The Effects of Exercise Training on Functional Balance in a Community-Dwelling Elderly Population

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THE EFFECTS OF EXERCISE TRAINING ON FUNCTIONAL BALANCE IN A COMMUNITY-DWELLING ELDERLY POPULATION

Kathryn E. Smith

THESIS

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MASTER OF SCIENCE IN PHYSICAL THERAPY

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Abstract

The objective of this study was to determine the effectiveness of aerobic exercise training to improve balance in healthy adults over age 65. Twenty-five habitual exercisers (mean age 75.3 yrs.) and 25 control subjects (mean age 72.8 yrs.) were recruited from a senior day center. Balance was measured by the functional reach test. A two-sample t-test revealed no significantly higher difference in the mean balance score of the exercise group compared to the control group. Regression analysis indicated that none of the other variables collected (age, group, or level of fitness) were significant predictors of the functional reach scores. There was insufficient evidence to conclude that regular exercise had an effect on the balance scores of the subjects. However, this outcome was affected by the small sample size of the study. A benefit of the exercise treatment may have been present but not detected. Future studies in this area might be improved by using larger control and treatment groups.
ACKNOWLEDGEMENTS

A research project requires the work of many people. I would like to extend special thanks to all my committee members for contributing their time, effort, and special skills to this project: to Jane Toot for her editorial guidance and shaping of the project, to Jennifer McWain for her keen critical judgement, and to Justine Ritchie who contributed not just her statistical expertise, but her enthusiasm as well.

It was through the assistance of program director Rose McDoniels and the willing participation of the members of Evergreen Commons in Holland, Michigan that the ideas for this study were transformed into an actual research project. Their graciously given help was much appreciated.

Research assistant Christina Olson spent many early mornings gathering data. A special thanks for her skills and good humor. A note of appreciation is extended to Jane Grey who generously offered her assistance as a skilled proofreader.

This year's worth of work would not have been possible without the support of my dear husband, Ken Smith, who seemed to overcome as many challenges as I did on this journey.
DEFINITION OF TERMS

**Anticipatory Set** - a pattern of muscular adjustments that precede a desired voluntary movement. This pattern functions to prevent dysequilibrium and may be a programmed part of a larger movement synergy (Crutchfield & Barnes, 1993).

**Center of Pressure (COP)** - the focus of the mass of the body as translated through the support of the feet. It is located in the foot in unilateral stance and between the feet in bilateral standing postures (Horak, 1987).

**Center of Pressure Excursion (COPE)** - a test of dynamic balance which uses a force platform to assess the degree to which a subject's center of gravity is displaced after self-initiated or external perturbation. Commonly used in the laboratory to assess balance skills (Duncan, Weiner, Chandler, & Studenski, 1990).

**Dynamic Balance** - the ability of the body to maintain equilibrium in response to its own changing base of support during movement or as a response to external perturbations (Duncan et al., 1990).

**Elderly person** - someone who has attained or passed the age of 65 years.
Equilibrium - sense of the body's orientation in space which is maintained by automatic postural reactions (Crutchfield & Barnes, 1993).

Functional Balance - the ability to maintain one's bodily equilibrium while conducting daily activities and to resist loss of balance caused by destabilizing forces; equivalent to dynamic balance (Studenski, Duncan, Weiner & Chandler, 1989).

Functional Reach - a test of functional balance developed by Pam Duncan and colleagues (1990) to predict falls in elderly people.

Healthy Subject - a person who is independent in daily activities, who is able to walk without an assistive device and is free of neurological, vestibular or orthopedic limitations.

Perturbation - a slow or a sudden force which requires a compensatory postural response to maintain postural equilibrium. It may be externally or self-generated.

Posture - the alignment of body parts in relation to one another at any given moment (Kaufman, 1990).

Postural Sway - normal oscillating movements of the body over the feet during quiet standing.

Posturography - a quantitative laboratory test of balance which assesses postural sway in quiet standing or under conditions of altered sensory input (Hu & Woollacott, 1994).
Romberg Test - a test of static balance. The subject stands in a normal stance with arms crossed on the chest or behind the back. The amount of postural sway is observed by the tester.

Sharpened Romberg - a variation of a Romberg test. The subject must maintain balance while standing with one foot directly in back of the other.

Somatosensory - the various sensory pathways in the body (such as touch, temperature, pain, and awareness of body position) which supply afferent input to the central nervous system.

Static Balance - the ability of the body to maintain equilibrium during quiet standing.

Synergy - a group of muscles which work together to accomplish a specific movement. Typically, the prime mover, or agonist, will be assisted by other muscles to provide stability or directly aid in the performance of a desired action (Norkin & Levangie, 1992).

Vestibular System - a system of internal reference in the body that determines the orientation of the head in space. The peripheral vestibular organs are located in the inner ear.
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CHAPTER 1: INTRODUCTION

Falls are a serious health problem for the elderly and for those responsible for their care. The incidence of falls increases with advancing age and represents a major threat to the health status and independence of the elderly (Tinetti et al., 1994). As many as 30% of community-dwelling elders over age 65 and 40% of those over age 75 fall each year. The risk is much higher among persons living in long-term care institutions than among those in the community (Campbell, Borrie, & Spears, 1989). A very small percentage of these falls are fatal, but about 10% result in serious injuries such as fractures of the hip or pelvis (Nevitt, Cummings, & Hudes, 1991). Falls can erode self-confidence; up to 25% of the elderly who have fallen limit their daily activities because they fear falling again. Once injured, many elderly people become caught in a destructive cycle of diminished strength, reduced mobility and increased dependency (Tinetti, Speechly, & Ginter, 1988; Campbell et al., 1989).

Until recently, injurious falls and impaired mobility were considered to be the inevitable accompaniments of aging and therefore received little remedial attention (Koch, Gottschalk, Palumbo, & Tinetti, 1994). Many researchers have attempted to identify specific factors which cause
falls or increase the likelihood of their occurrence. Others have devised strategies to improve balance or to modify environmental risk factors (Reinsch, MacRae, Lachenbruch, & Tobis, 1992; Tinetti et al., 1994). Most falls are associated with multiple risk factors. As the number of risk factors increases, so does the likelihood of a serious fall (Campbell et al., 1989; Tinetti, 1986).

The superficial cause for falling is a loss of balance. However, a fall may actually be the result of complex, underlying causes which are associated with deterioration in some aspect of the postural control system. Balance impairments may originate in a variety of sensory, effector or integrative processes. Their origin may be biological and stem from normal aging processes such as decreased sensory acuity, slowed reaction times, or a lessening of strength and endurance. But many deficits reflect the cumulative negative effects of a sedentary lifestyle (Lewis & Bottomley, 1990).

Particular disease conditions such as Parkinsonism, hemiplegia, vertigo, depression, orthopedic abnormalities, epilepsy, Alzheimer's disease or certain medications, may substantially impact the risk of falling (Ray & Griffin, 1990; Reinsch et al., 1992). Falls are not simply the result of increasing age. They represent the accumulated effects of trauma, multiple impairments or disabilities (Nevitt et al., 1991; Tinetti, 1986).
Interventions to reduce the risk of falls have focused on modifiable risk factors such as environmental hazards, medication incompatibilities, losses in muscle strength and balance impairments. Fear of falling and loss of confidence issues have also been addressed in research and clinical practice (Reinsch et al., 1992; Tinetti et al., 1994).

In the clinic, the physical therapist is able to intervene in several ways to assist elderly adults with balance problems who are at risk for falls. Professional responsibilities for the physical therapist include assessment of balance, prescription of therapeutic and rehabilitative measures, as well as instruction in fall prevention measures.

Direct instruction in balance training and general conditioning exercises is commonly used to remediate balance deficits and age-related functional decline (Judge, Lindsey, Underwood, & Winsemius, 1993; Lichtenstein, Shields, Shiavi, & Burger, 1989; Lord & Castell, 1994). The focus of this study was to assess the effectiveness of exercise as an intervention to improve balance in the elderly.

Statement of the Problem

A problem which exits in the clinic is a lack of experimental evidence demonstrating that exercise can improve the balance of elderly people. Exercise is frequently prescribed to remediate postural control
deficits, yet there is little research to indicate its efficacy, to provide protocol for its administration, or to describe outcomes of treatment. A second problem lies in the lack of uniform methods for assessment of balance. Simple clinical tests with proven validity, sensitivity, and reliability are needed to accurately quantify and describe the many aspects of postural control.

Purpose of the Study

This study attempted to determine if habitual exercise can contribute to the maintenance or improvement of normal balance in a population of healthy elderly adults. The key terms used in this study are defined as follows: **habitual exercise** is regular participation (90 min./week, 8 times/month) in an organized exercise program; **balance** is the ability of the body to maintain its equilibrium as its center of gravity changes (Duncan et al., 1990); **healthy elderly adults** are those individuals age 65 and over who are free of balance deficits or any impediment to regular exercise. Additional terms are defined in the preface.

The question whether habitual exercise can improve or maintain normal balance in this population will be addressed by comparing the functional reach test (FRT) balance scores of healthy exercising adults with the balance scores of similar healthy adults not enrolled in an exercise program.
The Concept of Balance

Balance is a force which acts as a positioning interface between our bodies and gravity as it creates postural stability. For balance to occur, the body must be in equilibrium with the forces of gravity, muscular energy and inertia (Norkin & Levangie, 1992). Balance is usually unnoticed until it is lost or impaired.

Different authors describe balance in different ways, according to their theoretical or professional perspectives. In this study, balance will be viewed from the perspective of a systems theory of motor control. Systems theory has diverse formulations and applications. Its basic premise asserts that, in a given organized structure, all components of a structure or system exert an influence on and are mutually affected by one another and by forces which impinge on the system as a whole. Control does not reside within one area but is broadly distributed among the parts. The unit in charge will vary according to the requirements of a particular task (Crutchfield & Barnes, 1993).

As the body moves, it must maintain its unstable equilibrium with the forces of gravity, muscular energy and inertia. To accomplish this, multiple neural, sensory and biomechanical factors must interact with precise timing and
coordination (Woollacott, 1990).

In some studies, the term balance and the term postural control are used to refer to separate phenomena; here they will be used interchangeably. Postural control encompasses both static and dynamic balance; it is the "ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support" (Horak, 1987).

Control of Balance

Balance is maintained through a sophisticated and complex process which involves sensory detection of body motions, integration of sensorimotor information within the central nervous system, and execution of appropriate musculoskeletal responses (Nashner, 1989).

The three components of sensory organization are the vestibular, visual and somatosensory systems. They interact synergistically to create postural orientation in the body. These systems detect and transmit essential input for feedforward and feedback motor responses, with the somatosensory providing the most crucial quantity (Horak, 1987; Alexander, 1994). The close integration of these systems implies that deficiencies which develop in one system must be offset by increased dependence on another system (Alexander, 1994).

The musculoskeletal system acts as the biomechanical
effector component of postural control. Any reduction in joint range of motion, the presence of pain, or alteration in muscle strength, length or endurance can affect the maintenance of equilibrium or contribute to postural dysfunction (Crutchfield & Barnes, 1993). Smooth, finely graded movements are possible as adjacent or opposing muscles are constrained by one another to work as units, or synergies. These synergies permit the nervous system to control and coordinate many joints during a single movement (Woollacott, 1990).

The role of the central nervous system is to rapidly integrate sensory information with response processes. Automatic postural reactions are centrally mediated to produce coordinated motor responses which maintain the body mass over the base of support. The smallest movement of the center of gravity - up or down, forward or backward, or side to side - will produce some response (Woollacott, 1989).

Protective reactions, also described by Horak and Shumway-Cook (1989) as stepping strategies, function to protect the body from pain and injury once the center of gravity is displaced too far for recovery (Crutchfield & Barnes, 1993). These reactions are acquired very early and persist throughout life. As an example: if a seated person were suddenly pushed horizontally from the side, the arm opposite the direction of force would immediately extend to prevent falling, as would the opposite lower limb.
Tilting reactions are elicited when the base of support is unstable or the support surface very irregular; equilibrium reactions keep the body upright in response to perturbations; both function to maintain the center of gravity over the base of support. Prevention of falling or loss of balance is achieved by anticipatory weight shifting or an alteration in movement pattern. Changes in the relationship of forces of mass, gravity and inertia are rapidly processed by the central nervous system motor programs to produce rapid new movement in both feedforward and feedback modes (Studenski et al., 1989; Woollacott, 1990; Crutchfield & Barnes, 1993).

Automatic postural reactions are the adjustments made to regain equilibrium following a perturbation. The term "automatic" is used because the reactions precede the earliest voluntary movements and are not modified by conscious effort. They are more centrally organized and adaptable than the segmental reflex systems (Naschner, 1989). These reactions can be repeated with little variation by the same or other individuals.

The ankle, hip and stepping strategies are examples of automatic postural reactions displayed by standing subjects in response to external perturbations. The ankle strategy involves shifting the center of body mass by moving around an imaginary axis at the ankle joints with little movement at the hip or knee joints. The hip strategy uses hip
flexion or extension to counteract displacement of the center of body mass, while the stepping strategy realigns the base of support by one or more rapid steps in the direction of the perturbation (Horak, 1987; Wolfson, Whipple, Amerman & Kleinberg, 1986).

Static postural control requires activation of many different muscle groups to stabilize a particular posture against gravity. Gravitational forces work downward in a vertical projection from the body's center of gravity, located just anterior to the second sacral vertebra, to fall within the base of support defined by the feet (Norkin & Levangie, 1992). This point is the center of pressure. In the quiet standing posture, the body undergoes a constant swaying motion referred to as postural sway. The biomechanical limits of this sway are described by Horak and Shumway-Cook (1989) as a "perceptual cone of stability" created by the central nervous system. In normal postural control, this corresponds to the points where the center of body mass reaches the limits of the base of support, i.e. the position which immediately precedes the need to change the base of support to maintain balance. Nashner (1989) has approximated these biomechanical limits as eight degrees of forward sway and four degrees backwards for adults in a standing posture.
Normal Aging and Balance

Developmental forces lead a child to the mastery of balance in upright stance; the physiological forces of aging can eventually erode that mastery. Slight changes in posture and balance ability can become dramatic alterations as individuals pass through their later years (Schenkman, 1989). Aging results from cumulative effects, so it is difficult to determine to what extent normal, or primary, aging processes play in loss of postural control (Daleiden & Lewis, 1990). Pathological factors such as disease and fractures, or functional causes such as disuse or poor compensatory movement patterns, are secondary causes which may have greater influence on balance impairment (Payton & Poland, 1983; Kaufman, 1990). In this study, our primary interest is to look at the process of physiologic aging, or aging in the absence of disease, as it affects the ability to maintain postural equilibrium.

The postural control system of many elderly people is challenged to adjust to alterations in their biomechanical alignment. Each individual presents, especially with advanced age, a unique postural adjustment in accordance with personal variations in body morphology, habits, lifestyle and history of trauma (Kaufman, 1987). In spite of this considerable variability among individuals, there are several common features of elderly stance. These include: rounded shoulders, a forward positioning of the
head, a forward inclination of the trunk with increased flexion of the thoracic spine, elbows and fingers (Lewis & Bottomley, 1990). The base of support is usually widened. Increased flexion of the hips and knees alters the angle of the pelvis which in turn flattens the lumbar spine. Loss of bone density, degeneration of intervertebral disks and reduction of tensile strength in the spinal ligaments all contribute to these postural changes (Vansant, 1995). In turn, these changes in body alignment may shift the center of gravity forward and require new, adaptive movement patterns (Kaufman, 1987). Then each component of the balance system - sensory, coordinative, and effector - must respond synergistically to accommodate these subtle and gross changes within the body's available capacity for adjustment (Woollacott, 1990). Such changes may predispose an elderly person for a fall (Kaufman, 1990).

As people age, their bodies sway more in quiet standing (Baloh, Spain, Socotch, Jacobson & Bell, 1995). Most of this movement occurs in the sagittal plane. Evidence of alteration in postural control has been documented in studies comparing the magnitude of postural sway in quiet standing between young and old adults (Maki, Holliday & Fernie, 1990; Hasselkus & Shambes, 1975; Whipple, Wolfson, Derby, Singh & Tobin, 1993). This observed increase in postural sway with aging has not been shown to be detrimental or associated with an increased risk of falls.
(Era & Heikkinen, 1985; Woolacott & Shumway-Cook, 1990; Baloh et al., 1995).

Just as the magnitude of sway increases in older adults, the velocity of sway also increases in older subjects (Baloh et al., 1994). In a later study, Baloh and colleagues (1995) found that sway velocity was not significantly increased among subjects who had reported having falls compared to those who had not fallen. These findings reinforce the lack of association found by Era and Heikkinen (1985) between postural sway and the incidence of falls in the elderly. By contrast, subjects who reported a fear of falling (both fallers and nonfallers) had significantly increased sway velocity compared to those who reported no fear of falling (Baloh et al., 1995).

Bohannon, Larkin, Cook, Gear and Singer (1984) used a different measure to correlate balance with age and establish objective, age-related norms for clinical use. Nearly 200 subjects, aged 20-79 years, performed a timed one-leg stance test with eyes open and eyes closed. Subjects over the age of 60 were less able to balance on one leg, particularly with their eyes closed, than the younger subjects. Briggs, Gossman, Birch, Drews and Shaddeau (1989) studied single leg balance in 71 elderly women. Subject's eyes-open performance was consistently superior to their eyes-closed test performance. The one-leg stance test mean balance time decreased significantly as age increased.
Wolfson et al. (1986) developed the Postural Stress Test to provide a quantitative assessment of postural control. Graded destabilizing forces, applied suddenly to a subject's center of gravity at hip level, elicit automatic postural reactions and specific muscle synergies which are proportionate to the amount of force applied. The researchers found that both young and old subjects, except those with a history of falls, demonstrated functionally effective balance. Normal elderly subjects, however, had delayed latency and alterations in the sequence of activation of postural control synergies.

When Chandler, Duncan and Studenski (1990) used the same postural stress test to study a large group (n=108) of healthy adults aged 20-40 years and 60-102 years. Like Wolfson et al., they found no significant difference in the stress test scores of the younger subjects compared to those of the older group. They did not find a difference in the balance strategies employed by both groups, however. Also, the PST scores of ten elderly fallers (age 66-95 yrs.) were much lower than the healthy elderly adults. Chandler et al. concluded that the poor performance could not be attributed to aging alone and suggested that underlying pathological processes may have been factors.

In another study, a force platform was used to perturb the balance of subjects while their electromyographic (EMG) responses were recorded (Manchester, Woolacott, Zederbauer-
Hylton & Marin, 1989). They found no decrease in the muscle response latencies of a group of older adults (mean age 68 yrs.) when compared to a group of young adults (mean age 25 yrs.). These results are in contrast to the decreases found by Wolfson et al. (1986). Both researchers observed that older subjects tended to use more antagonistic muscle activation and muscle sequences not seen in young adults (Manchester et al.; Wolfson et al.).

Schumway-Cook and Horak (1986) and other researchers have noted a decline in some older subjects in the ability to organize sensory information for balance. As visual cues were removed or the base of support altered, postural sway in the standing position greatly increased or a loss of balance occurred (Horak & Shumway-Cook, 1989). If one source of sensory input is reduced, another source may be relied on more heavily. Vision impairments result from a variety of deficits in the elderly. Some subjects experience losses in visual acuity, peripheral vision or depth perception. Response to glare or contrast sensitivity may also decline aging (Alexander, 1994). Loss of sensory input, particularly from the visual system, can present risks (Stones & Kozma, 1987). An injurious fall during a nighttime trip to the bathroom is an extremely common accident among elderly people (Tinetti et al., 1988).

The function of the vestibular system is to monitor head position and to detect movements of the head. If
is deprived of visual and lower extremity somatosensory information, the vestibular system is left to provide sensation for control of balance (Daleiden & Lewis, 1990). Although changes in the vestibular organs have not been closely correlated with aging processes, degeneration may occur in the sensory receptors in both the otoliths and semicircular canals (Crutchfield & Barnes, 1993). In a group of 117 veterans who complained of chronic dizziness, various dysfunctions of the peripheral vestibular system were the principal cause of dysequilibrium in nearly 60% of the cases (Davis, 1994). Vestibular function might also be affected in healthy older adults if cervical osteoarthritis or lost range of motion make them less able to stabilize their heads in response to perturbations to balance (Alexander, 1994).

Another alteration in somatosensation is an increase in the threshold for vibration sensation and a decrease in proprioception in the lower extremities (Lord, Clark & Webster, 1991). This change in the vibratory sense has been correlated negatively with increased postural sway (Era & Heikkinen, 1985). Sensation from the lower extremities provides information regarding the location of the feet, movements of the feet and movement of the body over the feet. When elders were asked to stand on a foam surface with eyes open, their balance times were markedly lower than younger subjects. When asked to stand again with eyes
closed, a much larger discrepancy appeared between the scores of the two groups (Whipple et al., 1993; Hasselkus & Shambes, 1975).

The musculoskeletal component of the balance system undergoes several changes in the normal aging process. Most noticeable is a loss of strength caused by gross atrophy in the number and size of muscle fibers (Taylor, 1992), a decrease in the number of functional motor units (Payton & Poland, 1983), and a decrease in the proportion of fast-twitch muscle fibers to slow-twitch or oxidative fibers (Spirduso, 1980). Decreased collagen production reduces the quality and strength of related soft tissues such as joint linings, tendons and fascia (Kaufman, 1987).

Because motor units are reduced in number and size, voluntary muscle responses become less forceful and less rapid (Taylor, 1992; Vandervoort, 1992). Age-related slowing of the time between the stimulus onset and muscle activity onset has been documented in ankle dorsiflexion, hip extension and knee extension (Rogers, Kukulla & Soderberg, 1992; Alexander, 1994). Studenski et al. (1989) also found the tibialis anterior muscle response for dorsiflexion of the foot significantly delayed in a group of elderly fallers. The researchers concluded that effector factors, specifically muscle strength and range of motion, were more impaired than the automatic postural reactions.

Loss of fast-twitch muscle fiber accounts for a portion
of the decline in strength with age. Higher level processes, such as motor neuron recruitment, account for the remaining deficits in strength (Daleiden & Lewis, 1990). This suggests that the decline in strength during aging depends on both neurological and muscular factors. Some gerontologists take the view that losses in muscle strength occur in response to changes in nerve activity (Vansant, 1995).

Function of the aging brain is thought to be affected by loss of neurons, internal changes within nerve cells and a reduction in brain weight (Cech & Martin, 1995). In reviewing evidence for the relationship between aging and psychomotor performance, Spirduso (1980) notes that "deficits in central processing rather than peripheral function has been targeted as the primary contributor to a decline in behavioral responses. Peripheral functions, such as reflex and motor time, apparently do not decline with the same celerity as central processing does."

An indication of such changes in the central nervous system can be demonstrated by comparing the same individual's performance on static sway tests, which elicit reflex-supported automatic balance reactions, and on dynamic balance tests such as tandem walking, sit to stand transfers or directional changes (Berg, Maki, Williams, Holliday & Wood-Dauphine, 1992; Alexander, 1994). The voluntary activities require higher processing by the sensorimotor and
associative cortexes of the cerebrum (Daleiden & Lewis, 1990). Results of one study found that while elderly fallers could not be distinguished from non-fallers on tests of static posturography, the same group of fallers scored more poorly on the functional portions of the Balance Test (Berg et al., 1992).

Many factors other than age can adversely influence postural control; it is often difficult to separate the effects of age-related changes from subtle, undiagnosed disease conditions. Performance on balance tests may reflect the use of medications or the presence of pathological conditions in any bodily system (Patla, Frank & Winter, 1990; Payton & Poland, 1983).

Evaluation of Balance

Laboratory based studies of postural sway during standing have provided a baseline of quantitative data. This research has been used as a foundation of knowledge regarding aging and postural control (Alexander, 1994). Force platforms equipped with precision measuring instruments are employed to record the magnitude of postural sway during quiet standing under varied sensory conditions (Schumway-Cook & Horak, 1986; Horak, 1987) or after application of an external destabilizing force (Wolfson et al., 1986). The center of pressure excursion (COPE) is used to quantify equilibrium reactions to anterior/posterior
sliding or lateral tilting perturbations of the force platform. The observation of body sway, subsequent to alteration of visual or proprioceptive input, is a commonly used test in the clinic as well as laboratory (Schumway-Cook & Horak, 1986).

Some tests require self-generated perturbations such as raising an arm or leaning forward to the margin of stability (Duncan et al., 1990; Gehlsen & Whaley, 1990). Wolfson and colleagues (1986) have studied automatic stepping reactions elicited by a sudden posterior perturbation. They found that subjects with impaired balance took one or more steps to maintain balance while healthy older subjects more frequently used a hip strategy to recover from the same destabilizing force.

From a clinical perspective, the primary limitation of these complex laboratory tests is their lack of sufficient sensitivity to discriminate between fallers and non-fallers. Baloh et al. (1995) found no significant difference in the sway velocity of elderly subjects with a history of falls compared to normal controls. Measures of postural sway generally lack predictive power, although Maki et al. (1990) found lateral spontaneous sway amplitude to be the single best predictor of future falling risk among other measures of sway. Other recent research indicates that measurement of sway velocity rather than magnitude has sufficient sensitivity to separate fallers from non-fallers.
(Lichtenstein, Burger, Shields & Shiavi, 1990; Baloh et al., 1994).

Many simple tests of balance are used as "standards" in the clinic. Some examples of these are the one-leg stance test, the Romberg test, tandem walking or stance and perturbed stance. Although they can provide general information about a subject's postural control, these tests lack objectivity and a standardized for protocol. Nor do any of them have proven statistical validity (Alexander, 1994).

Trends in balance assessment of elderly persons have shifted in emphasis to performance-oriented assessment in the clinic (Tinetti, 1986; Piotrowski & Cole, 1994). How well a person is able to maintain various positions (Bohannon et al., 1984), to perform various mobility tasks (Berg, 1989; Tinetti, 1986; Mathias, Nayak, & Issacs, 1986), to react to external disturbances (Wolfson et al., 1986) or to respond automatically to voluntary body and extremity movements (Duncan, Studenski, Chandler, Bloomfield & LaPointe, 1990) are all factors within the domain of postural control. No single approach to clinical balance assessment of older adults nor one test instrument has yet proved to be a complete, valid measure of balance (Piotrowski & Cole, 1994). Balance tests which have the sensitivity and reliability to identify individuals or groups of people at risk for falls are valuable clinical
One test which has proven ability to identify frail individuals who have an increased risk of falling is the functional reach test (FRT). It was developed by Duncan, Weiner, Chandler and Studenski (1990) at Duke University. The instrument is simple to use and has been well validated. No equipment other than a wall mounted yardstick is required. A distance measurement is taken as a subject reaches toward his maximum limit of stability. This test is based on the laboratory COPE measure, but is more reliable, more precise and far easier to administer than the COPE. It can also detect improvements in balance over time (Duncan, Studenski, Chandler & Prescott, 1992; Weiner, Bongiorni, Studenski, Duncan & Kochersberger, 1993).

A more extensive test is the Balance Scale developed by Berg, Wood-Dauphine, Williams and Maki (1992). The execution of various movement tasks is used to assess a subject's ability to maintain balance during various functional movements. The test has demonstrated reliability and validity. Results from the Balance Scale have shown significant correlations (Lichtenstein et al., 1990) with laboratory measurements of spontaneous sway as well as the Performance-Oriented Balance and Gait Scale (Tinetti, 1986) and Get Up and Go Test (Mathias et al., 1986).
Exercise Training and Balance

An important issue in the study of balance, especially with respect to prevention of falls, is whether deterioration of postural control is an intrinsic part of the aging process or if a significant component of this deterioration is due to inactivity or disuse (Lord, Caplan & Ward, 1993). Loss of strength and decline in reaction times associated with the aging process may simply be the result of physical inactivity. In a study by Spirduso (1975), young and old subjects were grouped as physically active or non-active. Each of the four groups were timed at executing simple and complex tasks. Movement times of the older subjects were significantly slower than their younger counterparts in the same activity class. However, the active subjects, whether young or old, had faster movement times than the non-active groups (Spirduso, 1975).

Habitual physical activity may influence postural control. Iverson, Gossen, Shaddeau and Turner (1990) grouped 54 elderly men by activity level to look for correlations between balance, lower extremity strength and activity level. All three groups were free of balance impairments. After testing each group for strength and balance, the most active men had significantly higher balance scores on the the one-leg stance test eyes-closed (EC) and the sharpened Romberg EC (tandem stance) as well as greater strength.
Documented increases in strength and cardiovascular performance suggest that exercise can bestow the same benefits of increased aerobic capacity and physical fitness on elderly people as on younger individuals (Nichols, Omizo, Peterson & Nelson, 1993). A recent study suggests potential effects on strength. Healthy men aged 60 to 72 years were trained for 12 weeks with a standard resistance training program. Loads were equivalent to 80% of one maximal repetition (1-RM). Group strength increased throughout the three month session. At the end of training, composite knee flexion improved by 100%; knee extension by more than 200%. There was also considerable muscle hypertrophy of both Type I and Type II fibers. The 5% average weekly gain was similar to increases reported for young adults (Frontera, Meredith, O'Reilly, Knuttgen & Evans, 1988).

Several other studies have found that regular adherence to an exercise program can significantly improve muscle strength (Nichols et al., 1993; Lord et al., 1993; Nelson et al., 1994). Because loss of strength in the lower extremities has frequently been cited as a factor in impaired postural control (Tinetti et al., 1993; Maki et al., 1993; Lord et al., 1991), exercise programs intended to increase strength have been viewed clinically as one remedy for balance deficits. Direct training of balance skills, such as tandem walking, unipedal stance or improving response to perturbation have also been undertaken (Judge,
Whipple & Wolfson, 1994; Johansson & Jarnlo, 1991). However, the specific effects of exercise on various functional systems has not been adequately shown (Buchner et al., 1993; Reinsch et al., 1992), and may contribute to the diversity of conclusions reached by similar types of studies.

Studies that have measured the effects of exercise training on static balance present conflicting results. Lord and Castell (1994) found a significant decrease in all four conditions of body sway (standing with EO or EC on foam or on floor) after 22 weeks of gentle aerobic training. In an earlier pilot study with exercising women, Lord et al. (1993) used the same four test conditions for body sway; only the amount of sway with eyes closed on a foam surface was significantly different from the control group. Era (1988) reported decreases in postural sway following general exercise training, while Crilly, Willems, Trenhol, Hayes and Delaquerriere-Richardson (1989) reported no post-exercise decrease in postural sway on a force platform. These results should be evaluated with some reservations. Although many researchers have shown a positive association of aging with postural sway, no such association has been demonstrated between postural sway and balance problems.

Another consideration in comparing the results of different studies is the age of the subjects. Lichtenstein et al. (1989) trained elderly women in static and dynamic
swayed significantly less with their eyes open, but swayed more than the controls with their eyes closed. These women were at least 10 years older (mean age, 77.5 years), as were the women in the Crilly study (mean age, 82 years), than the subjects in the other studies cited. The differences in subject age may have affected study results.

Judge et al. (1993) noted significantly improved balance times in women (mean age, 68 years) on the one-leg stance test after six months of strength and balance training. In a much larger study, the same researcher (Judge et al., 1994) combined resistive training with balance training in a group of elderly people (mean age, 80 years). After three months there was no significant change in a timed sit-to-stand test or an increase in maximum gait speed.

None of these studies is able to state conclusively that exercise can improve balance. Some of the problem may lie in the small scope of these studies; none employed more than 23 treatment subjects.

Another consideration is whether exercise is being used to remediate balance deficits or to improve already adequate postural control. If the purpose is to correct balance impairments, then the severity and duration of the subject's problems, or at least their functional limitations, should be known before comparing the treatment results of one study with another.
with another.

Time parameters and exercise protocols show a lack of consistency from one study to another. In the studies reviewed, treatment regimens varied from as little as 5 weeks to as long as 1 year. Some treatments consisted of direct balance training, others were general strength and endurance training. In a few cases, the description of the exercise intervention was so brief that assessment of it was not possible.

The age and the health of the subjects are other variables which should be examined carefully when comparing research results. In the studies cited above, the mean age of the subjects ranged from 61 years to 82 years. Subjects in some studies were closely screened to exclude health disorders, while in others subjects were included because they had neurological or other problems.

Some very large studies have been done. They also display contrasting results. In a fall prevention program, which lasted one year and included 236 adults over age 60, the effectiveness of cognitively oriented interventions, as well as strength and balance programs, to reduce falls was assessed. No significant changes in either strength or balance measurements were found (Reinsch et al., 1992). Yet in another large study, Province et al. (1995) reported that direct balance training for elderly subjects was positively associated with reductions in the total number of falls.
HYPOTHESIS

This study attempted to demonstrate the effectiveness of gentle, aerobic exercise as a means to improve balance in elderly people by supporting the research hypothesis. The test instrument used was the functional reach test (FRT).

The research hypothesis: "the FRT scores of the elderly exercising group will be significantly higher than the FRT scores of the control group which does not participate in an exercise program".
CHAPTER 3: METHODOLOGY

Study Design

This research was a descriptive study using a nonrandom selection of 25 treatment and 25 control subjects. The treatment subjects were solicited from already formed exercise groups. Members of various social groups were asked to volunteer as control subjects. A health questionnaire was used to select all subjects in the study. The two essential criteria for selection of subjects were: (a) the ability to participate in a regular exercise program and (b) an absence of balance problems. Individual balance scores obtained from administering the functional reach test (FRT) yielded statistics for comparing the composite balance scores of the two groups and provided a basis for accepting or rejecting the research hypothesis (refer to Chapter 2).

The decision to study balance with a nonrandomly chosen pool of subjects was based on two considerations: (a) the desirability of long-term exercise participation (1-10 years) of the group members. Theoretically, they could provide a stronger reference for comparison of treatment and control groups than a group which had exercised for a shorter period and (b) the time and resources required to implement a 6 month program of exercise for randomly chosen treatment subjects with controls exceeded the scope of the
current planned work.

Before the population was sampled and the data analyzed, certain potential limitations were acknowledged. The nonrandom research design and the selection of subjects from a single source would result in a very limited power to generalize from the sampling frame to the target population. Also, it would not be possible to establish a strong causal relationship between any observed differences in balance and the effect of exercise because of the nonrandom design. The small sample size could result in low statistical power for the test and create difficulty in identifying confounding variables in either the treatment or control group. The sample might be biased by socioeconomic or cultural factors. A lack of sensitivity of the test instrument chosen might also affect results. And finally, the study was not double-blind; researchers and subjects knew who belonged to the treatment and control groups.

In this study, the independent variable was participation or nonparticipation in a low-impact aerobics class for at least 6 months with 80% attendance or more. This participation was designated as the treatment portion of the study.

A single exercise treatment began with 10 minutes of gentle trunk and limb stretching and ended with a similar, but shorter, cool down period. The 30 minute aerobic component consisted of instructor led walking, marching, and
stepping in place to music with a variety of repeated upper body motions. All activities were done in a standing position; a few were done in single leg stance. There were three such exercise sessions per week.

The dependent variable consisted of the balance scores obtained from administering the functional reach test (FRT) developed by Pam Duncan and colleagues (1990) to each member of the exercise and control groups.

Study Site

Evergreen Commons is a large day center for elderly people in Holland, Michigan and adjacent areas. More than 4000 people are members. It is housed in a modern, well-equipped facility. Daily meals are served to members, guests and those who are homebound. Special care is provided on a regular basis for people recovering from strokes or other disabling health conditions. A gift store sells items made by members. Some regular day activities at the center are: exercise, swimming, dance and other recreational classes; choir and community service groups; seasonal dances and social events, as well as opportunities for education and travel.

Sampling Frame

The sampling frame consisted of healthy adults, aged 65 or over, who were enrolled in an exercise class at Evergreen
Commons. Similar subjects who were not enrolled in an exercise class served as controls. This sampling frame was selected to study the target population of all healthy adults over age 65 who were capable of regular, moderate exercise.

Subjects for the exercise and control groups were recruited directly from the senior day center (Evergreen Commons). Several brief presentations of the study were made by the researcher to the exercise classes to obtain volunteers for the treatment group; selected social groups were approached for control subjects. Specific social groups were chosen on the basis of a convenient morning meeting time for data gathering. Social groups which provided volunteers for control subjects included: a card players' group, a sewing club, the harmonica band, a handbell choir, and the Evergreen choir.

Test Instruments

Two instruments were used in this study: a health questionnaire for qualifying subjects and a clinical test to assess balance.

The health questionnaire (see Appendix A) was developed by the researcher to select healthy subjects, free of balance problems, who had the physical capacity to exercise in an age-appropriate program. All subjects filled out the questionnaire. Assignment to either exercise or control
group, or exclusion from the study, was determined by applying the criteria of the study. The health questionnaire and the initial personal data questions contained the criteria.

The following lists describe the inclusion and exclusion criteria of the study and relate them to questions on the health questionnaire.

Inclusion Criteria for All Subjects:

Note: Bracketed [ ... ] numbers correspond to questions on survey.

1. Age sixty-five years or older [ personal data ]
2. Able to raise dominant arm to shoulder level. [ 1 ]
3. Capable of participating in a regular exercise class for elders and is not disqualified by any of the exclusion criteria. [ "yes" response for: 2,3,5; "no" response for: 4,6,7,8,9,10,11 ]

Exclusion Criteria for All Subjects:

1. Any impairments of gait and/or the use of an assistive device (cane, walker or wheelchair) for mobility made necessary by any of the following conditions: hip or knee replacement, bone fractures, acute or chronic orthopedic problems, the disabling effects of arthritis or lower limb amputation. [ 2,3,4 ]
2. Any impairments of balance resulting from orthostatic hypotension, vestibular disorders or uncorrected visual deficits or abnormalities. [ 5,6]  
3. Neurological disorders such as Parkinson's disease, Huntington's, Alzheimer's, multiple sclerosis or diabetic neuropathy. [ 9,10 ]  
4. Medical history of stroke or heart attack as diagnosed by a physician. [ 7 ]  
5. Physician ordered limitation of physical activity due to heart attack, angina or other cause. [ 8,11]  
6. Body weight which is 35% greater than amount recommended for height in the AMA Family Medical Guide (Kuntz & Finkel, 1987). [ personal data ]

**Inclusion in the Treatment Exercise Group:**

1. Regular attendance in one of the two aerobic exercise classes at Evergreen Commons. These classes differ only in meeting time.  
2. Minimum attendance is 8 times per month for at least 6 months.

**Inclusion in the Control Group:**

1. No participation in any type of regularly scheduled exercise class.
The functional reach test (FRT) is the second test instrument used. It approximates the center of pressure excursion (COPE) test used in laboratory settings. Duncan, Weiner, Chandler and Studenski (1990) developed the FRT to provide a reliable, inexpensive means to assess dynamic balance in the clinic.

The FRT differs from other clinical measures of balance such as the Romberg or one-leg stance test because it is based on voluntary movement. A standing subject is asked to reach forward with his or her dominant arm to the limit of perceived stability, or just to that point at which a step forward might be necessary to maintain balance.

During the test movement, the subject undergoes a series of feedforward postural adjustments to prepare for reaching and to maintain balance during the reaching. The preparatory phase which immediately precedes movement is referred to as the anticipatory set (Crutchfield & Barnes, 1993).

The distance that a subject is able to reach forward is measured by a yardstick mounted parallel to the floor at shoulder height. Functional reach is defined by Duncan et al. (1990) as "the difference between an arm's length and maximal forward reach, using a fixed base of support". Subsequent studies were conducted to demonstrate the test's reliability, precision, concurrent validity with COPE and test-retest reproducibility (Duncan et al., 1990 & 1992;
Weiner et al., 1992). Weiner and colleagues (1992) have shown the test to be highly correlated with physical frailty ($r=-0.84$). It has demonstrated ability to predict the risk of recurrent falls (Duncan et al., 1992). The test was also shown to be sensitive to changes in the rehabilitative status of 28 male veterans (Weiner et al., 1993).

**Procedures**

The methods, which were used to implement the various phases of the study, are described below. They were observed in order to provide consistency and reproducibility for the study as well as to allow for critical assessment of results.

**Recruitment of Subjects:** To each exercise or social group, the researcher presented the following information: the purpose of the study, its possible significance to the problem of preventing injurious falls, the need for volunteer subjects, the requirement of filling out a health survey form and the small amount of additional time required if selected as a subject. Interested volunteers filled out a health questionnaire and informed consent form (see Appendix A for both forms).

Question # 15 on the health questionnaire asked subjects to rate their own physical fitness on a 5 level scale. They had to mark the most difficult walking activity they could sustain for a full 5 minutes. Activities ranged
from slow walking to fast running. Many subjects found the rating task to be confusing. To ensure consistency of response, the researcher clarified the intent of the question with each subject. This need for clarification may have introduced an element of experimenter bias which had not been anticipated. Other questions concerning the forms or the study itself were also addressed.

Nine presentations on six separate mornings were given. Twenty-eight people volunteered from the exercise groups; 27 others volunteered as controls. Three of the exercisers and two of the nonexercisers did not qualify under the study criteria. Each study group then contained 25 subjects.

**Administration of the Functional Reach Test:** This procedure very closely followed the protocol for clinical measurement described by Duncan et al. (1990). Any deviation from her method is noted.

The subject was asked to stand with feet comfortably spaced, toes touching a line on the floor, arms relaxed at the sides. Shoes were not removed unless the heel was greater than .5 inches. Duncan measured her subjects in bare feet. This deviation from her method was considered minor because Bohannon et al. (1984) had found no significant difference between the scores of subjects who performed the one-leg stance test with their shoes on or with them off.
A moveable measuring device was attached to a wall. The shoulders of the subject were positioned perpendicular to the wall. The measuring device employed was a 36" metal yardstick which could be adjusted and leveled to the height of each subject's acromion process.

After correct positioning of subject and measuring tool, the subject was instructed to raise his right arm until horizontal at shoulder level and make a fist. The researcher recorded the starting position as the point on the yardstick where the top of the subject's third metacarpal, or third knuckle, fell. This was designated as position 1.

The subject was next instructed to "lean as far forward as you can without taking a step" (Weiner et al., 1993). The new placement of the third metacarpal on the yardstick was recorded as position 2. If a subject contacted the wall or stepped forward accidentally, the trial became invalid and another was repeated.

In accordance with the protocol developed by Duncan et al. (1990), each subject was given two practice trials and three test trials. A balance score for each subject was calculated by applying the definition of functional reach: "the mean difference between positions 1 and 2, over three trials." (Duncan et al.).

To maintain identical foot placement during all test conditions, Duncan traced foot positions on paper on the
force platform and transferred these positions to the "yardstick" test for clinical use. Recording of foot positions was not done in this study. Subjects assumed a stance and maintained it for all five trials. If stance was altered, the subject returned to the line on the floor. Use of such a line is not mentioned in the Duncan's original study (1990).

In the original 1990 study by Duncan and colleagues, all subjects were right-hand dominant and were tested while using their dominant right arm. In this study, subjects were tested by using whichever arm was dominant. One exception occurred when a woman experienced some shoulder discomfort from reaching and was allowed to use her nondominant arm to do the test.

Precautions: At all times during the FRT, one person guarded the test subject for falls. Falls were not likely because subjects with postural instability had been screened out of the study and the test movement itself was controlled by the subject. However, both researcher and assistant were available to assist as necessary. No problems were encountered during the testing.

Confidentiality of data was assured by numbering the health questionnaires. The numbers from questionnaires were used to identify individual test results. When compiling the data and analyzing results of the study, use of the numbers helped somewhat to blind the researcher to other
characteristics of the participants. At the time of testing, subjects signed and received a copy of their informed consent form which safeguarded their right to confidentiality.

Data Collection: This was done at the senior day center before and after scheduled classes on eight different mornings. Subjects filled out a screening health questionnaire prior to testing and had an opportunity to ask questions about the study or refuse to participate during the initial recruitment session. Those who wished to participate, and who were also qualified, read and signed an informed consent form. Groups of 5 to 7 subjects were measured at each testing session. The primary researcher directed subjects into the appropriate test position, conducted the test and recorded all trial measurements. The research assistant helped organize screening forms, answered questions and stood by as close guard during the test trials. A data collection form (see Appendix B) was used to record the results of all valid trials for each subject.

Data Analysis

The statistical analysis of the data collected consisted of the use of a two-sample t-test to compare the mean FRT score of the exercise group to the mean FRT score of the control group. The variables of age, gender, and fitness level were used to describe the characteristics of
the experimental and control groups. Regression analysis was used to determine the degree of influence that the variables of age, fitness level or membership in either of the two groups might have had on the FRT scores.
CHAPTER 4: ANALYSIS OF DATA

Characteristics of Subjects

Four variables were collected for each subject: age, gender, fitness level and functional reach test score. The variables were then analyzed by group. The exercise group was 2.5 years older (mean age 75.3 years) than the control group (mean age 72.8 years). The mode for the distribution of ages was 73 years for the exercise group and 68 years for the control. Table 1 describes the age and gender attributes of both groups.

Most of the subjects were females: they accounted for 88% (n=22) of the subjects in the exercise group; 72% (n=18) in the control group. There were 28% more male subjects (n=7) present in the control group than in the exercise group (n=3).

Table 1

AGE and GENDER CHARACTERISTICS of the SAMPLE

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Age</th>
<th>Range</th>
<th>Median Age</th>
<th>% Female</th>
<th>% Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>75.3</td>
<td>65-85</td>
<td>74</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>Control</td>
<td>72.8</td>
<td>65-84</td>
<td>72</td>
<td>72</td>
<td>18</td>
</tr>
</tbody>
</table>

* $n_1=n_2=25$
Each subject had described his or her fitness on a five level scale (see health questionnaire, Appendix A). The exercise group had a few more of its subjects at the most difficult level (Level 5) and the middle level (Level 3) compared to the control group. And at each fitness level, the mean age of the exercise group was greater. The full distribution of mean ages and fitness levels for each group is shown in Table 2.

The following statements characterize the exercise group: it is somewhat more fit than the control group, it is older; it contains more females than the control group.

Table 2

**NUMBER AND MEAN AGE OF SUBJECTS AT EACH FITNESS LEVEL**

<table>
<thead>
<tr>
<th>Level</th>
<th>EXERCISE GROUP</th>
<th>CONTROL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number %</td>
<td>Age</td>
</tr>
<tr>
<td>Level 1</td>
<td>n=0 0%</td>
<td>-</td>
</tr>
<tr>
<td>Level 2</td>
<td>n=2 8%</td>
<td>75.5</td>
</tr>
<tr>
<td>Level 3</td>
<td>n=9 36%</td>
<td>75.8</td>
</tr>
<tr>
<td>Level 4</td>
<td>n=9 36%</td>
<td>73.7</td>
</tr>
<tr>
<td>Level 5</td>
<td>n=5 20%</td>
<td>77.2</td>
</tr>
<tr>
<td>Totals</td>
<td>n=25 100%</td>
<td>75.3</td>
</tr>
</tbody>
</table>
Comparison of Performance

Table 3 provides some descriptive statistics for the FRT scores calculated for each group separately. The performance of the two groups was compared by calculating the mean FRT scores for each group. A two-sample t-test was then performed to determine if the mean FRT score for the exercise group was significantly higher than that of the control group. At the $\alpha=0.05$ level, it was not found to be significantly higher ($t=-.2849$, df=38, p-value=.61155).

Table 3

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Score/SD**</th>
<th>Q1</th>
<th>Median</th>
<th>Q3</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>11.53/2.49</td>
<td>9.83</td>
<td>11.83</td>
<td>13.17</td>
<td>6.17,16.17</td>
</tr>
<tr>
<td>Control</td>
<td>11.75/2.63</td>
<td>10.17</td>
<td>12.17</td>
<td>13.83</td>
<td>5.33,16.00</td>
</tr>
</tbody>
</table>

* $n_1=n_2=25$

** mean FRT score in inches/standard deviation

Therefore, there was insufficient statistical evidence to conclude that the mean FRT score for the exercise group was larger than the mean FRT for the control group. The sample means from this study even went in the opposite direction; the mean FRT score of the control group (11.75 in.) was slightly larger than the mean FRT score of the exercise group (11.53 in.).

To assess the degree of possible effect that the variables...
of age, fitness level or group membership might have had on the balance scores, a least squares regression analysis was performed. Gender was not analyzed due to the small number (n=3) of males in the treatment group. The high p-values (see Table 4) indicate that no statistically significant influence was found (using α=0.05) for any one of the variables.

The values of $R^2$ in Table 4 show the percentage of variation in the FRT scores which can be explained by each model. For example, Model I contains an intercept term and the covariates of age, group and fitness level. (The ranked fitness levels were coded as dummy variables). This model shows that only 3.9% of the variation in the FRT scores can be explained by the model. The p-value of .8739 suggests that the $R^2$ value is not significantly different from zero. Therefore, Model I is not useful in predicting the FRT scores.

Table 4

SUMMARY OF THE REGRESSION MODELS EXAMINED*

<table>
<thead>
<tr>
<th>Model</th>
<th>Intercept</th>
<th>Levels</th>
<th>Age</th>
<th>Group</th>
<th>F-value</th>
<th>$R^2(%)$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>0.36</td>
<td>3.9</td>
<td>.8739</td>
</tr>
<tr>
<td>II</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>0.34</td>
<td>1.4</td>
<td>.7115</td>
</tr>
<tr>
<td>III</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>0.35</td>
<td>3.0</td>
<td>.8430</td>
</tr>
<tr>
<td>IV</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>0.44</td>
<td>3.8</td>
<td>.7269</td>
</tr>
</tbody>
</table>

* the FRT scores are the dependent variable
The least squares regression analysis shows that even if one adjusted for age and fitness levels (Models II and III), the mean FRT score for the exercise group was not significantly different from the mean FRT score for the control group (see p-values in Table 4 for Models I, II and III).

Assessment of Results

To assess the probability that we had failed to reject a false null hypothesis, or made a Type II error, we performed a power analysis. The analysis was used to determine if the size of the sample in this study had sufficient strength to identify a higher mean for the exercise group if this were actually true.

The power analysis was used in two ways. First, to interpret the strength, or power, of the statistical results and secondly to obtain an estimate of the sample size that might be more useful for further research.

With a sample size of 25 treatment subjects and a power level of approximately 80% (using α=0.05), the smallest real difference which could have been detected between the mean FRT scores of the control and exercise groups was 2 inches (with this same sample size, there was a 10%-17% chance of detecting a .5 inch difference between the means). Table 5 displays the potential of the study sample (n₁=n₂=25) to detect a significantly higher true mean for the exercise group (expressed in inches) when compared to the true mean of the control group using α=0.05. This relationship is notated as μ₁−μ₂.
Table 5

POWER AVAILABLE* TO DETECT DIFFERENCES BETWEEN TWO MEANS

<table>
<thead>
<tr>
<th>$\mu_1 - \mu_2$</th>
<th>Effect Size***</th>
<th>Level of Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>.5</td>
<td>.195</td>
<td>(.10, .17)</td>
</tr>
<tr>
<td>1.0</td>
<td>.390</td>
<td>(.28, .40)</td>
</tr>
<tr>
<td>1.5</td>
<td>.585</td>
<td>(.54, .67)</td>
</tr>
<tr>
<td>2.0</td>
<td>.780</td>
<td>(.79, .88)</td>
</tr>
<tr>
<td>2.5</td>
<td>.976</td>
<td>(.88, .97)</td>
</tr>
</tbody>
</table>

* $n_1 = n_2 = 25; \alpha = 0.05$

** $\mu$ is the true mean FRT score of each group; units are inches

*** magnitude of difference between the FRT score means

The statistical power of future studies could be improved by increasing the sample size. The following sample sizes refer to the number of experimental subjects needed for each group.

To detect a difference between $\mu_1$ and $\mu_2$, with $\alpha = 0.05$ and 95% power, a sample of 144 subjects in each group is required to detect a 1.0 inch difference in the mean FRT scores of the treatment and control groups; 64 subjects in each group are necessary to detect a 1.5 inch difference in the mean FRT scores.

Fewer subjects are needed as power is reduced. By lowering the power to a level of 80%, a 1 inch mean difference in FRT scores can be detected with a sample size of 83 subjects in each group; 37 subjects per group can detect a 1.5 inch difference.
Summary

The following statements summarize the results of the analysis of the data. The mean of the FRT scores of the exercise group was not significantly higher than that of the control; in fact, the exercise mean displayed a negative effect. The sample size did not have sufficient power to rule out the possibility of a Type II error. If the FRT scores of the exercise group had been found to be higher, an actual difference of 2 inches was necessary for it to be detected by the study sample (at .80 confidence level). Finding a difference of this magnitude was not likely since the FRT scores of both groups varied within a range of only 10 inches. Regression analysis showed that none of the variables of age, group membership or fitness level had a significant influence on the FRT scores. The results of the t-test comparison of the mean FRT scores of the two groups indicated a lack of support for the research hypothesis. From these statistical analyses it was not possible to conclude that a real difference existed between the groups. However, the possibility that no real difference existed between the two groups could not be ruled out, since power of the 25 subjects in each group was sufficient to detect only relatively large differences.
CHAPTER 5: DISCUSSION OF FINDINGS

Interpretation of Results

The goal of this study was to demonstrate that the balance scores of the exercise group would be significantly higher than those of the control group. Statistical analysis of the data failed to support such a difference. We did not have enough evidence to determine whether or not a regular, aerobic exercise program is a significant factor in the maintenance or improvement of balance in a normal healthy population of elderly adults without balance problems. The exercise treatment may have provided a benefit factor which was not statistically observable.

This possible benefit is suggested by the differences in fitness levels and age which were observed between the two groups. The exercise group was older (2.5 years) than the control group, yet those subjects described themselves as somewhat more fit. Those subjects in the exercise group who could "run fast for 5 minutes" (Level 5), were 6.5 years older than the control subjects at the same level. The exercisers who could "walk fast for 5 minutes" (Level 3) were also 4 years older than their control group counterparts.

This observation that some of the older exercising subjects would have greater fitness than the nonexercisers
is supported by the accepted relationship between regular exercise and increased fitness. It also indicates the potential benefit of regular exercise to offset some of the effects of normal age-related physiological decline such as muscle weakness and loss of flexibility.

The control group was found to have a comparable but slightly lower overall fitness level. The extraneous variable of independent exercise may have confounded the true effect of the exercise treatment and skewed the fitness profile of the control group. Several control subjects reported walking regularly for exercise or riding a stationary bicycle; many described their fitness at Level 4 (slow jog for 5 min.) or Level 5 (run fast for 5 min.). The potential effects of any form or amount of exercise were not excluded from the control group. The self-rating of fitness was included in the initial questionnaire to identify the possible effects of this variable and provide some means of descriptive control.

The Work of Other Researchers

General aerobic exercise can improve fitness, but it may not be sufficient to improve balance in healthy adults. If the exercise and control groups in this study were in fact about equally fit, would the inclusion of specific balance exercises in the regimen have produced higher functional reach test (FRT) scores? Several studies address
Johansson and Jarnlo (1991) administered a 5 week program of walking and balance exercises to a group of 18 healthy women, all aged 70 years. The exercise program described was similar to the one in this study, except the subjects directly practiced the tests used to assess their balance. Nine balance tests were given before and after training; significant improvements were shown on 6 of the 9 tests, but on none by the matched controls.

Two tests in the Johansson and Jarnlo (1991) study involved timed walking; a third, walking a balance beam. The remaining six tests were variations of the one-leg stance test (eyes open, eyes closed, head rotated) performed on both right and left legs. From the improved performance scores of these tests, the authors concluded that healthy women could improve their standing and walking balance.

Whether the authors of this study (Johansson & Jarnlo, 1991) should have used both the right and left leg scores as separate tests to support their hypothesis is questionable. They did not compare the scores from each leg to determine if there were significantly different. In a descriptive study of static balance in 71 elderly women, Briggs et al. (1989) found no difference between right or left leg one-leg stance test (OLST) scores, regardless of dominance. Heitmann, Gossman, Shaddeau and Jackson (1989) warn about a possible practice effect for the OLST and
sharpened Romberg test based on significant differences between the first and best scores of subjects taken during a single test session. A similar learning effect from mental practice of the OLST in a short time span has also been documented (Fansler, Poff & Shepard, 1985). Results from studies where the training method and the assessment tools are very similar require careful interpretation.

Direct balance training was used by Judge et al. (1994) in a large, well-constructed study (n=110). Subjects over age 75 practiced dynamic and static balance exercises and learned to stand on a moving force platform. After three months, tests of gait velocity and chair-rise time indicated no improvement in balance. The subjects had not trained specifically for these activities, but their performance raises the question of transferability of specific skills to functional activities. Another issue is whether the practice of a part of an action will enhance the performance of the whole action (Winston, 1989).

Crilly et al. (1989) reported no change in balance, as measured by postural sway, following three months of specific balance and general exercise training in 25 elderly women (mean age 82 yrs.). This was attributed to deterioration in their nervous systems. One aspect of the test procedure seems inappropriate for such an elderly sample. Subjects had to stand with 6 cm. (2.4 in.) distance between their feet. This narrow base of support increased
the difficulty of postural control (Heitmen et al., 1989) and may have obscured functional gains. A group of elderly disabled veterans failed to show improvement on a balance test, but did demonstrate functional improvements after balance training (Sauvage et al., 1992).

In a pilot study, Lichtenstein, Shields, Shiavi and Burger (1989) trained 24 women (mean age 77.5 yrs.) in balance and general exercise for four months, but obtained inconsistent results. Exercisers could stand longer on one leg with eyes open, but not as long as the controls with eyes closed.

The physical characteristics of the study subjects have the potential to influence findings. For the Seattle FICSIT/MOVEIT Study (Buchner et al., 1993), 180 subjects with gait and balance impairments were chosen to determine if exercise could improve function. It was reasoned that in older adults with adequate physiologic reserve, exercise would be expected to further increase reserve but not improve daily function in gait or balance. The findings of greater fitness at increased ages in the exercise group of this study, but not higher balance scores, tends to support this reasoning.

Lack of a generally accepted balance test or series of tests to serve as a standard makes comparisons among this study and others difficult, even though some researchers have worked to establish correlational validity between some
tests (Berg et al., 1992; Piotrowski & Cole, 1994).
Variability in elderly study populations further complicates comparisons between them.

Applications to Practice

These findings suggest that while exercise may be beneficial to remediate identified balance problems in certain populations (e.g. stroke and head injury), it may not be an important tool for affecting balance in a healthy population. The relatively high fitness level of the control group suggests that functional activities, which include the normal activities of daily living, may furnish a similar or greater potential to affect balance than an organized exercise program.

The apparent absence of balance problems in this study population indicates that balance impairments are not an inevitable accompaniment of the aging process. Or it may be possible that healthy, active adults are able to compensate for the subtle effects of age-related declines within the various bodily systems. When elderly adults do experience balance problems, the causes are more likely to be found in the effects of medications, disease processes, deconditioning or orthopedic disabilities.
Limitations of the Study

The limitations of this study are in three general areas: the population from which the study sample was drawn, the characteristics of the test instrument used, and the size of the sample.

The ability to generalize from this study population is restricted to similar populations for two reasons. First, the exercise and control group subjects were not chosen with a random method and secondly, all were chosen from a single, somewhat unique subject pool. Because of the study exclusion criteria, they do not represent all adults over age 65; the subjects may not even be representative of most healthy adults over age 65. Several features of the population may have made this sample unique: most of the people belonged to a middle or upper middle class socioeconomic group; most were of a common ethnic ancestry; all were members of a senior social center which provided opportunities for exercise, education, service work and socializing on a scale few senior centers offer.

Use of this particular test instrument affected the findings of this study. The possibility of obtaining significant results might have been increased if a different type of balance test had been used. The FRT is based on a feedforward response. Subjects initiate movement and control the excursion of their center of pressure (COP) to the limit of their perceived margin of stability. A
perturbation test, such as the postural stress test (Wolfson et al., 1986), evokes a different type of balance response. It elicits an automatic postural response which relies on a feedback rather than feedforward pattern. This test might have been more challenging to the subjects or more sensitive to differences between them.

As an alternative, one or more other test instruments could have been used in conjunction with the FRT. Administration of a clinical test with normed values, such as the one leg stance test, or a functional battery such as the Balance Scale (Berg et al., 1992) or Tinetti's Performance-Oriented Assessment (1986) may have provided a better description of balance ability in this population. Because postural control is a complex phenomenon, there is no single valid test of measurement or method of assessment.

Some subjects might have had minor impairments or other deficiencies in balance that were not detected by the functional reach test. Test scores on the low end of the range may have indicated the presence of balance disturbances which were unnoticed by the subjects. Eight subjects in the exercise group and 5 subjects in the control group had FRT scores of less than 10 inches. According to Duncan, these people are twice as likely to have an unexplained fall. One control subject had a FRT score of less than 6 inches, which put her at a fourfold risk for a fall (Duncan, unpublished data, given on Jan. 13, 1992).
Another consideration is the appropriateness of using the FRT to assess balance in an active, healthy population. This test was developed as a measure of frailty to identify elderly people who were likely to have an unexplained fall (Weiner et al., 1993). It may lack sufficient sensitivity to detect subtle differences among healthy, active adults; it might have obscured a small, but nonetheless real, difference in balance ability between the two groups.

The other rating instrument used, the fitness level categorization, was based on the subject's appraisal of his or her fitness. It was included to categorize subjects for purposes of comparison between the two study groups and between individual group members. This classification strategy was limited by its subjective format; it also proved difficult for the subjects to understand. To ensure the consistency of responses, the researcher carefully explained the fitness rating question to each subject individually. While this strategy may have helped to maintain the internal validity of the study, it may also have introduced an unknown measure of researcher bias.

The third limitation of this study was the small size of the sample. The statistical power of this sample was able to detect only a relatively large difference of 2 inches or more at a reasonable level of confidence (80%). See chapter 4 for a more complete discussion of sample size.
Conclusion

The results of data analysis led to the conclusion that in a population of healthy adults, participation in a regular exercise program may not be an important factor in the maintenance or improvement of balance. However, most of the subjects in both exercise and control groups maintained active lifestyles. The maintenance of health and full mobility through exercise and an active lifestyle may be key factors in reducing the risk of injurious falls. Further research might be done to test the same hypothesis by using larger groups to increase statistical power and by selecting a more sedentary control group.
REFERENCES


exercise training. Physical Therapy, 73, 254-265.


APPENDIX A
PARTICIPANT'S HEALTH QUESTIONNAIRE

TODAY'S DATE

NAME

ADDRESS

CITY ZIP

APPROXIMATE HEIGHT WEIGHT

BIRTHDATE HOME PHONE

PLEASE RESPOND TO EACH QUESTION BY CIRCLING YES OR NO

1. I am able to raise my arm to shoulder level or higher. Yes No

2. I am able to climb stairs without pain or difficulty. Yes No

3. I never use a cane, walker or wheelchair for getting around. Yes No

4. I have had hip or knee replacement surgery or a lower limb amputation. Yes No

5. My vision is within (or corrected to) normal range. Yes No

6. In the past month, I have experienced dizziness when walking or when standing up from sitting. Yes No

7. I have been treated for a stroke by a physician. Yes No

8. I have been treated for a heart attack by a physician. Yes No

9. I have Parkinson's disease or some other neurological disorder. Yes No

10. I have diabetes. Yes No

11. My physician has placed limitations on my physical activity. Yes No

12. I have been enrolled in and participated in a regular exercise program (at least 90 minutes per week) for the last 6 months. Yes No
13. I take prescription medication for certain health conditions.  Yes  No
If yes, please list the conditions.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

14. I take over the counter medication for certain health conditions.  Yes  No
If yes, please list the conditions.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

15. Look at the boxes with pictures.
Circle the box which shows the HARDEST ACTIVITY you think you could do for FIVE MINUTES WITHOUT STOPPING.

<table>
<thead>
<tr>
<th>WALK slow pace*</th>
<th>WALK medium pace</th>
<th>WALK fast pace</th>
<th>JOG slow</th>
<th>RUN fast</th>
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<td><img src="image" alt="Slow Jog" /></td>
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</table>

*(note: for 5 minutes without stopping)*

*Slow pace* is the speed required to cross an intersection with a traffic light.
INFORMED CONSENT FORM

I UNDERSTAND THAT the purpose of this study is to gather information about the combined effects of aging and activity on the postural control, or balance system, of the body. Results of this study will add to our current knowledge, which may help physical therapists or other researchers find better ways to reduce the risk of falling for some elderly individuals. I have been selected to participate on the basis of my current good health and my age.

I ALSO UNDERSTAND THAT:

1. I will participate in one test session at Evergreen Commons lasting not more than ten minutes.

2. I will be asked to stand comfortably, raise my dominant arm to shoulder height and then lean as far forward as I am able to, without taking a step. I will practice this twice, then repeat it three more times while the researcher measures how far I reach. An assistant will help me catch my balance if needed.

3. These activities are intended to be comfortable rather than stressful amounts of movement. There might be a slight risk of falling. As a safety precaution, one researcher will guard against falls. I may experience some temporary discomfort the next day from stretching forward, if this is a movement I'm not accustomed to doing.

4. The information I provide will be kept completely confidential. Data from the test will be coded so that my individual performance will not be identifiable.

5. I may withdraw from the screening or testing part of this study at any time.

7. I may ask questions of researcher Katie Smith (616)454-7668 or Grand Valley State University Professor Paul Huizenga (616)895-2470 at any time during the study.

8. I may obtain a summary of the results of this study on request. [ ] CHECK HERE if you would like to have a copy.
I CONFIRM THAT:

1. I understand the purpose of this study and that my voluntary participation may help other researchers or caregivers who are trying to reduce the risk of falls for elderly people.

2. I have had an opportunity to ask questions about this study and they are answered to my satisfaction.

3. I know I may contact researcher Kathryn Smith at (616) 454-7668 or someone at the front desk at Evergreen Commons if I decide not to participate in the study and that there will be no consequences as a result.

4. I am willing to release the information obtained in this study to the scientific literature and that I will not be identified by name.

I HAVE READ AND UNDERSTOOD THE ABOVE INFORMATION AND AGREE TO PARTICIPATE IN THIS STUDY.

Participant's Signature ____________________________ Date ________

Witness' Signature ____________________________ Date ________
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