFICER(S), . . .

"Focus on the poster."

ONCE 20 SECOND DATA COLLECTION PERIOD IS OVER, . . .

"And relax."

MAXIMAL STATIC LEANS

"The next set of tasks involves leaning as far as you can in different directions while standing. There will be four separate directions: forward, backward, to the left, and to the right. You will be asked to lean in each of the directions for 20 seconds. There will be a one minute rest between each 20 second lean. The 'rules' are: lean as far as you can without taking a step, keeping your arms comfortably at your side, keeping at least part of each foot in contact with the force plates, keeping your feet within the marked tape, and keeping your eyes focused on the poster. You will be asked to perform each of the four leans three times each, in a random order."

"I will now demonstrate the tasks for you."

DEMONSTRATE THE TASKS FOR THE SUBJECT

"You are now allowed to practice these tasks and ask any questions."

ALLOW PRACTICE AND ANSWER QUESTIONS

"The instruction for each task will be simply 'Lean (forward, backward, left, or right)'."

"We are ready to begin, please place your feet in the area outlined with the tape."

"Again, the 'rules' are to lean as far as you can without taking a step, keeping your arms comfortably at your side, keeping at least part of each foot in contact with the force plates, keeping your feet within the marked tape, and keeping your eyes focused on the poster."

"Between each task, you may bend your knees or wiggle your toes or whatever you feel necessary to keep yourself relaxed."

Maximal Anterior Static Lean

WHEN SUBJECT IS READY, INFORM THE DATA OFFICER(S)

WHEN CUE IS GIVEN FROM DATA OFFICER(S),:

"Lean forward."

ONCE 20 SECOND DATA COLLECTION PERIOD IS OVER . . .

"And relax."

AFTER THIRTY SECONDS REST PERIOD, PROCEED TO NEXT TASK

Maximal Posterior Static Lean

WHEN SUBJECT IS READY, INFORM THE DATA OFFICER(S)

WHEN CUE IS GIVEN FROM DATA OFFICER(S),:

"Lean backward."

ONCE 20 SECOND DATA COLLECTION PERIOD IS OVER . . .

"And relax."

AFTER THIRTY SECONDS REST PERIOD, PROCEED TO NEXT TASK

Maximal Left Static Lean

WHEN SUBJECT IS READY, INFORM THE DATA OFFICER(S)

WHEN CUE IS GIVEN FROM DATA OFFICER(S),:

"Lean left."

ONCE 20 SECOND DATA COLLECTION PERIOD IS OVER . . .

"And relax."

AFTER THIRTY SECONDS REST PERIOD, PROCEED TO NEXT TASK

Maximal Right Static Lean

WHEN SUBJECT IS READY, INFORM THE DATA OFFICER(S)

WHEN CUE IS GIVEN FROM DATA OFFICER(S),:

"Lean left."

ONCE 20 SECOND DATA COLLECTION PERIOD IS OVER . . .

"And relax."

AFTER THIRTY SECONDS REST PERIOD, PROCEED TO NEXT TASK

AT THE END OF THE THIRD ROUND OF TRIALS INFORM THE SUBJECT:

"You may now take a five minute break."

AT THE END OF THE BREAK:

"You will now be asked to complete the same tasks, this time with a sling on your (surgical/dominant) arm."

PLACE SLING ON ARM, ASSURING 90° OF ELBOW FLEXION

FOLLOW PROTOCOL BEGINNING WITH STATIC SWAY. INSTRUCTIONS ARE GIVEN AS BEFORE, WITHOUT DEMONSTRATION BY THE RESEARCHER (UNLESS REQUESTED BY THE SUBJECT). PRACTICE IS AGAIN ALLOWED IF REQUESTED BY THE SUBJECT.