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The effect of low intensity aerobic exercise on muscle strength, flexibility, and balance among sedentary elderly persons

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THE EFFECT OF LOW INTENSITY AEROBIC EXERCISE ON MUSCLE STRENGTH, FLEXIBILITY, AND BALANCE AMONG SEDENTARY ELDERLY PERSONS

by

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Submitted in partial fulfillment of the requirements
for the Degree of Doctor of Philosophy

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CASE WESTERN RESERVE UNIVERSITY
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Eugene M. Mills

THE EFFECT OF LOW INTENSITY AEROBIC EXERCISE
ON MUSCLE STRENGTH, FLEXIBILITY, AND BALANCE
AMONG SEDENTARY ELDERLY PERSONS

Abstract

by

EUGENIA M. MILLS

The purpose of this study was to determine the effects of a low intensity aerobic exercise program on muscle strength and flexibility of the lower extremities and balance among sedentary elderly persons. Proprioception, vibratory sensation, and visual acuity were assessed and statistically controlled for when they were significantly related to the dependant variables. Using Birren and Renner's (1977) use/disuse theory, the low aerobic exercise program was expected to increase balance and perception of balance and increase flexibility and muscle strength of the knees and ankles.

This pretest-posttest quasi-experimental study consisted of 47 sedentary subjects not engaged in regular exercise and living in metropolitan housing in southwestern Ohio. Convenience sampling was used with two apartment complexes randomly assigned to the experimental or comparison groups. To prevent diffusion of treatment, subjects were assigned to these groups depending on their place of residence. The 20 experimental subjects, with a mean age of 75.3, participated in eight weeks of low intensity exercise while the comparison group (n = 20), with a mean age of 74.8, maintained their usual level of activity for eight weeks.

The low intensity aerobic exercise program was three times a week for eight weeks. Experimental subjects also did the exercises on their own between classes. The program consisted of stretching and strengthening exercises for the lower extremities, and, except for two exercises, they were done while sitting in a chair.

The exercise group had significantly greater flexibility of the ankles and the right knee than the comparison group. No significant differences were found between the groups for muscle strength. Although balance and perception of balance were not significantly different between the groups, the experimental group improved their balance by 22.4% from pretest. This study demonstrated that sedentary elders can safely perform these exercises, find them easy to do, and are able to fit them into their daily routine.

Replication of this study should be done with different populations of sedentary elders and with longer duration for the exercise program. These may increase the effect of the program.

DEDICATION

To my parents and mother-in-law who understood my absence from family activities and offered support and encouragement.

To Judy Strayer and Mary Smith, friends extraordinaire, who were always there.

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CHAPTER I

PURPOSE AND SIGNIFICANCE

The purpose of this study was to determine if sedentary elderly persons participating in low intensity aerobic exercises, specific to the muscles of the knees and ankles, would have greater muscle strength, flexibility, and balance than sedentary elderly persons who did not participate in this intervention. Intervening variables of proprioception, vibratory sensation, and visual acuity were also assessed to identify whether they were confounding variables that needed to be controlled.

Falls pose a serious health problem for persons over 65 years of age and are the leading cause of accidental death in the 75 year and older age group. In 1984, 73% of the deaths due to falls were in the 65 years and older age group, with 59% of those deaths in the 75 years and older age group (Accident Facts, 1987). Falls may require medical and hospital care and may extend the hospital length of stay for those who fall while hospitalized (Andrews, 1986; Uden, 1985). Victims of falls fear falling again, and this fear may greatly limit their activities (Hadley, Radebaugh, & Suzman, 1985; Mossey, 1985; Murphy & Isaacs, 1986; Tideiksaar, 1986). Persons who fall and those at risk of falling are of concern to nursing as evidenced by nursing's goal to assist persons to adapt to changes in their physiological needs (Andrews & Roy, 1986).

Factors cited as having a major influence in falls are poor balance (Brocklehurst, Exton-Smith, Barber, Hunt, & Palmer, 1978; Overstall, 1980; Ring, Nayak, & Isaacs, 1988; Sheldon, 1960) and decreased muscle strength in the extensors and flexors of the knees and ankles along with markedly decreased plantar-dorsiflexion torque (Whipple, Wolfson, & Amerman, 1987).

To realign the center of body mass over supporting structures needed to maintain balance, good muscle strength and flexibility in the lower legs are required (Nashner, 1987). An intervention designed to prevent falls in the elderly would be extremely important; however, before these are initiated, specific interventions need to be tested for their effect on muscle strength, flexibility, and balance among elderly persons.

Theoretical Framework

Many theories of aging posit a genetic component of development (Ebersole & Hess, 1985). Genetics cannot be escaped or altered and have a profound effect on individual development. Omenn (cited in Birren & Renner, 1977) suggested that environmental factors also have an important influence on manifestations of aging. He believed genetics control the limits within which the environment can have an effect.

Birren and Renner (1977) used the term disuse-disease to describe the nonheritable portion of the aging process that they accredit to environmental influences. They stated that these influences often force an aging individual to limit activities. Such decreases in physical activities among elders lead to disuse resulting in characteristics similar to those attributed to aging.

Birren and Renner (1977) identified two components of the aging process. One component is genetics, and the second is environmental. Genetic and environmental influences may predispose a behavior pattern of disuse in elderly persons. Genetic factors are an endowment from an individual's parents and cannot be changed. It is variations in genetic factors that influence aging. However, Birren and Renner suggested that environmental influences that result in disuse in elderly persons can be altered and consequently reverse some of the characteristics of disuse.

Persons in Western society slow down and exercise less as they age (Shepard, 1978). Lack of activity contributes to characteristics of disuse, such as a decrease in aerobic power, an increase in body fat, and loss of calcium from the bone (Shepard, 1978). Other factors associated with disuse include a decrease in muscle fiber (type II) and muscle strength (deVries, 1970; Larsson, 1982), decrease in flexibility (Munns, 1981; Rikli & Busch, 1986), and a decrease in balance (Roberts, 1989).

Use would be a means of reversing the effects of disuse. That is, as activity increases, characteristics of disuse decrease. This research addressed three factors of use/disuse in elderly persons and focused on the effect of use, in the form of an exercise program, on balance, muscle strength, and flexibility of the lower extremities.

According to Birren and Renner (1977) participation in exercise will improve the function of parts of the body used in it. Thus, among inactive elderly persons, a low intensity aerobic exercise program targeted to the muscles and joints of the lower extremities may improve muscle strength and flexibility in the lower extremities and improve balance (see Figure 1 for the theoretical model).

Age-related Changes Influencing Muscle Strength, Flexibility, and Balance

Researchers reported that aging was associated with decreases in muscle strength (Aniansson, Hedberg, Henning, & Grimby, 1986; Gutmann & Hanzlikova, 1975; Larsson, Grimby, & Karlsson, 1979; Oretel, 1986) and delayed neurological response causing a less smooth motor response and impaired coordination (Mankovsky, Mint, & Lisenyuk, 1982; Scheibel, 1985; Woollacott, Shumway-Cook, & Nashner, 1982). Additionally reduced flexibility of joints with increasing age has been reported (Rikli & Busch, 1986). The combination of many age-related changes impair the ability of elderly persons to maintain their balance when their center of gravity is displaced.

Age-related changes in muscle strength and flexibility affect balance. Adequate muscle strength and range of motion are necessary for an individual to maintain balance when a disruption in position occurs such as with a jolt or stumble. The ability to recognize and respond to imbalance requires a well-functioning nervous system which receives and integrates input from various parts of the body. Decreased vibratory sensation and proprioception in the lower extremities have been associated with impaired balance (Wolfson,

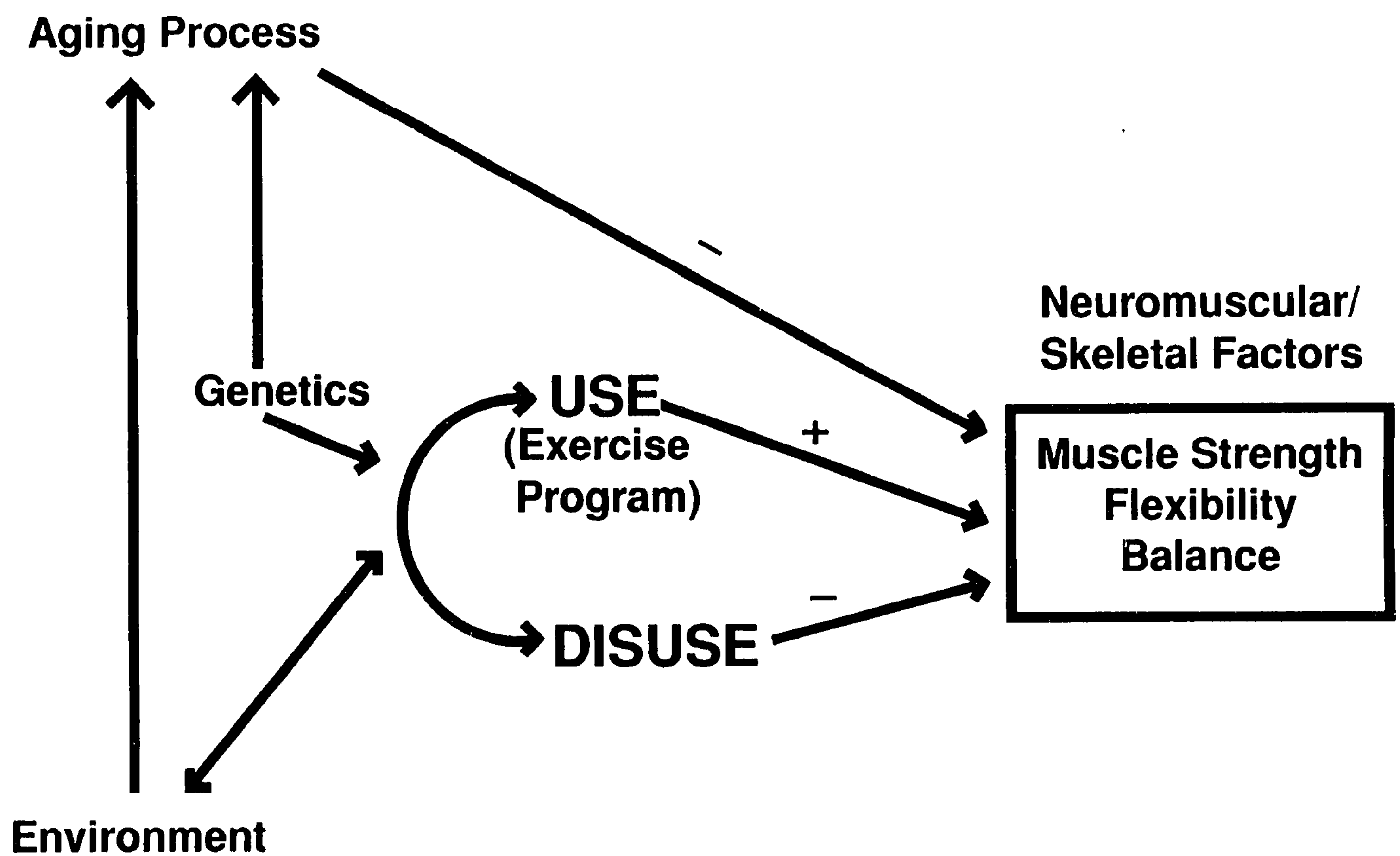

Figure 1. Theoretical model.

Whipple, Amerman, Kaplan, & Kleinberg, 1985; Woollacott et al., 1982). Vibratory sensation and proprioception are afferent inputs that are necessary for the nervous system to make the rapid motor responses required to maintain balance. Another important source of sensory inputs that affect balance are visual cues. Decreased visual acuity has been associated with a decrease in balance (Stones & Kozma, 1987; Woollacott et al., 1982).

Aging and Exercise

Exercise is generally believed to improve muscle strength and flexibility. However, the pervasive question is will exercise have a positive effect on an aging human body? Exercise programs for elderly persons have been shown to increase type II muscle fibers and increase strength and aerobic capacity of muscles (Larsson, 1982; Orlander, & Aniansson, 1980; Suominen, Heikkinen, & Parkatti, 1977). In a study of the effect of exercise on aging muscles of male and female subjects, researchers found that exercise significantly increased strength (Brown & Harrison, 1986; deVries, 1970; Kauffman, 1985). Additionally exercise programs to enhance flexibility have significantly improved flexibility in the hips, knees, and ankles (Bassett, McClamrock, & Schmelzer, 1982; Frekany & Leslie, 1975).

Research on interventions to improve balance are quite limited. Roberts (1989) studied the effects of walking as a form of exercise on balance. She concluded that walking had a significant effect on improving balance. She did not examine muscle strength, flexibility, or factors which influence balance such as visual acuity, vibratory and proprioception sensation.

Researchers have shown that exercise reverses physical decline in the elderly. Elderly persons who do not engage in regular physical activity are at risk for the effects of disuse and are the persons most in need of an exercise intervention. Wolfson, Whipple, Ammerman, and Kleinberg (1986) found that elderly fallers had very poor strength in the ankle muscles. Considering this finding, an exercise program which targeted muscles of the lower leg would be especially important. However, no known researcher has tested the effect of low intensity aerobic exercise to the lower leg and particularly the flexor and extensor muscles of the ankle among elderly persons. This study advances the research in this area by examining the effect of low intensity aerobic exercise on muscle strength and flexibility of the lower extremities and on balance in elderly persons with limited physical activity.

In this study, the dependent variables were muscle strength of the flexors and extensors of the knees and ankles, flexibility of the knees and ankles, balance, and perception of balance. Intervening variables which may have an effect on balance are vibratory sensation, proprioception, visual acuity, and previous activity level. The exercise intervention was not expected to effect directly these intervening variables. Because of their association with balance, they may confound the results of an exercise program and, thus, were measured. The following section contains the theoretical and operational definitions followed by the research questions and hypotheses.

Definitions

Low intensity aerobic exercise--exercises that involve simple stretching and strengthening of muscles in the lower leg and ankle. Low intensity aerobic exercises will raise the pulse rate from the resting pulse but not above 70% of the predicted age-adjusted maximal heart rate.

Flexibility--the maximal range of motion that is possible for a given joint. Flexibility was measured in degrees by goniometer.

Muscle strength--the force a muscle generates in a maximal effort against resistance. Muscle strength of the lower extremities was measured in kilograms using the Nicholas Manual Muscle Tester.

Balance--ability to maintain an upright position. Balance was measured by the Roberts Balance Scale (Roberts & Mueller, 1987).

Perception of balance--how subject views own stability when arising from a chair, standing, and walking as measured by the balance perception questionnaire (Roberts, 1989). Subjects rated their perception on a Likert scale ranging from 1 to 4. The score was the sum of the ratings.

Proprioception--an awareness of the position of a body part. Proprioception was measured by having the subject, with eyes closed, identify the position in which the subject's knee or ankle had been placed. The score was the number of incorrect responses.

Vibratory sensation--the ability to perceive vibrations transmitted through the skin to deeper level tissue. Vibratory sensation was measured by placing a tuning fork over a bony prominence and having the subject identify if the tuning fork was vibrating. The score was the number of incorrect responses.

Visual acuity--a measure of the acuity of the eye to see at a distance. Visual acuity was measured by the Snellen eye chart. The unit of measurement was the denominator of the line on which the subject was able to read 50% of the letters correctly.

Physical activity--activities beyond activities of daily living. Physical activity was measured by the Physical Activity Questionnaire (Walker, Sue, Miles-Elkousy, Ford, & Trevelyan, 1984).

Research Questions and Hypotheses

Research question 1: Is there a difference in muscle strength of the flexors and extensors of the knees and ankles, flexibility of the knee and ankle joints, balance, and perception of balance among elderly persons who participate in an eight-week, low intensity aerobic exercise program as compared to those who do not participate in such a program?

Hypothesis 1: Elderly persons who participate in a low intensity aerobic exercise program will have higher balance scores and perception of balance scores than those elderly persons who maintain their usual activity level for eight weeks.

Hypothesis 2: Elderly persons who participate in a low intensity aerobic exercise program will have greater flexibility scores of the knee and ankle joints than those elderly persons who maintain their usual activity level for eight weeks.

Hypothesis 3: Elderly persons who participate in a low intensity aerobic exercise program will have greater muscle strength in the flexor and extensor muscles of the knee and ankle than those elderly persons who maintain their usual activity level for eight weeks.

Research question 2: Will the differences between the two groups on muscle strength of the flexors and extensors of the knees and ankles, flexibility of the knee and ankle joints, and balance hold when controlling for vibratory sensation, proprioception, visual acuity, and previous activity level?

Hypothesis 1: Elderly persons who participate in a low intensity aerobic exercise program will have greater muscle strength of the flexors and extensors of knees and ankles, greater flexibility of the knee and ankle joints, better balance, and better perception of balance when controlling for variables identified as covariates than those elderly persons who maintain their usual activity level for eight weeks.

CHAPTER II

REVIEW OF LITERATURE

With aging, the human body undergoes many changes. Of particular importance to this study are changes affecting muscle strength, flexibility, and balance. This literature review is divided into the following sections: the effect of aging on selected neuromuscular/skeletal factors, specifically muscle strength, flexibility, and balance; and the effect of use, in the form of exercise, on muscle strength, flexibility, and balance.

Aging and the Neuromuscular/Skeletal System

The nervous and the muscular systems are integral to human motor performance (Gutmann & Hanzlikova, 1975). The ability of the nervous system to relay appropriate messages to the muscular system influences motor performance. Several age-related changes in the nervous system influence the ability of the nervous system to receive and transmit information in a timely and coordinated manner. One such age-related change occurs in the synaptic junctions. In studying the aging nervous system in rodents, researchers found that the oldest group of rodents had a significant decrease in numerical and surface density of the synaptic junctions (Bertoni-Freddari, Guili, Pieri, & Danilo, 1986; Bondareff, 1981; McNeill, Koek, Brown, & Rafols, 1987). Bondareff questioned whether the loss was caused by degeneration or if an ability to reform synapses was lost in the aging process. Bertoni-Freddari et al. (1981) suggested that a decrease in synaptic contact area observed with aging was due to a decrease in the number of synaptic junctions.

Scheibel (1985) studied the pyramidal cells of Betz which he believed to be good indicators of neurological aging. He found that with age, the Betz cells have a marked decrease in dendritic spines and a thickening of the shafts. By age 65, almost all spines had been lost. A loss of dendritic spines may result in slower firing response and stiffness of movement. The delay in firing results in a motor response upon muscles already in contraction for another purpose, and as a result, the individual perceives stiffness in movement.

McNeill et al. (1987) suggested that the loss of dendritic spines in some neurons could result in a reduction of a neurotransmitter, dopamine, in the striatum. Decreased dopamine could result in altered motor function especially a marked decrease in initiation of movement (Spirduso, 1983). In looking at the pyramidal tract of mice of varying ages, Samorojski, Friede, and Ordy (1971) found that aged mice have an increase in microtubules and a decrease in the number of neurofilaments. They suggested these changes have functional implications which could mean alterations in the rate of conduction velocity and skilled motor response.

The accumulation of lipofuscin in the cell is believed to be the most common aging manifestation (Bondareff, 1981; Brody &

Vijayashankar, 1977). Bondareff reported that lipofuscin was selective and as a result was found in greater amounts in certain cells. Lipofuscin is deleterious to the neuron, but just how it damages the neuron is unclear. However, as lipofuscin continues to collect in the cell, there is less and less space for intracellular functioning.

To summarize, age-related changes in the nervous system affect the functioning of cells internally and externally, and they affect synaptic functioning. As a result neurological responses to the muscular system could be altered or decreased causing delayed muscle response or discoordinated muscle action.

Among human beings, the age-related change most commonly reported in the muscular system is a decrease in muscle fibers (Aniansson et al. 1986; Aniansson, Zetterberg, Hedberg, & Hendriksson, 1984; Campbell, McComas, & Petito, 1973; Larsson et al., 1979; Hooper, 1981; Oertel, 1986; Scelsi, Marchetti, & Poggi, 1980). Using a cross-sectional design in studying muscle fiber changes with aging, researchers found a decrease in type II--fast-twitch fibers--with no decrease in type I--slow-twitch fibers (Aniansson et al., 1986; Aniansson et al., 1984; Larsson et al., 1979; Oertel, 1986). Scelsi et al. (1980) noted a decrease in the size of both type I and type II muscle fibers. Larsson et al. (1979) investigated muscle strength and speed of movement in 114 healthy males between the ages of 11 and 70 years. They found a decrease in the type II fiber/type I fiber ratio. In studying the vastus lateralis musculus quadriceps in a population of sedentary elderly, Scelsi et al. (1980) found atrophy of type II fiber and a predominance of type I fiber in their subjects. Aniansson et al. (1984) also studied the vastus lateralis quadriceps muscle of elderly persons with hip fracture. They, too, found a shift in the fast-twitch/slow twitch muscle fiber ratio with the greatest decrease in this ratio in patients 78-85 years of age. Additionally, they found a reduction in fiber size. Oertel (1986) investigated age-related changes in the deltoid and vastus lateralis muscles. His subjects ranged from 20 years of age to 80 years of age. He reported finding that 50 percent of his subjects over the age of 60 had atrophy of muscle fiber.

In an eight-year longitudinal study, important since most studies of age-related changes in the muscular system have been cross-sectional, the investigators examined the vastus lateralis and biceps brachii muscles (Aniansson et al., 1986). They found a decrease in fast-twitch (type II) muscle fiber and a decrease in cell mass which supported the findings in the cross-sectional studies.

In summary, investigators using both cross-sectional and longitudinal studies found a decrease in muscle fibers. That is, with aging there is a decrease in type II muscle fibers resulting in a decrease in type II/type I muscle fiber ratio.

A decrease in muscle fibers would surely alter muscle function. Decreased muscle strength with increased age has been reported, with the decrease in muscle strength the greatest in the oldest persons (Aniansson et al., 1986; Johnson, 1982; Larsson et al., 1979; Murray, Duthie, Gambert, Sepic, & Mollinger, 1985; Murray, Gardner, Mollinger, & Sepic, 1980; Shock & Norris, 1970). Murray (1980, 1985) reported the strength in the oldest group was 56-78% less than the muscle strength of the youngest group. Although significant differences have been noted between young and old groups in muscle strength (both isometric and dynamic), endurance was not significantly different between the young and old groups (Johnson, 1982). Limited loss of endurance would be expected with the predominance of type I fibers usually found in the aged.

Larsson et al. (1979) measured muscle strength and speed of movement. They found isometric and dynamic strength increased in the 20-29 year group, it leveled off and remained about the same in the 40-49 year group, and it decreased significantly in the old aged group. The investigators reported a significant correlation between a decrease in strength and atrophy of type II muscle fiber. The speed of movement followed a pattern similar to strength in the various age groupings. Aniansson et al. (1986) confirmed the findings of Larsson et al. (1979) and also noted that the atrophy of the vastus lateralis quadriceps was greater than the atrophy of the biceps brachii muscle while muscle strength was greater in the upper extremity than in the lower extremity.

Researchers found a decrease in muscle strength with aging. Also, they found a decrease in muscle fibers associated with a decrease in muscular strength, with the loss of strength greater than the loss of endurance.

Good muscle strength and a signaling system which has the ability to communicate to muscles to contract in an orderly manner is necessary for smooth movement and good motor control (Evarts & Fromm, 1979). Investigators who examined motor control in a group of elderly persons noted an increase in the muscle intentional activity, the organization of readiness for spontaneous movement, and an increase in the latent period of spontaneous movement (Mankovsky et al., 1982). With aging, this intentional process that precedes movement is decreased and spontaneous movement is delayed. As a result, movements requiring exactness and precision are poorly executed.

Evidence supports numerous age-related changes in the neuromuscular system that have an effect on motor control. Importantly, decreased muscle fiber results in decreased muscle mass and decreased muscle strength. Additionally, changes in dendritic spines and in synaptic junctions affect the ability of the neuron to function properly resulting in poor conduction velocity and poor coordination in motor performance.

Flexibility and Aging

Flexibility of joints among elderly persons has received very little study. Adrian (1981), in reviewing the research literature, cited age-related alterations in connective tissue resulting in a more resistive tissue. These changes in connective tissue translate to reduced joint movement. Chapman, deVries, and Swezey (1972) compared joint resistance between two groups of men (n = 40), a younger group (15-19-year-olds) and an older group (63-88-year-olds). The investigators measured joint stiffness by taking the finger joint through passive range of motion and measuring resistance to movement. They found significantly greater joint stiffness in the older group. Investigating gait patterns in two groups of female subjects (n = 26), Hageman and Blanke (1986) found the older group (over 60 years) to have less range of ankle movement than the younger group (20-35-year-olds). Adequate range of motion in joints of the lower extremities is important in assisting an individual to recover from a disruption of position.

Poor flexibility of joints contributes to stiff movement. Additionally, decreased muscle strength, impaired nerve conduction velocity, and coordination may greatly alter motor performance so that muscles contract out of sequence, are poorly coordinated, and, along with stiff joint movement, can be related to poor balance.

Balance and Aging

Balance is the maintenance of a stable upright position through neuromuscular and skeletal changes to realign the center of body mass in relation to gravitational forces and supporting structures. To maintain balance, motor responses must be rapid and are initiated through automatic reflexes, and appropriate muscle strength, joint flexibility, and coordination are required (Nashner, 1987; Ring, Matthew, Nayak, & Isaacs, 1988). Sensory information important to balance is supplied by the visual and vestibular systems and proprioceptive input (Nashner, 1987; Ring, Matthew et al., 1988).

Since these sensory factors are essential contributors to the maintenance of balance, they must be considered in a study focusing on balance.

Age-related neuromuscular changes cited earlier in this review have a definite effect on the ability of the elderly to maintain balance. In an early study, Sheldon (1963) found that the amount of sway reached a plateau from the teen years through the forties. After 40 years of age, sway continued to increase with age. Other researchers found increased sway in their elderly subjects (Fernie, Gryfe, Holliday, & Llewellyn, 1982; Hasselkus & Shambes, 1975; Ring et al., 1988; Ring, Nayak, & Isaacs, 1988). Ring, Nayak, and Isaacs (1988) reported a greater sway path in their elderly subjects, but amplitude was similar to younger subjects. This is an indication that older subjects were not as efficient as younger subjects in making the rapid responses needed to maintain balance. That is, the nervous system of older subjects may be slower in integrating somatosensory input, resulting in slower or less coordinated muscle responses causing a longer sway path. Woollacott et al. (1982) noted sway was initiated at the ankle level. In addition, they noted a delay in automatic postural responses and an alteration in the pattern of muscle firing among elderly subjects. They observed among these elderly subjects that muscles of the upper leg often fired in advance of the muscles of the lower leg. Normally the tibialis anterior would contract ahead of the quadriceps, but these researchers found the opposite often happened in their elderly subjects.

Vibratory sensation and proprioceptive sensation provide important sensory information to assist the nervous system in identifying the body's position in space. Investigators found that proprioception is decreased in elderly persons with poor balance (Wolfson et al., 1985; Woollacott et al., 1982). Since balance is decreased when eyes are closed or visual input decreased, visual inputs are believed important to balance (Stones & Kozma, 1987; Woollacott et al., 1982). Sensory inputs of vibratory and proprioceptive sensation and visual acuity are mechanisms used by the individual to identify the body position in relation to center of gravity and supporting structures. When visual and somatosensory inputs were decreased, Woollacott, Inglin, and Manchester (1988) found older adults lost their balance much more than younger adults. Consequently, input from these mechanisms are important to maintaining balance, and when this input is decreased, balance becomes more difficult.

The research cited indicate that many of the factors which contribute to balance change as a person ages; it would seem that balance would also be altered with age. Wolfson et al. (1986) examined balance in three groups of people: young nonfallers (n = 21), elderly fallers (n = 22), and elderly nonfallers (n = 18). The researchers used weights to displace the subject's center of gravity backwards. The ability of the subjects to use adaptive responses to reestablish balance was measured. The youngest group had significantly better scores than the two elderly groups, and the elderly nonfallers' scores were significantly better than the elderly fallers. Additionally, in comparing the older and younger group of nonfallers, the older group had delayed onset of muscle response, and the muscle responses were less vigorous and frequently incomplete.

Whipple et al. (1987) compared torque and power in the extensors and flexors of the knees and ankles of elderly fallers (n = 17) and nonfallers (n = 17) and found a marked decrease in lower leg and ankle muscle strength of the fallers. Additionally, they observed the combined ankle plantar-dorsiflexion torque of fallers to be markedly less than nonfallers. They reported the ankle dorsiflexion power among the fallers to be the most compromised. That is, the dorsiflexion power fallers exhibited was 7½ times less than the ankle dorsiflexion power of nonfallers.

In summary, age-related changes in the neuromuscular system have a negative effect on balance. Poor muscle strength and diminished flexibility impair the necessary responses to realign the body mass over the base of support. Of particular interest, since it had not been reported before in the literature, is the finding of greatly reduced ankle muscle strength in elderly fallers. In addition, poor vibratory and proprioceptive sensation reduces afferent information to the nervous system. A decrease in synaptic junctions may result in poor coordination or jerky movement resulting in inappropriate firing of muscles. All of these factors can result in poor balance or even a fall.

The Effects of Exercise

Exercise is purposeful activity that affects only the structures exposed to the exercise (Astrand, 1987). Factors which are of importance in exercise are flexibility of joints, muscular strength, and endurance (American College of Sports Medicine, 1986, 1990) as well as the functioning of the central nervous system so that appropriate psychomotor speed is manifested and smooth coordination of muscle action is achieved. Studies reported earlier in this literature review support that there is a general decline in all of these physical factors with aging. The important question is will exercise reverse age-related physical decline?

Exercise has been shown to improve central nervous system functioning particularly by improving psychomotor speed (Spirduso & Clifford, 1978; Spirduso & Farrar, 1981). Researchers looking at response times in rats (Spirduso & Farrar, 1981) studied four groups of rats, young exercise group, old exercise group, and a young and old control group (n = 10 for each group). The experimental groups were exercised for six months. The rats were evaluated on rate of response to conditioned (buzzer rang and if rat released bar fast enough nothing happened) and unconditioned (bar not released fast enough and electric shock experienced) stimuli. The researchers observed that the old rats were significantly slower than the young rats at the fastest intervals. The unexercised rats were the slowest. The researchers concluded that exercise contributes positively to psychomotor speed. Some of the response was attributed to an exercise effect that increased blood flow and enhanced oxidative capacity to motor control areas of the brain.

Investigating the functional effects of exercise on the central nervous system in humans, researchers studied reaction and movement time in young and old persons (Spirduso, 1975; Spirduso & Clifford, 1978). Spirduso (1975) used male volunteers (n = 60) and divided them according to age groups (20-30-year-olds and 50-70-year-olds) and activity level (active and nonactive). She found active groups were faster than the nonactive groups. The study was replicated by Spirduso and Clifford (1978) and produced similar results. Older active men were faster than their inactive peers (n = 15 in each group). Both the research with animals and with human beings support that exercise improves psychomotor speed.

Thus, exercise has been shown to improve central nervous functioning particularly by improving psychomotor speed, and it may enhance other central nervous system functions. Quick central nervous system responses would be important to achieve the rapid motor response needed to maintain balance.

The effect of exercise on muscle fiber and muscle functioning in aging has been studied. Researchers found an increase in type II muscle fibers following subjects' participation in an aerobic strength training program (Larsson, 1982; Orlander & Aniansson, 1980). Larsson (1982) also noted an increase in type I muscle fiber. With an increase in physical activity, an increase in the oxidative capacity of muscles has been noted (Orlander & Aniansson, 1980;

Suominen et al., 1977). Such changes in the muscles would indicate the ability for improved muscle strength and endurance. Since exercise improves structure it would seem to follow that it would also improve function.

DeVries (1970) studied the effect of a high intensity aerobic exercise program on 112 elderly men. He found that muscular strength improved after six weeks of exercise and improved to a greater extent after 42 weeks of exercise. DeVries evaluated past physical activity and did not find a relationship between past activity and physical improvement. His findings would imply that present rather than past activity level is more important to muscular strength.

Other researchers support deVries findings that exercise improves muscle strength in aging subjects (Brown & Harrison, 1986; Kauffman, 1985; Larsson, 1982). Kauffman (1985) studied young (n = 10) and old women (n = 10) who took part in isometric exercises of the abductor digiti minimi for six weeks. Both groups had improved muscle strength, although not significantly. Brown and Harrison (1986) also looked at exercise effect on young and old subjects by using four groups (n = 25 each group): young control, young experimental, old control, and old experimental. The experimental groups participated in a 12-week weight training program. The researchers found both experimental groups improved their strength.

Larsson (1982) studied the effect of a 15-week strength training exercise program on 18 males, 22-65 years of age. Although muscle strength was not significantly improved, there was a trend toward increased muscle strength in all age groups. The small sample size may have influenced the nonsignificant findings for muscle strength.

Exercise to increase muscle strength often includes the addition of resistance in the form of weights (American College of Sports Medicine, 1990). Agre, Pierce, Raab, McAdams, and Smith (1988) studied the effect of light resistance and stretching exercises on muscle strength in elderly female subjects (n = 47). The subjects volunteered for the exercise or control group. The subjects in the exercise group were randomly assigned to a weighted exercise group or a nonweighted exercise group. The exercise program consisted of stretching, strengthening, and aerobic exercise. The weighted exercise group had weights for the ankles and wrists gradually introduced into their exercise program. Muscle strength was measured using the Cybex II. Muscle groups tested were the elbow flexors and extensors, shoulder internal and external rotators, and knee flexors and extensors. The researchers found that the exercise groups significantly increased the muscle strength of the shoulder rotator, elbow extensor, and the knee flexor muscle groups. There were no significant findings between the two exercise groups. The findings of these researchers imply that the addition of resistance to the exercise program would not add any benefit for elderly persons.

In summary, an active life style among the aged has an effect on increasing the number of muscle fibers, particularly type II muscle fiber. Additionally, exercise improves muscle strength, and the addition of resistance to the exercise program did not result in greater increases in muscle strength.

The effect of exercise has been found to improve significantly joint flexibility (Bassett et al., 1982; Chapman et al., 1972; Frekany & Leslie, 1975; Rikli & Busch, 1986; Munns, 1981). Chapman et al. (1972) used an experimental design with two age groups of subjects, 15-19-year-olds and 63-88-year-olds (n = 40). The experimental group participated in a six-week weight lifting exercise program to the metacarpophalangeal joint of the index finger. The experimental groups had significant improvement in flexibility, with the younger group having greater flexibility than the older group.

Other researchers, although vague as to methods of measurement and protocol for the exercise program, reported significant improvements in flexibility (Bassett et al., 1982; Frekany & Leslie, 1975). Frekany and Leslie (1975) studied 15 elderly female volunteers who participated in an exercise program specific for improving flexibility of several joints. Yet, the researchers only measured flexibility of the ankles and back. They found significant improvement in the flexibility of the back and ankle joints. The researchers did not describe the exercises and were vague in reporting the frequency and duration of the exercise program. The researchers reported the exercises were usually done for 30 minutes, two times a week, and for approximately seven months.

Bassett et al. (1982) conducted a 10-week exercise program for 18 elderly persons at a congregate meal site. The exercise program consisted in part of exercises specific to improving flexibility of shoulder, hip, and knee. Bassett et al. noted significant changes in the range of motion of these joints.

Munns (1981), using more precise measurement of flexibility, had 40 subjects between 65 and 88 years of age participate in a twelve-week exercise program. This program was a combination of exercise and dance designed to put the neck, wrist, shoulders hip, back, knee, and ankle joints through a full range of motion. Flexibility was measured by the Leighton flexometer, and reliability was not reported. Munns found this exercise program significantly improved the range of motion in all the joints studied.

The question of whether resistance will improve joint flexibility was considered by Raab, Agre, McAdams, and Smith (1988). Their subjects, 47 women between the ages of 65 and 89 years of age, volunteered for the exercise or the control group. The subjects who volunteered for the exercise group were randomly assigned to one of the exercise groups (exercise with weights or exercise without weights). Measurements were made by a goniometer and were taken only from one side. No reason was stated for measuring flexibility on only one side of the body. The right side was used unless pain was reported and then the left side was used. The same side was used in pretesting and posttesting. The exercise program included exercises for increasing strength and flexibility. The classes lasted 60 minutes and were held 3 times a week for 25 weeks. The researchers found that exercise significantly improved flexibility over not exercising, and that the exercise group that did not use weights had even greater gains in one joint than did the group that used weights. This study supports the findings reported in another study by these same researchers that resistance exercise with elderly persons does not produce greater gains.

To summarize, research supports exercise as a means to improve muscle strength and flexibility in elderly persons. Exercise programs should be targeted for the particular muscles and joints of concern. Researchers found that the use of weights did not improve strength or flexibility over exercising without weights. These findings imply it would not be of benefit to use resistance in exercise programs with elderly persons. No study reported an exercise program which has targeted the ankle muscles of elderly persons.

Few studies linked exercise with balance in the elderly. Bassett et al. (1982) investigated the effect of an exercise program on balance among 18 elderly persons. The exercise program consisted of stretching exercises, strengthening exercises for the quadriceps, and ended with a dance. The exercise sequence required 30 minutes to complete and was conducted three times a week. Balance was measured by the length of time the subject could stand on one foot. Balance was not improved by the exercises. Factors which might have been important to maintaining balance, such as vibration sensation and proprioception, were not assessed nor used as controls.

Thompson, Crist, Marsh, and Rosenthal (1988) studied 35 elderly subjects with chronic illnesses. The experimental group participated in a 16-week exercise program. The exercise program consisted of graduated rhythmical dance and calisthenic exercises to improve strength and flexibility. Balance was measured by the length of time the subject could maintain a one-leg stance. Balance scores improved, but did not reach significance. A major problem in this study was a 28 percent drop-out rate in the experimental group due to illness.

Roberts (1989) studied the effect of walking, as a form of exercise, on balance among 61 elderly persons living in the community. The experimental group participated in a six-week walking program. Roberts demonstrated that the walking program had a significant effect on balance. Roberts did not examine muscle strength or flexibility, and the walking program is a higher intensity aerobic exercise than proposed in this study. Thus, the pervasive question remains: Will a low intensity aerobic exercise program improve muscle strength, flexibility, and balance?

In summary, for a person to maintain balance the ability to receive and integrate sensory information and the ability to make rapid motor responses are necessary. Investigators have shown that there is a decrease in neuromuscular functioning with aging, and that exercise will improve neuromuscular functioning.

There is a dearth of research linking balance and exercise. Roberts (1989), however, found walking significantly improved balance. Despite Whipple et al.'s (1987) findings that the ankle muscles of elderly fallers are greatly decreased in comparison to elderly nonfallers, no known researchers have investigated the effect of exercise on these muscles among elderly persons with limited activity. Although vibratory sensation, proprioception, and visual acuity have been measured in other studies in which the researchers were investigating balance, no known researchers have investigated the effect of a low intensity aerobic exercise program for the flexor and extensor muscles of the knees and ankles, flexibility of knee and ankle joints, and balance among elderly subjects with limited physical activity and controls for such intervening variables as sight, proprioception, and vibration sensation.

Preliminary Study

Mills, Roberts, and Seiman (1988) conducted a pilot study to investigate the effect of a low intensity aerobic exercise program on muscle strength, flexibility, and balance among persons living in an elderly residential community. The subjects were randomly assigned to the control ($\underline{n}$ = 8) or experimental group ($\underline{n}$ = 7). All subjects were sedentary whose major physical activity was cleaning their apartment. Pretest measurements were made of muscle strength (gastrocnemius, hamstrings, quadriceps, tibialis anterior, toe extensors, gluteus maximus, gluteus medius, and hip adductors), flexibility of the joints of the lower leg (hip flexion, extension, hyperextension, knee flexion, extension, ankle plantar flexion, dorsiflexion, inversion, eversion) and balance. Intervening variables of visual acuity and vibratory and proprioception sensation were also measured.

Muscle strength was measured by the manual muscle testing technique described by Kendall and McCreary (1983). This technique measures muscle strength against gravity and resistance as applied by the researcher throughout the range of motion. Flexibility was measured by a goniometer. The goniometer measures range of motion of a joint in degrees and is described in the methods section of this paper. Balance was measured by the Roberts Balance Scale (Roberts & Mueller, 1987) described in methods section of this paper. Physical activity was assessed using a physical activity questionnaire (Walker et al., 1984) also described in the methods section. Intervening variables of vibratory sensation, proprioception, and visual acuity were assessed by the procedures described in the methods section of this paper.

The experimental group participated in a low intensity aerobic exercise program of 30 minutes, 2 times a week for 4 weeks. Experimental subjects were encouraged to do the exercises on their own the days the exercise group did not meet. Most of the exercises were done sitting in a chair and included stretching and strengthening exercises for the lower extremities. One exercise required the subjects to stand behind their chair and, while holding on to the back of the chair, raise up on their toes and back down on their heels. For more detail on these exercises see the methods section of this paper.

Two of the control group did not return for posttesting because of an acute illness. Because of the small sample size, normality, an assumption for analysis of variance, was not met; therefore, the nonparametric test, Mann Whitney U, was used for data analysis. Given the small sample size, the power to identify significant results was low, and an alpha level of .10 was used for significance to decrease probability of type II error. The physical activity level of both groups was low (control $\underline{M}$ = 22.6, $\underline{SD}$ = 26.5, experimental $\underline{M}$ = 12.6, $\underline{SD}$ = 13.9) with cleaning of the subject's apartment the greatest activity reported. There were no significant differences between the two groups on pretesting except for the strength of the left quadriceps, which was stronger for the control group.

It was important to know if the exercise program made any change on the variables, and for this reason difference scores were examined. Significant difference scores between the two groups were found on muscle strength for left gluteus medius ($\underline{z}$ = -1.90, $\underline{p}$ = .06), left hip adductor ($\underline{z}$ = -2.57, $\underline{p}$ = .01), left quadriceps ($\underline{z}$ = -1.94, $\underline{p}$ = .05), and right quadriceps ($\underline{z}$ = -1.65, $\underline{p}$ = .10). Although the difference scores for balance showed the experimental group improved 90% while the control group improved 57%, this was not a significant improvement.

The findings of this pilot study support that the exercises in this proposal can be done by a population of elders whose physical activities are limited, and they can do these exercises safely and independently. The exercise program was only four weeks duration to avoid interfering with Christmas activities. Given the significant findings after a four-week period of exercise, greater improvement would be expected to be found with a longer duration of exercise. For this reason, this study extended the exercise program to eight weeks.

This study addressed areas not heretofore addressed in investigations of exercise effect in elderly subjects, that is, the effect of a low intensity aerobic exercise program on flexor and extensor muscles of the knees and ankles, flexibility of knee and ankle joints, and balance among elderly subjects with limited physical activity.

CHAPTER III

METHODS

Design

This study, a pretest-posttest quasi-experimental design, used a comparison and experimental group. Following pretesting, the experimental group participated in an exercise program consisting of low aerobic intensity exercises three times a week for eight weeks, while the comparison group continued their usual activities. After eight weeks, both groups again were tested for muscle strength of the extensor and flexor muscles of the knees and ankles, flexibility of joints of the lower extremities, balance, and perception of balance.

Sample

This research took place in senior high rise apartments located in Hamilton, Butler County, Ohio. Convenience sampling was used with two apartment complexes randomly assigned to the experimental or comparison groups. Subjects were assigned to the experimental or comparison group depending upon their place of residence.

Fifty-six subjects were recruited from the two apartment complexes. The sample consisted of 26 experimental subjects, 2 (8%) males and 24 (92%) females, and 30 control subjects, 1 (3%) male and 29 (97%) females. Mean age of the experimental group was 74.5 (SD = 6.82, range 65-88) and mean age for the comparison group was 75.2

(SD = 6.08, range 65-87).

Recruitment consisted of an informational meeting with the residents councils of the high rise apartments as well as individual contacts. Subjects recruited were sedentary persons, that is, not engaged in any regular physical activity. Since it would be important for subjects to remember the sequence of the exercise program and to do it on their own between classes, persons were excluded who had cognitive impairment as determined in the initial interview. Others excluded were persons whose health placed them at risk for safely performing the exercise program. This included persons with severe neurological diseases (e.g., Alzheimer's Disease, Parkinson's Disease, Multiple Sclerosis, Meniere's Disease), and persons who used walking assistive devices. Subjects in the experimental group received the permission of their physician to participate in the exercise program to eliminate persons for whom an exercise program would be contraindicated.

Concepts and Their Measurement

Balance was measured by the Roberts Balance Scale (Roberts & Mueller, 1987). For the subject to receive the maximum proprioceptive information from the lower leg and ankle, the subjects performed the stances in their stocking feet. The Balance Scale (see Appendix A) required the subject, with arms at the side, to stand on toes and to stand on one foot. Also, the subject was required to stand on toes on a beam which was 3 inches wide and 2 inches high, and stand on the beam with one leg. These stances were done with eyes open and then repeated with eyes closed. The subject was asked to maintain the stances as long as possible up to a maximum of 30 seconds. To minimize the risk of falling, the researcher stood near the subject ready to steady the subject if necessary. A second person timed the stances. The balance score was the sum of the time the subject maintained each stance up to a maximum of 30 seconds (for a maximum score of 240 seconds). Construct validity was established by Roberts and Mueller who performed a factor analysis on the scale. The factor analysis yielded four factors: (a) monopedal factor, (b) visual factor, (c) bipedal nonvisual factor, and (d) beam factor. A beam factor was extracted, but it had not been theoretically expected. The researchers suggested this factor may not represent a component of balance but rather represent a perception of balance. Reliability of the scale was determined by measurements of internal consistency, a standardized alpha coefficient of .82 for the total scale (Roberts & Mueller). Roberts and Fitzpatrick (1983) reported an interrater coefficient of .99.

Perception of balance was measured by the Balance Perception Questionnaire (Roberts, 1989) and was used to determine how subjects perceived their balance. Subjects ranked their stability during walking, standing, and arising from a chair on a 4-point scale with 4 being the most stable (see Appendix B). The score was the sum of the ratings on the three questions with a range of 3 to 12. Roberts (1989) reported a standardized alpha coefficient of .78, while Cronbach's alpha for this study was .59. Construct validity was supported by factor analysis that revealed one theoretically expected factor, perception of balance, that accounted for 69.4 percent of the variance. Structure correlations were high and ranged from .72 to .91.

Muscle strength was measured by the Nicholas hand-held dynamometer. In using this device the same techniques for positioning of the limbs were employed as in Manual Muscle Testing, that is, individual muscles were isolated and then tested. In using the hand-held dynamometer, the device was held between the hand of the tester and against the skin over the muscle of the subject. The tester moved the body part that the muscle activated through maximum range of motion. The subject was asked to hold the maximum range of motion against gravity while the tester applied opposing pressure to the muscle. The hand-held dynamometer is a small force-measuring device. The dynamometer was held between the muscle of the subject and the tester's hand as the tester applied pressure. The dynamometer reading was made at the time maximum pressure was exerted by the tester or when the subject was unable to resist the tester's force. The unit of measure was kilograms with a range from 0 to 100 kilograms.

The hand-held dynamometer is able to detect finer muscle differences than is possible with manual muscle testing (Mario, Nicholas, Gleim, Rosenthal, & Nicholas, 1982; Wadsworth, Krishman, Sear, Harrold, & Nielson, 1987). However, reliability may decrease as a result of differences in technique if the force is off center or the force is not in the opposite direction from the vector of rotation (Mario et al., 1982). Wadsworth et al., investigating test-retest reliability of hand-held dynamometric muscle testing, found test-retest coefficients ranged from .69 to .90. All test-retest reliability coefficients except for shoulder abductors ($\underline{r}$ = .69) were significant. The investigators offered no explanation for a lack of significance for the shoulder abductor measurement. Additionally, Wadsworth et al. reported hand-held dynamometric muscle testing to be more discriminating than manual muscle testing because it provides a continuous range of torque values. They stated such discrimination is particularly important when identifying small differences in muscle strength, as would be the case in elderly subjects. To minimize intrarater error, this researcher test-retested 18 individuals using the Nicholas hand-held dynamometer. An intrarater coefficient of $\underline{r}$ = >.93 was established prior to beginning the study. Kendall and McCreary (1983) recommended the gastrocnemius muscle be measured by the number of times (to a maximum of 10) the subjects can raise up on their toes. This does not allow for use of a hand-held dynamometer. In this study muscle strength measurements of the right and left quadricep, hamstring, soleus, and tibialis anterior, were made using the hand-held dynamometer. Measurement of the gastrocnemius was the number of times the subjects could raise up on their toes. See Appendix C for the pretest/posttest data collection tool for muscle strength.

<u>Flexibility</u> of the joints of the lower extremities was measured

using the universal goniometer. Joints included in measurement were knee flexion and extension, and ankle plantar flexion, dorsiflexion, inversion, and eversion. When full extension (180 degrees) of the knee was not possible for a subject, the degrees of limited motion were noted. The axis of the goniometer was placed on the axis of rotation of the joint being measured. The stationary arm was placed along the longitudinal axis of the proximal part of the joint, and the moving arm in like manner was placed along the longitudinal axis of the distal part of the joint (Norkin & White, 1985). The degrees of maximal motion of the joint was recorded. When considering reliability of goniometer measurements two factors are involved. They are interrater reliability and device reliability. To assure tester reliability, prior to beginning the research project, interrater reliability was determined between the investigator and a physical therapist experienced in taking goniometer measurements. Interrater reliability was established within 5 degrees for all measurements of the lower extremities. Investigators studying validity of the goniometer compared measurements made by the goniometer with measurements made by roentgenogram (Gogia, Braatz, Rose & Norton, 1987). They found high criterion-related validity between the two instruments with correlation coefficients ranging from .97 to .99. See Appendix D for the pretest/posttest data collection tool for flexibility.

Vibratory sensation of the lower extremities was assessed as this sense is often decreased in persons with poor balance.

Vibratory sensation was measured by using a tuning fork placed over the bony prominences of the head of the tibia and the lateral malleolus. The subject was asked to identify if the tuning fork was vibrating and if so, identify when the vibration stopped. The subjects' eyes were closed during this procedure. The sequence was repeated five times to avoid guessing (DeMyer, 1979; J. D. Heiss, personal communication, September 28, 1989). Measurement of vibratory sensation in this manner has construct validity. It is a common neurophysiological clinical procedure for identifying a person's ability to detect sensation in the lower extremities (DeJong, 1979; Marshall, Marshall, Vos, & Chestnut, 1990). Detection of this sensation is based on neural innervation and is markedly decreased to totally absent in persons with spinal cord disease or injury. Scoring was whether the subject correctly identified starting and stopping vibratory sensation. The correct answer was scored as 0 and the incorrect answer was scored as 1. The number of inaccurate responses were summed with a range of 0 to 8 (see Appendix E).

Proprioception was assessed as it is often decreased in those with poor balance. To measure proprioception the researcher placed the right and left lower extremity of the subject in the positions of knee extension and flexion, ankle dorsiflexion, plantar flexion, inversion, and eversion. The subject self-reported (with eyes closed) the positions in which the researcher had placed the lower extremity. The sequence was repeated five times to avoid guessing

(DeMyer, 1979; J. D. Heiss, personal communication, September 28, 1989). Measurement of proprioception in this manner has construct validity. It is a common neurophysiological clinical procedure for identifying a person's ability to detect position of the lower extremities (DeJong, 1979; Marshall et al., 1990). Detection of position sensation is based on neural innervation and is markedly decreased to totally absent in persons with spinal cord disease or injury. Scoring was whether the subject had correctly identified the position of the leg or ankle, with the correct response scored as 0 and the incorrect response scored as 1. The number of inaccurate responses were summed with a range of 0 to 12 (see Appendix F).

Visual acuity was assessed using the Snellen eye chart. This chart assesses distance vision and consists of several lines of alphabet letters with each line, from top down, in a smaller sized print. Each row is scaled so it can be read at 200, 100, 70, 50, 40, 30, 20, 15, and 10 feet. Visual acuity is expressed as a fraction with 20/20 being normal. The numerator indicates the distance the subject is from the chart and the denominator is the distance at which the normal eye can read the chart (Phipps, Long, & Woods, 1983). To assess visual acuity, the subject stood 20 feet from the chart and then read the smallest print line possible. If the subject usually wore glasses, then vision was assessed with the subject wearing glasses as this represented the subject's usual way of seeing the environment. The score was the denominator of the line in which the subject was able to correctly read at least 50 percent of the letters.

Physical activity was assessed since the population of interest for this study were sedentary elderly persons. An activity level for the present year which indicated no regular physical activity was a criterion for this study and may indicate disuse. Physical activity for past years and present year was assessed using the Physical Activity Questionnaire (Walker et al., 1984). Based on a comparative expenditure of energy as reported in research studies, these researchers assigned a weighting to each physical activity. To obtain a past years activity level score, each activity weighting was multiplied by the frequency per week times the number of years the activity was carried out and then summed. For example, a subject who reported swimming at a moderate pace once a week for three years would be scored as: 4 (activity weighting for moderate paced swimming) times 1 (number of times a week), times 3 (number of years) equals 12 (4 x 1 x 3 = 12). The score for each activity was summed for a total score for past years activities. In like manner the score for present year activity was obtained by multiplying the activity weighting times the frequency per week for each activity and then summing. For example, the subject who reported walking at a stroll twice a week would be scored as: 1 (activity weighting for walking at a stroll) times 2 (number of times a week) equals 2 (1 x 2 = 2). The score for each activity was summed for a total score for present year activities. The authors did not report reliability or validity of the instrument. (See Appendix G.)

Data Collection Techniques

Directors of City of Hamilton, Butler County, Ohio, high rise apartment complexes were contacted and asked to participate. The two apartment complexes which agreed to participate were randomly assigned by the flip of a coin to either the experimental or comparison group. To avoid persons in the comparison group from becoming interested in the exercises and perhaps doing them on their own, the facility was the unit for sampling. Thus individuals were assigned to the experimental or comparison group depending upon their place of residence. The assignment of the facilities to the experimental or comparison group was made prior to recruiting subjects. Recruitment began as soon as permission had been obtained from the directors of the facilities to utilize the facility and recruit residents. Recruitment strategies consisted of signs, an informational meeting with residents, and individual contacts.

After the experimental group obtained their physicians' consent to participate and subjects in both groups consented in writing, demographic and baseline data were collected on each subject (Appendix H). Baseline data included questions regarding health status and medications to avoid including subjects whose health status might prevent them from safely doing the exercise program. Physical activity would have an impact on muscle strength, flexibility, and balance and could indicate use rather than disuse, thus an activity instrument which assessed past activity and present activity levels was completed by subjects at pretesting.

Measurements were made of balance, perception of balance, flexibility and muscle strength of the lower extremities, proprioception, and vibratory sensation. See Appendix I for table of concepts measured.

Subjects in the experimental group participated in an eight-week exercise program. These exercises were carried out three times a week in a group setting. The experimental group was encouraged to do the exercises once a day on their own on the days between the exercise classes. Both groups kept a journal of their physical activities during the eight weeks. This allowed the researcher to determine how much the experimental group did the prescribed exercises and to determine if anyone in the comparison group increased their physical activities during the eight-week period. Both groups were posttested eight weeks after pretesting. Subjects were posttested for perception of balance and balance. Flexibility of the knee and ankle joints and muscle strength of the lower extremities were measured. Also, visual acuity (only at posttest) and vibratory and proprioception sensation were measured. The exercise journals of the experimental group were assessed as to number of times in which the exercise routine was carried out and any additional exercise they may have participated in during the eight weeks (see Appendix J). The journals of the comparison group were assessed as to what physical activities they may have participated in during the eight weeks of the study (see Appendix K). The activity, excluding the exercise program for the experimental group, was scored by how much exercise was done per week. No exercise in a week was scored as 0. Participation in any type of exercise one or two times a week was scored as 1, and participation in any type of exercise three or more times a week was scored as 2. The weekly score was summed with a possible range of 0 to 112.

During the eight weeks that the experimental group participated in the exercise program, the comparison group continued their usual activities. Between pretest and posttest, the only contact the researcher made with the comparison group was to send each subject a Valentine's Day card. In the card was a note reminding the subjects to record any exercise participation in their journal.

Protocol for the Exercise Program

The type, intensity, frequency, and duration of an exercise program is important to the effect on balance, perception of balance, and flexibility and muscle strength of the lower extremities. However, research literature does not identify the specific type, intensity, frequency, and duration needed to effect change in muscle strength, flexibility, and balance. Increases in muscle strength and flexibility have been reported at low levels of resistance (Agre et al., 1988; Raab et al., 1988). The American College of Sports Medicine (1990) recommends a training frequency of 3-5 days a week for 20-60 minutes. Additionally, they suggest 8-12 repetitions of several exercises that target major muscle groups. In the pilot study, Mills et al. (1988) found that sedentary elders who participated in a low intensity aerobic exercise program two times a week for four weeks improved balance and significantly improved muscle strength of the left gluteus medius, left hip adductor, and the left and right quadriceps.

The exercise program in this research study was developed based on pilot study findings (Mills et al., 1988). Subjects in the experimental group participated in a group exercise program that met three times a week for eight weeks. The exercise program began with stretching exercises of the lower leg and ankle followed by strengthening exercises involving the entire lower extremity. While sitting in a straight chair the subjects stretched ankle muscles by raising heels, thus placing the ankles in plantar flexion, followed by raising toes and lowering heels, placing the ankles in dorsiflexion. They then extended their legs, one at a time, and circled their ankle. These exercises would help increase flexibility of the ankles and knees. Subjects were then asked to raise and lower one leg at a time without touching the floor. This exercise would strengthen the quadriceps. The next two exercises had the subjects extend their leg, point and flex ankles, and then extend and flex the knee without touching the floor. Again, only one extremity at a time was exercised. These two exercises would increase flexibility of the ankles and knees and strengthen the quadriceps and hamstrings. Following these seated exercises, the subjects were asked to stand behind their chair and to hold onto the back of their chair for support. They raised up on their toes and back down. This exercise would strengthen the gastrocnemius and soleus muscles. This was followed by the subjects doing standing knee bends while holding onto the back of their chair. This exercise would strengthen the quadriceps and the hamstrings. The exercises ended with the subjects seated and repeating the stretching exercises of the ankles. Each exercise was done eight times. The subjects were directed through the sequence twice, thus requiring approximately 20 minutes to complete the entire exercise program.

This particular program provided stretching and strengthening exercises for the quadriceps, hamstrings, tibialis anterior, soleus and gastrocnemius muscles. Muscle strengthening exercises require some resistance usually in the form of weight applied to muscles. In these exercises the subjects used their own weight. That is, some exercises required the subject to raise and lower the leg against gravity. As noted above, in one of these exercises the knee extensor and flexor muscles were required to lift the weight of the leg. In another exercise the extensor and flexor muscles of the ankle supported the subject's body weight.

The exercises were of low aerobic intensity and should have had little if any effect on the cardiovascular system. For an exercise program to be high aerobic intensity it must involve continuous and repetitive contraction of the large muscles such that 65%-70% of the age-adjusted maximal heart rate is reached and maintained for a period of time, unlike the exercises in this program (American College of Sports Medicine, 1986). However, given the diminished physical and cardiovascular fitness expected in this sample, the pulse rate was taken when one-half of the exercise sequence had been completed during the first five weeks of the program. This means the subjects had completed the stretching exercises and two of the strengthening exercises. When the pulse rate was greater than the age-adjusted maximal heart rate, the subject did three to four repetitions instead of the eight until their pulse rate dropped below the age-adjusted maximal heart rate. This rate was calculated by subtracting the subject's age from 220 and multiplying this number by 70% (American College of Sports Medicine, 1986). To calculate the maximal heart rate for an 80-year-old person, subtract 80 from 220 (= 140), then multiply by .7 (140 x .7 = 98).

Each subject in the experimental group was given a booklet that described the exercises (see Appendix J). The booklet was used as a guide to assist the subjects in doing the exercises on their own at home. The subjects were encouraged to do the exercises on their own the days they were not involved in the group, as this would reinforce the importance of getting into a habit of exercising and should enhance the exercise effect on muscle strength, flexibility, and balance. The subjects were asked to keep a log of the number of times they did the exercises and to include any other exercises they might engage in during this eight-week period. Noting the amount of activity by subjects during the period of the exercise program assisted in determining effect of exposure.

Data Analysis

The dependent variables--muscle strength, flexibility, balance, and perception of balance--are interval level measures. To look at functional units, all measurements of muscle strength for the ankle and knee were added together, and all measurements for flexibility of the ankle and knee were added to together. This resulted in one score for muscle strength of the ankle, muscle strength of the knee, flexibility of the ankle, and flexibility of the knee. Combined scores for muscle strength were used by Whipple et al. (1987) in studying the strength of flexor and extensor muscles of the knees and ankles. The balance scale and the perception of balance questionnaire each had one total score. The intervening variables of vibratory sensation and proprioception are ordinal but were summed and treated as interval. The intervening variables, visual acuity and activity level are interval. The data analysis is divided into three parts: (a) description, (b) preliminary analysis, and (c) hypothesis testing. A significance level of .05 was used for all tests.

Description of the sample. Means, standard deviations, frequencies, and percentages were computed on all interval level control and dependent variables.

Preliminary analysis. Multivariate analysis of variance with Hotelling's T^2 as the significance test was used to determine any pretest differences between the two groups on the dependent variables of muscle strength, flexibility, and intervening variables of proprioception, vibratory sensation, and Snellen Score. The t-test was used for determining any pretest difference for balance and perception of balance and the intervening variable of physical activity. Pearson's correlations were computed between the dependent variables and the intervening variables. Those intervening variables found to significantly correlate with the dependent variables were used as covariates. If differences between the two groups had been significant, multivariate analysis of covariance would had been used in the hypotheses testing.

Hypothesis testing. Both univariate and multivariate analysis of variance and the t-test were used in hypothesis testing.

Hypothesis 1: Elderly persons who participate in a low intensity aerobic exercise program three times a week for eight weeks will have higher balance scores and perception of balance scores than those elderly persons who maintain their usual activity level for eight weeks.

The t-test was used to determine if there was a significant difference between the experimental and comparison groups on balance and perception of balance.

Hypothesis 2: Elderly persons who participate in a low intensity aerobic exercise program three times a week for eight weeks will have greater flexibility scores of the knee and ankle joints than those elderly persons who maintain their usual activity level for eight weeks.

Hypothesis 3: Elderly persons who participate in a low intensity aerobic exercise program three times a week for eight weeks will have greater muscle strength of the flexor and extensor muscles of the knee and ankle than those elderly persons who maintain their usual activity level for eight weeks.

Hypotheses 2 and 3 were analyzed in the same manner. Multivariate analysis of variance (MANOVA) with Hotelling's T^2 as the significance test was used to determine any differences between the experimental and comparison groups on the dependent variables of knee and ankle flexibility and knee and ankle muscle strength. That is, two MANOVAs were computed. If significance was found, then analysis of variance (ANOVA) was computed to examine separately the mean group differences for muscle strength and flexibility. This procedure acknowledges the possibility of Rao's paradox occurring (Healy, 1969), where multivariate significance is present but not univariate significance, or multivariate significance is not present but univariate significance is present. Since muscle strength of the gastrocnemius required a different unit of measure than was used for the other muscles, the t-test was used to determine if there was a difference between groups.

Hypothesis 4: Elderly persons who participate in a low intensity aerobic exercise program three times a week for eight weeks will have better muscle strength of the flexors and extensor of the knees and ankles, greater flexibility of the knee and ankle joints, and better balance and better perception of balance when controlling for variables identified as covariates.

Multivariate analysis of covariance (MANCOVA) was used to analyze hypothesis 4. MANCOVA with Hotelling's T^2 as the significance test was computed using the dependent variables where intervening variables were significantly correlated with them at posttest or both pretest and posttest. The independent variable was the exercise program. The dependent variables were balance, balance perception, flexibility, and muscle strength. To assess change from pretest to posttest, six MANCOVAs were computed using the pretest scores on each of the aforementioned dependent variables as covariates and their posttest scores as the dependent variables. The exercise program was the independent variable.

Human Subjects

Informed consent was obtained from all participants. The consent form (see Appendixes L and M) described all the requirements of the subject, risks involved, right to withdraw at any time without penalty, and the risks and benefits to participation. The risks and benefits were also explained orally. The benefits to the experimental group may be an improvement in muscle strength of the lower leg, increased flexibility of the knee and lower leg, and an improved balance. There were no direct benefits to the control group except providing information to the subjects about their scores on muscle strength, flexibility, and balance. Subjects may wish to have this information about themselves. The risk to both experimental and control groups was falling during the testing of balance. To minimize this risk a person stood close to the subject being tested and steadied the subject during measurement if necessary. Since the subjects in this study have had limited physical activity, there was a slight chance for the experimental group to tire while doing the exercises. The subjects were instructed that should they feel especially tired during the exercise session, they were to discontinue doing the exercises. The exercises were expected to be of low intensity and should not result in overworking of the cardiovascular system. To be assured of this, the researcher took pulses half-way through the exercise sequence and reduced repetitions for anyone with a pulse outside 70% of the age-adjusted maximal heart rate. To minimize exacerbation of a health problem, the subjects obtained their physicians' approval to participate. The consent form gave the name and phone number of the researcher should the subject wish to contact the researcher.

CHAPTER IV

RESULTS

The results of this study are presented as follows: (a) description of the sample, (b) inferential findings, and (c) post-hoc findings. Also included is a summary of the findings.

Multivariate analysis of variance (MANOVA) was used to examine the effect of the low aerobic intensity exercise program on muscle strength and flexibility, and t-test was used to determine the significance of the difference between the two groups on balance and perception of balance. Using the pretest scores as covariates, multivariate analysis of covariance (MANCOVA) was used to determine the effects of the exercise program on muscle strength, flexibility, balance, and perception of balance. The results were considered significant at the .05 alpha level. Statistical Package for the Social Sciences (1990) was used in the data analysis.

Description of Sample

Twenty-six experimental subjects comprised of 8% (n = 2) males and 92% (n = 24) females and 30 comparison subjects comprised of 3% (n = 1) males and 97% (n = 29) females consented to participate in the study. An attrition rate of 16% was experienced: 6 (23%) experimental subjects and 3 (10%) comparison subjects. Four experimental and three comparison subjects dropped out due to acute illnesses and surgery, while one experimental subject was on an extended vacation during several weeks of the exercise program. Another experimental subject attended only eight (33%) of the exercises classes and reported that he did not do the exercises on the days between the classes. Thus, he was dropped from the analyses because of limited participation in the exercise program.

Forty-seven subjects completed the study: 20 experimental and 27 comparison subjects. The experimental subjects were all female, and of the 27 comparison subjects, 1 (4%) was male and 26 (96%) were female. The subjects ranged in age from 65 to 88 (experimental $\underline{M}$ = 75.25, $\underline{SD}$ = 7.04; comparison $\underline{M}$ = 74.78, $\underline{SD}$ = 6.14).

The experimental and comparison subjects were similar in the number of self-reported chronic illnesses ($\underline{M}$ = 1.00, $\underline{SD}$ = .86; $\underline{M}$ = 1.18, $\underline{SD}$ =.88, respectively). The illness categories included cardiac, diabetes mellitus, emotional/psychiatric, eye and other diseases. (See Table 1 for frequency of chronic illnesses.) No significant differences were found between the experimental and comparison groups for number of categories of chronic illnesses [$\underline{t}(45) = .72$, $\underline{p} = .47$]. The chronic illness most often reported by both groups was cardiac disease (experimental $\underline{n}$ = 9; comparison $\underline{n}$ = 16) followed by diabetes mellitus (experimental $\underline{n}$ = 4; comparison $\underline{n}$ = 4). There were no significant differences between the two groups with regard to these two illnesses [$\underline{X}^2(1) = .94$ and $\underline{X}^2(1) = .22$ respectively].

The experimental and comparison subjects were also similar in reported number of categories of medications. The experimental group

Table 1

Frequency and Percent of Self-reported Chronic Illness Categories for the Experimental (n = 20) and the Comparison (n = 27) Groups

	Group			
	Experimental		Comparison	
Number of illness categories	n	%	n	%
0	6	30	5	18.5
1	9	45	15	55.6
2	5	25	5	18.5
3	0	0	2	7.4

had a mean of 2.1 (SD = 1.21), with the comparison group reporting slightly less (M = 1.74, SD = 1.46). Cardiac medications (experimental n = 16, comparison n = 17) were the most frequently reported medications for both groups. There was not a significant difference between the experimental and comparison groups in number of medications [$t(45) = .90$, $p = .36$]. The frequency of medications is presented in Table 2.

Since sedentary activity was a criterion for inclusion, the subjects' level of physical activity prior to this study was important. Physical activity for the present year was measured, and the results are summarized in Table 3. Present year activities of both groups were similar, with the most frequent activity being cleaning the apartment. The present year activity was not significantly different between the groups.

Table 2

Frequency and Percent of Medication Categories for Self-reported Medications Per Subject for the Experimental (n = 20) and the Comparison (n = 27) Groups

Number of medication categories	Group: Experimental n	Experimental %	Comparison n	Comparison %
0	2	10	5	18.5
1	7	35	11	40.7
2	8	40	4	14.8
3	3	15	7	26.0

Table 3

Means, Standard Deviations, and t Tests for Present Year Level of Physical Activity for Experimental (n = 20) and Comparison (n = 27) Groups

Variable	M	SD	df	t
Present year activity				
Experimental	29.40[a]	30.81	24.49[b]	-1.60
Control	16.87[a]	13.35		

[a]Weighting by aerobic intensity multiplied by the frequency per week for each activity and then summed.

[b]Separate variance estimate.

Subjects in the experimental group participated in the exercise classes and did the exercises on the days between classes. Subjects reported doing the exercises from 21 to 139 times during the study period (M = 48.00, SD = 27.94, approximately six times a week).

Since aerobic activity other than the experimental intervention would confound the results of this study, this also was measured. Subjects in both groups were asked to keep a journal of exercise they participated in during the eight weeks. Among the experimental group, the exercise associated with the experimental intervention was not included in this assessment. Analysis of the journals indicated that the comparison group was slightly more active than the experimental group (M = 2.59, SD = 4.36, and M = 1.50, SD = 4.15 respectively). Although the comparison group reported more exercise during the eight weeks than the experimental group (with the exception of the exercise program), this difference was not significant [$t(45) = .87$, $p = .39$].

Pretest

Pretest variables considered were muscle strength and flexibility of the lower extremities, balance, and perception of balance. As done by Whipple et al. (1987), muscle strength and flexibility measurements that made up functional units according to the joint involved were added together. This resulted in one score for muscle strength of the muscles of the left and right ankles and another for muscles of the right and left knees, and four scores, one each for flexibility of the ankles and knees. In contrast to the measurement of strength for other muscles, the gastrocnemius was measured by the number of times the subject could raise up on toes (for a maximum of 10 times). The t-test was used to assess the difference between the two groups at pretest on strength of the gastrocnemius, balance, perception of balance, proprioception, and vibratory sensation, while MANOVA was used for analyses of muscle strength (right and left knees and ankles) and flexibility of the knees and ankles. Muscle strength and flexibility were not significantly different between the groups, with Hotelling's T^2 ranging from 1.06, p =.70, for muscle strength of the ankles to 3.18, p = .29, for muscle strength of the knees and 1.06, p = .59, and 2.65, p = .34, respectively for flexibility of the knees and ankles. In addition, the two groups were not significantly different at pretest for strength of gastrocnemius, balance, and perception of balance [t(45) = .31, p = .76; t(29.38) = -.43, p = .67; and t(45) = -.82, p = .41 respectively]. Moreover, pretest vibratory sensation was not significantly different between the groups [t(45) = .51, p = .61]. The variability for proprioception was too small for any meaningful interpretation. Visual acuity was assessed at posttest only. (See Table 4 for means and standard deviations of pretest variables.)

Effect of the Exercise Program

To insure subjects did not exceed 70% of their age-adjusted maximum heart rate, a criterion for low aerobic intensity (American College of Sports Medicine, 1986), subjects were taught to monitor their pulse rate during the exercises. One subject had a resting

Table 4

Means, Standard Deviations, and Ranges for Pretest Balance, Perception of Balance, Muscle Strength, Flexibility, and Vibratory Sensation for Experimental (n = 26) and Comparison (n = 30) Groups

	Comparison group				Experimental group			
Variable	M	SD	Min	Max	M	SD	Min	Max
Balance	16.23	11.51	2.17	46.90	17.49	16.96	0.05	71.50
Balance perception	4.13	1.48	3.00	8.00	4.58	1.79	3.00	10.00
Muscle strength								
Left knee	14.82	2.05	9.90	20.30	14.89	2.39	9.40	18.70
Right knee	14.87	2.30	11.00	21.80	15.04	3.10	7.50	21.00
Left ankle	8.54	1.43	6.60	11.90	8.39	1.80	5.60	12.20
Right ankle	8.83	1.63	3.90	11.80	9.17	1.89	5.20	15.00
Gastrocnemius	9.20	1.96	3.00	10.00	9.15	2.40	0.00	10.00
Flexibility								
Left knee	310.67	6.64	295.00	373.00	311.96	8.00	295.00	325.00
Right knee	309.40	8.30	295.00	325.00	311.00	7.28	296.00	324.00
Left ankle	133.73	20.10	92.00	175.00	127.70	26.23	84.00	198.00
Right ankle	131.30	26.20	76.00	189.00	129.00	26.11	84.00	204.00
Vibratory sensation	1.27	2.29	0.00	8.00	1.15	2.26	0.00	8.00

pulse that was above her age-adjusted maximum heart rate, and her exercise-induced rate never exceeded this by more than 18 beats per minute (range 6-18). The minimal increase in pulse during the exercises indicated that they were of low aerobic intensity for this subject.

> Hypothesis 1. Elderly persons who participate in a low intensity aerobic exercise program three times a week for eight weeks will have higher balance scores and perception of balance scores than those elderly persons who maintain their usual activity level for eight weeks.

Although the posttest measures of balance and perception of balance were higher for the experimental group than the comparison group, they were not significantly different. Thus, the hypothesis that elderly persons who participated in a low intensity aerobic exercise program for eight weeks will have better balance and perception of balance was not supported. Results are summarized in Table 5. Post-hoc power analyses revealed moderate effect sizes with t-tests and power of .37 for balance and .43 for perception of balance.

> Hypothesis 2. Elderly persons who participate in a low intensity aerobic exercise program three times a week for eight weeks will have greater flexibility scores of the knee and ankle joints than those elderly persons who maintain their

Table 5

Means, Standard Deviations, and Ranges for Posttest Balance, Perception of Balance, Vibratory Sensation, and Visual Acuity for Experimental (n = 20) and Comparison (n = 27) Groups

	Comparison group				Experimental group				
Variable	M	SD	Min	Max	M	SD	Min	Max	*t*
Balance	16.20	11.07	4.35	57.76	21.41	24.68	0.03	102.35	-0.88
Balance perception	4.33	1.78	3.00	10.00	5.10	2.20	3.00	9.00	-1.33
Vibratory sensation	1.59	2.65	0.00	8.00	1.00	2.00	0.00	6.00	0.84
Visual acuity	32.78	16.15	15.00	100.00	47.37	38.38	20.00	200.00	-1.56

Note. None of the *t* tests were significant.

usual activity level for eight weeks.

Flexibility scores were combined to represent a range of motion score for the ankles and knees. Considered as conceptual units, measurements that made up the flexibility scores for the ankles included plantar flexion, dorsiflexion, inversion, and eversion. Posttest measures of flexibility were significantly greater for the experimental group with Hotelling's $T^2 = 7.92$ and 41.80 for knees and ankles respectively. The hypothesis was supported that elderly persons who participate in a low intensity aerobic exercise program have greater flexibility of the knee and ankle joints than those elderly persons who maintain their usual activity. Except for the left knee, univariate analysis revealed that the experimental group had significantly greater flexibility for the right knee and both ankles than the comparison group. (See Table 6 for means, standard deviations, and univariate and multivariate test statistics for flexibility.) Post-hoc power analyses revealed moderate to large effect sizes with MANOVAs and power of .66 for flexibility of knees and .97 for flexibility of ankles.

Univariate tests of each range of motion considered in the conceptual unit of the ankle (plantar flexion, dorsiflexion, inversion, and eversion) revealed that the experimental group had significantly greater inversion, eversion, and dorsiflexion of the left ankle and for all four range of motions of the right ankle. For flexibility of the knees, there were two measures making up the conceptual unit, flexion and extension. Extension of both knees had

Table 6

Means, Standard Deviations, and Test Statistics for Posttest Flexibility for Experimental (n = 20) and Comparison (n = 27) Groups

Variable	Comparison group				Experimental group				Hotelling's		
	M	SD	Min	Max	M	SD	Min	Max	T^2	F	t
Knees									7.92*		
Left knee	310.04	6.08	299	320	311.35	8.39	295	328		0.39	
Flexion	130.04	6.08	119	140	131.35	8.39	115	148			-0.62
Extension	180.00	0.00	180	180	180.00	0.00	180	180			
Right knee	307.07	7.31	289	322	312.95	8.17	301	329		6.72*	
Flexion	127.07	7.31	109	142	132.95	8.17	121	149			-2.59**
Extension	180.00	0.00	180	180	180.00	0.00	180	180			
Ankles									41.80***		
Left ankle	130.44	14.02	103	152	158.10	16.88	127	191		37.57***	
Plantar flexion	54.22	5.82	41	65	56.00	5.58	45	63			-1.05
Dorsiflexion	-4.52	4.60	-13	2	-0.05	3.49	-8	5			-3.63**
Inversion	43.93	6.14	30	58	53.00	8.11	40	65			-4.37***
Eversion	36.82	5.72	20	45	49.15	7.32	37	63			-6.49***
Right ankle	128.07	19.54	72	164	161.70	20.79	115	194		32.23**	
Plantar flexion	55.26	6.04	44	70	59.35	6.22	45	68			-2.27*
Dorsiflexion	-8.63	8.82	-40	6	-4.40	5.01	-21	1			-2.08*
Inversion	43.67	5.79	30	60	54.00	9.14	28	65			-4.44***
Eversion	37.78	8.09	22	54	52.75	7.83	35	67			-6.36***

*$p < .05$ **$p < .01$. ***$p < .001$.

such little variation (SD = 0.00) that interpretation was not possible. Thus, only right knee flexion was significantly greater for the experimental group than for the comparison group.

> Hypothesis 3. Elderly persons who participate in a low intensity aerobic exercise program three times a week for eight weeks will have greater muscle strength of the flexor and extensor muscles of the knee and ankle than those elderly persons who maintain their usual activity level for eight weeks.

As with flexibility, muscle strength scores were combined to represent the muscular conceptual units working the knees and ankles. No significant differences were found between the groups on muscle strength with Hotelling's T^2 ranging from 1.32 to 4.40 for knees and ankles respectively. Moreover, no significant differences were found between the experimental and comparison groups [$t(45) = .20$]) for strength of the gastrocnemius. Thus, the hypothesis was not supported that elderly persons who participate in a low intensity aerobic exercise program will have greater muscle strength of the flexor and extensor muscles of the knee and ankle than those elderly persons who maintain their usual activity for eight weeks. Post-hoc power analyses revealed small effect sizes with all t-tests and MANOVAs and power of .15 for muscle strength of the gastrocnemius and knees and .40 for the ankles.

Univariate tests of the individual components for muscle strength of the knee (hamstring and quadriceps) and ankle (tibialis anterior and soleus), with the exception of the left tibialis anterior, revealed no significant differences between the groups for measurements of individual muscles. However, the comparison group had significantly greater left tibialis anterior muscle strength than the experimental group. Results of muscle strength are summarized in Table 7.

> Hypothesis 4. Elderly persons who participate in a low intensity aerobic exercise program three times a week for eight weeks will have better muscle strength of the flexor and extensor of the knees and ankles, greater flexibility of the knee and ankle joints, and better balance and perception of balance when controlling for variables identified as covariates.

No significant differences between the experimental and comparison groups on hypothesized control variables were found. To determine if any control variables (proprioception, vibratory sensation, visual acuity) were covariates in this study, Pearson's correlations were computed between the dependent variables and the control variables. Only vibratory sensation was significantly correlated with left knee muscle strength (pretest $r = -.36$, posttest

Table 7

Means, Standard Deviations, and Test Statistics for Posttest Muscle Strength for Experimental (n = 20) and Comparison (n = 27) Groups

Variable	Comparison group				Experimental group				Hotelling's T^2	F	t
	M	SD	Min	Max	M	SD	Min	Max			
Knees									1.32		
Left knee	15.52	1.77	9.70	18.40	16.06	1.41	14.30	19.10		1.25	
Hamstring	7.65	1.37	3.00	10.30	8.10	0.94	6.70	9.80			-1.25
Quadriceps	7.87	0.72	6.60	9.60	7.96	0.70	6.90	9.30			-0.43
Right knee	16.12	1.46	14.00	19.30	16.35	1.36	13.50	18.80		0.32	
Hamstring	8.28	1.01	6.60	10.70	8.22	0.98	5.80	9.40			0.20
Quadriceps	7.84	0.86	6.00	9.50	8.13	0.59	7.00	9.40			1.31
Ankles									4.40		
Left ankle	9.08	1.55	6.00	12.30	8.34	1.08	6.50	10.30		3.35	
Soleus	4.64	1.24	2.20	6.60	4.30	0.79	3.00	5.90			1.16
Tibialis anterior	4.43	0.57	3.50	5.70	4.04	0.65	3.00	4.90			2.23[a]
Right ankle	9.40	1.65	5.90	13.40	9.11	1.12	7.40	10.70		0.49	
Soleus	4.75	1.22	2.20	6.60	4.52	0.67	3.20	5.60			0.84
Tibialis anterior	4.66	0.76	3.30	6.80	4.59	0.60	3.50	5.80			0.32
Gastrocnemius	9.59	1.12	5.00	10.00	9.50	1.82	2.00	10.00			0.20

[a]Significant at $p < .05$ for the comparison group.

r = -.34) and, thus, was used as a covariate in subsequent analyses of muscle strength. Because there was no significant difference between pretest and posttest vibratory sensation [$t(45) = .84$], only posttest vibratory sensation was used as a covariate. Subsequent MANCOVA found no significant difference in posttest muscle strength of the left knee (Hotelling's $T^2 = 1.29$, $p = .48$). Even though visual acuity was not significantly different between the two groups, there was difference between the experimental ($M = 47.37$) and comparison ($M = 20.00$) groups. Since sensory information is important to balance (Woollacott et al., 1988), two ANCOVAs were computed with balance and perception of balance as dependent variables and visual acuity the covariate. No significant differences were found between the groups on these two variables (balance $F(1, 43) = 1.89$, perception of balance $F(1, 43) = 1.66$).

To control further for pretest differences, the pretest scores of each of the six dependent variables were used as covariates, and only flexibility of the ankles was significantly different between the groups (Hotelling's $T^2 = 84.00$). Although MANCOVA did not indicate a significant difference between the groups for knee flexibility, univariate analysis revealed that flexibility of the right knee was significantly greater for the experimental group than the comparison group. Muscle strength of the knees and ankles, balance, and perception of balance were not significantly different between the groups. These findings did not differ from previous ones. Results are summarized in Table 8.

Table 8

Hotelling's T^2, F Value for Analyses of Muscle Strength, Flexibility, Balance, and Perception of Balance Using Pretest Scores as Covariate For Experimental (n = 20) and Comparison (n = 27) Groups

Variable	Hotelling's T^2	Hypotheses df	Error df	F
Muscle strength				
Knees	0.84	2	42	
Right				0.15
Left				0.80
Gastrocnemius				0.00
Ankles	0.42	2	42	
Right				1.25
Left				3.95
Flexibility				
Knees	6.72	2	42	
Right				5.88*
Left				0.01
Ankles	42.00***	2	42	
Right				58.86***
Left				64.85***
Balance				0.74
Perception of balance				0.28

*p <.05. **p <.01. ***p < .001.

The frequency with which the exercises were done may influence flexibility, muscle strength, balance, and perception of balance. Thus, in the experimental group, correlations were computed between these posttest scores and the frequency of exercise. Except for muscle strength of the right and left knee, all dependent variables had a correlation coefficient of .2 or greater. However, only right ankle flexibility was significantly related to frequency of exercise ($r = -.55$, $p = .01$), and muscle strength of the left ankle approached significance ($r = .42$, $p = .06$). Additional analyses were done to determine if frequency of exercise would predict improvement in muscle strength and flexibility of the lower extremities, balance, and perception of balance. Eleven multiple regression analyses were computed with each dependent variable posttest as the dependent variable and the pretest and frequency of exercise as independent variables. For example, in one analysis, right ankle flexibility posttest was the dependent variable, with right ankle flexibility pretest and frequency of exercise the independent variables. With the exception of right ankle flexibility, the pretest variable entered the equation first. The explained variance of the 11 equations, which included both the pretest and frequency of exercise, ranged from 28% to 59%, and seven of these were significant (right ankle and right and left knee flexibility, right and left ankle muscle strength, gastrocnemius, and balance). Only the pretest beta coefficients were significant in the equations for right knee flexibility ($\beta = .61$), right ankle muscle strength ($\beta = .59$), right and left knee muscle strength ($\beta = .53$ and .50 respectively), and balance ($\beta = .62$). In the regression analysis of right ankle flexibility, the frequency of exercise contributed the most variance (30%), and when both variables (pretest and frequency of exercise) entered the equation, 43% ($p < .01$) of the variance was explained. In this equation only the beta coefficient for frequency of exercise

(β = .53) was significant. In the equations for left knee flexibility and left ankle muscle strength, the pretest contributed the most variance (45% and 27% respectively), but when both variables entered the equation, the variance explained was 59% and 48% respectively. Additionally, both beta coefficients were significant (left knee flexibility, β = .69 and .37; left ankle muscle strength, β = .55 and .46). These findings imply that the frequency of exercise was important to improvement in right ankle flexibility, left knee flexibility, and right ankle muscle strength. Results of the regression analyses are summarized in Table 9.

Other effects of the exercise program were self-reported by subjects. One subject had difficulty getting around and complained of stiff knees that made her movement very slow. When in the exercise class, she refused to do the exercises which required her getting up and standing behind her chair. She stated she was too slow for the group but reported doing these exercises several times a day on her own. Later in the exercise program, this subject reported that her knees were not as stiff. A second subject occasionally did not do the standing exercises, saying she did not feel up to getting out of her chair and doing them. Several other subjects reported they were able to walk with greater ease and one subject reported sleeping better at night since starting the exercise program.

Post Hoc Findings

The variables of interest in this study have been cited as factors influencing falls. That is, poor balance has been linked to

Table 9

ß, R^2, F Statistics for Regression Analyses for Variable Posttest as Dependent Variable and Pretest and Frequency of Exercise as Independent Variable for Experimental (n = 20) Group

Variable	ß	R^2	F
Flexibility			
Right ankle		.43	6.51**
Pretest	.36		
Frequency of exercise	-.53**		
Left ankle		.28	3.32
Pretest	.42		
Frequency of exercise	-.25		
Right knee		.41	5.96**
Pretest	.61**		
Frequency of exercise	-.11		
Left knee		.59	12.16***
Pretest	.69***		
Frequency of exercise	-.37*		
Muscle strength			
Right ankle		.41	6.03**
Pretest	.59**		
Frequency of exercise	.20		
Left ankle		.48	7.79**
Pretest	.55**		
Frequency of exercise	.46*		
Right knee		.26	3.00
Pretest	.53*		
Frequency of exercise	-.08		
Left knee		.26	2.95
Pretest	.50*		
Frequency of exercise	.03		
Gastrocnemius		.55	10.46***
Pretest	.72		
Frequency of exercise	-.06		
Perception of balance		.24	2.61
Pretest	.43		
Frequency of exercise	.13		
Balance		.45	7.01**
Pretest	.62**		
Frequency of exercise	-.18		

*$p < .05$. **$p < .01$. ***$p < .001$

falls (Brocklehurst et al., 1978; Overstall, 1980; Ring, Nayak, & Issacs, 1988; Sheldon, 1960), as well as a decrease in muscle strength and flexibility (Whipple et al., 1987). On pretest, 11 subjects from both the experimental (n = 4) and comparison (n = 7) groups reported a fall in the past six months. A post-hoc analysis was done dividing subjects into fall or no fall groups. The fallers had lower strength of all muscles and less flexibility of all joints except left knee, which was approximately the same for both groups. Although not significant, fallers had lower balance but slightly greater perception of balance scores.

Post-hoc power analysis revealed that the small effect sizes with all MANOVAs and t-tests and power were between .13 for knee flexibility to .30 for ankle flexibility. However, the effect size for perception of balance was .75. Results are summarized in Table 10.

Additional analyses were computed on this pretest data. To determine whether muscle strength and flexibility of the knees and ankles predicted balance, hierarchial regression was used. Several variables were highly correlated and indicated multicollinearity. Pretest scores for right and left knee and ankle were significantly correlated (r's from .62 to .71). Thus, to avoid multicollinearity, scores for only the right side were used in regression analysis. Additionally, knee and ankle muscle strength had a high correlation coefficient (r = .62), while the correlation coefficient for knee and ankle flexibility was r = .15. Thus, two regression analyses were

Table 10

Means, Standard Deviations, and Test Statistics for Flexibility, Muscle Strength, Balance, and Perception of Balance for No Fall (n = 45) and Fall (n = 11) Groups

Variable	No fall group M	No fall group SD	Fall group M	Fall group SD	T^2	F	t
Flexibility							
Knees					0.53		
Left	311.13	7.59	311.81	6.06		0.08	
Right	310.29	8.20	309.64	6.31		0.06	
Ankles					3.18		
Left	132.49	23.51	124.55	21.33		1.04	
Right	133.11	26.72	118.46	19.26		2.92	
Muscle strength							
Knees					1.06		
Left	14.98	2.11	14.30	2.55		0.83	
Right	15.10	2.74	14.32	2.41		0.75	
Ankles					2.12		
Left	8.61	1.70	7.90	0.96		1.70	
Right	9.14	1.83	8.36	1.21		1.82	
Gastrocnemius	9.27	2.04	8.82	2.64			0.62
Balance	17.59	14.93	13.66	10.51			0.82
Perception of balance	4.07	1.29	5.45	2.38			-1.87

Note. None of the tests were significant.

computed: The first included only knee muscle strength and flexibility as independent variables and the other included ankle muscle strength and flexibility as independent variables. In the first analysis, 11% of the variance in balance was explained by muscle strength and flexibility of the knee ($F = 3.19$, $p = .05$). In this analysis, both muscle strength and flexibility entered the equation, but neither beta coefficient ($\beta = .25$, $.22$ respectively) was significant. In the second analysis, 6% of the variance in balance was explained by muscle strength and flexibility of the ankle ($F = 3.54$, $p = .07$), with only muscle strength entering the equation, but the beta coefficient ($\beta = .25$) was not significant. Although significant variance was explained, none of the independent variables had significant beta weights. This suggests that other factors not considered in this study may have had significant influences on balance.

Summary

The findings in this research were that the elderly persons who participated in the low intensity aerobic exercise program had significantly greater flexibility of the right knee and ankle and left ankle than those who did not participate in the exercise program. Flexibility of the left knee was similar for both the experimental and the comparison groups. The experimental and comparison groups had similar scores for muscle strength of the lower extremities. Those elders who participated in the exercise program were not significantly different in balance and perception of balance than those elders who did not participate. The frequency with which the low intensity aerobic exercise program was done contributed significantly to flexibility of the right ankle, left knee, and right ankle muscle strength.

CHAPTER V

DISCUSSION AND IMPLICATIONS

The purpose of this study was to determine the effects of a low intensity aerobic exercise program, specific to the lower extremities, on muscle strength and flexibility of the lower extremities and balance among sedentary elderly persons. Proprioception, vibratory sensation, and visual acuity were assessed and statistically controlled as covariates when they were significantly related to the dependent variables of interest. Using Birren and Renner's (1977) use/disuse theory, the low aerobic exercise program was expected to increase balance and perception of balance and increase flexibility and muscle strength of the knees and ankles.

This pretest-posttest quasi-experimental study consisted of 47 sedentary subjects not engaged in regular exercise and living in metropolitan housing in southwestern Ohio. Convenience sampling was used by randomly assigning the two apartment complexes to the experimental or comparison groups. To prevent diffusion of treatment, subjects were assigned to these groups depending on their place of residence. The 20 experimental subjects, with a mean age of 75.3, participated in eight weeks of low intensity exercise, while the comparison group ($\underline{n}$ = 27), with a mean age of 74.8, maintained their usual activity for eight weeks.

The low intensity aerobic exercise program was three times a week for eight weeks. Experimental subjects also did the exercises on their own between classes. The program consisted of stretching and strengthening exercises for the lower extremities, and, except for two exercises, they were done while sitting in a chair.

The exercise group had significantly greater flexibility of the ankles and right knee than the comparison group. No significant differences were found between the groups for muscle strength. Although balance and perception of balance were not significantly different between the groups, the experimental group improved their balance by 22.4% from pretest.

Effects of the Exercise Program

Findings from this research support the use/disuse theory (Birren & Renner, 1977). That is, use in the form of exercise improves flexibility. The exercise program improved flexibility for the experimental group in three of four joints: both ankles and the right knee. These findings are consistent with those of other investigators who used stretching and range of motion exercises with elderly subjects (Bassett et al., 1982; Frekany & Leslie, 1975; Munns, 1981; Raab, 1988; Rikli & Busch, 1986). When individual measurements that made up the range of motion (knee flexion and extension, plantar flexion, dorsiflexion, inversion, and eversion) were considered separately, the experimental group had significantly greater inversion, eversion, dorsiflexion, and plantar flexion than the comparison group. The exercise group experienced a significant increase for only right knee flexion and not the left knee. A possible explanation for this finding is that more subjects may have been right-side dominant, making it easier for them to exercise the right leg, resulting in greater improvement in right knee flexibility.

As compared to the comparison group, the experimental group had significantly greater ankle flexibility that is similar to the findings of other researchers (Raab et al., 1988). Using only an experimental group, other researchers reported exercise improved flexibility of the lower extremities (Frekany & Leslie, 1975; Munns, 1981). Additionally, differences in right knee flexibility found in this study are consistent with similar findings by other researchers (Bassett et al., 1982; Munns, 1981). Because other researchers have only reported unilateral values and normal values for elderly persons are not available, a comparison to these subjects with those in the present study is not possible. However, only unilateral measurements were reported in these previous studies and none of the researchers included inversion and eversion of the ankle. Thus, the findings of the present study extend knowledge about the effects of low intensity aerobic exercise on right and left ankle flexibility.

Raab et al. (1988) were the only researchers to report findings on individual measurements of ankle flexibility: dorsiflexion and plantar flexion. They reported that the exercise program significantly improved plantar flexion but not dorsiflexion. Similarly, this researcher found that the exercise group had significantly greater left inversion, eversion, dorsiflexion, and all four range of motions of the right ankle than the comparison group. Thus, the findings of this study are consistent with Raab et al. (1988).

Contrary to the findings related to flexibility, muscle strength of the knees and ankles of sedentary elders participating in a low intensity exercise program was not significantly different from those sedentary elders who maintained their usual physical activities. When the individual muscles that made up the functional units of the knee and ankle were examined, none were significantly different between the experimental and comparison groups. The findings of this study on muscle strength were somewhat similar to those of Morey and colleagues (1989) who examined the strength of the quadriceps, one of the muscles making up the functional unit of the knee. They did not find a significant change in the strength of the quadriceps following a four-month aerobic exercise program that included stretching and strengthening exercises and brisk walking. They studied only the exercise group, and they measured only the right quadriceps. Thus, it was not possible to compare muscle strength of the right and left quadriceps with findings of this study.

A possible explanation of not finding the anticipated improvement in muscle strength is the duration of the exercise program. Other researchers reported significant differences for the experimental group for strength of the muscles (hamstrings and quadriceps) around the knee (Agre et al., 1988; Brown & Harrison, 1986; Larrson, 1982). These experimental groups participated in exercise programs lasting in length from 12 to 25 weeks, all of which were of longer duration than the exercise program in this study. Thus, the eight-week duration of the exercise program of the present study may not have been long enough to effect changes in muscle strength. Moreover, these investigators did not examine muscle strength of the ankles. In the present study, muscle strength of the ankles was assessed and, thus, provides new information regarding muscle strength of the ankles among sedentary elders.

A second possible explanation for nonsignificant changes in muscle strength in this study is that the intensity of the exercises may not have been great enough. The American College of Sports Medicine (1986, 1990) noted that muscle strength changes can result with low levels of resistance. In a study of progressive-resistive exercises, Fiatorone, Marks, Ryan, Meredith, Lipsitz, and Evans (1990) found these high intensity exercises significantly improved the strength of the quadriceps among adults aged 86 to 96. Again, these researchers did not measure muscle strength of the muscles of the ankle. Agre et al. (1988) found improvement in muscle strength without resistance, but their exercise program was 25 weeks in length. In contrast, the exercise program in the present study used the weight of the leg and the subject's body as the source of low resistance to the muscles in the leg.

The study findings also demonstrated that, except for left tibialis anterior for the comparison group, there were no significant differences between the experimental and comparison groups. The increase in muscle strength of the left tibialis anterior for the comparison group may have been caused by physical exercise beyond their usual activity pattern. During the time the study was conducted, the winter had mild temperatures and little snow. Thus, it was possible for the comparison group to get out of doors frequently and occasionally walk the two to three blocks to the city center. The activity involved in the occasional walk to town may have influenced muscle strength of the lower extremities. However, the daily log of activities did not reflect significant differences in physical activity.

Increases in muscle strength can result because of the experience gained by the subject during the first measurement. In the present study, to measure muscle strength the subject maintained a particular position and resisted the tester. This pretest experience may have been related to learning how to do these measurements, and this learning may have influenced posttest measurement. Because the baseline for the experimental and comparison groups was similar and testing effect would be expected to affect both groups, if the exercise program had had an effect, the experimental group would be expected to have greater muscle strength than the comparison group in spite of this learning effect. However, the posttest difference between the two groups was not significant. Thus, it could not be determined if learning did confound the measures of strength.

The group of sedentary elders who participated in the low intensity aerobic exercise program did not have significantly different balance than the sedentary elders who did not participate. Although this difference was not significant, the experimental group improved their balance while the comparison group did not. If the exercise program had been longer, greater differences may have been found. Although Roberts (1989) found a six-week walking exercise program improved balance in elders, the exercise programs in which elderly subjects experienced a significant increase in lower extremity muscle strength generally lasted 12 to 25 weeks (Agre et al., 1988; Brown & Harrison, 1986; Larrson, 1982). This suggests that future studies should include a longer duration of the low intensity aerobic exercise program, and, as noted for muscle strength, thus provide a longer period of time for the exercise to affect balance. The ability of the exercise program to effect a change in balance from pretest to posttest may be clinically significant if a modest improvement in balance were to reduce falls.

Perhaps the low intensity aerobic exercise used in the present study would not affect balance. Roberts (1989) found a walking program with elderly persons significantly improved their balance. This program included aerobic exercise that required prolonged movement of large muscle groups and may result in greater effect on physical factors than the low intensity aerobic exercise program in the present study. Although Roberts found a significant difference in balance between the experimental and control group, she did not measure muscle strength or flexibility. Thus, it was not possible to compare flexibility and muscle strength when there was a significant difference in balance with the findings in the present study. However, Bassett et al. (1982) found that following a stretching and strengthening exercise program, subjects significantly improved flexibility but not muscle strength or balance. Since balance is affected by muscle strength and flexibility (Nashner, 1987), greater muscle strength and flexibility than was found in the present study may be needed before balance is significantly affected by low intensity aerobic exercise.

The perception of balance was also not significantly different between the experimental and comparison groups and is consistent with Roberts' (1989) findings. Roberts suggested that a modest improvement in balance may not be large enough for subjects to recognize a change in balance, and thus their perceptions would remain the same. This assumption may be also true in this study.

Since maintenance of balance is influenced by sensory inputs of proprioception, vibratory sensation, and visual acuity (Stones & Kozma, 1987; Woollacott et al., 1988), these variables were also controlled in this study. Although significant differences on these control variables were not found between sedentary elders who participated in a low intensity aerobic exercise program and those who did not participate, vibratory sensation was found to be significantly related only to muscle strength of the left knee. When controlling for vibratory sensation, differences between the groups on the muscle strength of the left knee were not significant. Visual acuity has been reported to affect balance among elderly subjects (Stones & Kozma, 1987). That is, these researchers found poorer balance among elderly subjects when eyes were closed than when open. However, controlling for visual acuity did not reveal a significant difference between the groups for balance or perception of balance.

Other Findings

If use, in the form of exercise, improves muscle strength, flexibility, and balance, then the frequency of exercise would influence outcomes related to these variables. Analyses confirmed that frequency of exercise in this study did influence improvement in flexibility of the right ankle, left knee, and muscle strength of the left ankle. Even though the experimental group did not experience significantly greater improvement than the comparison group for flexibility of the left knee and muscle strength of the left ankle, those experimental subjects who exercised more achieved greater improvement. This finding lends support that a longer duration of exercise would allow greater improvement to take place. The frequency with which the subjects exercised was not significantly related to flexibility of the right knee, muscle strength of the knees and the right ankle, balance, or perception of balance.

In addition to frequency of exercise, other factors may be related to exercise effect. In studying exercise in frail elderly, Fiatorone et al. 1990 found large (180%) increases in muscle strength. Such outstanding gains in strength may indicate that persons with greater frailty benefit more from exercising than less frail persons. Since normal values for elders on the variables of interest in this study are not available, it was not possible to determine if subjects had greater deficits on some of the variables, such as ankle flexibility, than the elderly population in general. Thus, a possible explanation is that the exercise program in this study focused more on flexibility of the ankle.

Ankle flexibility and muscle strength of the lower extremities have been found to be related to balance (Nashner, 1987; Woollacott et al., 1982), and elderly fallers have been found to have decreased muscle strength of the lower extremities (Whipple et al., 1987). At pretest, 11 subjects reported they had fallen during the previous six months. Analysis of pretest data based on fall or no fall was not significant. Perception of balance was greater for those who had fallen than for those who had not fallen, but this difference was not significant. The small number of fallers decreased the statistical power, and, thus, decreased the ability to detect significant differences. Additionally, although not significant, fallers had less strength of all muscles and decreased flexibility and balance than those who had not fallen. These findings are consistent with Whipple et al. (1987) who found markedly decreased plantar-dorsiflexion torque among elderly person who had fallen, and with other researchers who noted fallers had poor balance (Brocklehurst et al., 1978; Sheldon, 1960).

Further analysis was done to determine if flexibility and muscle strength would predict balance. Although muscle strength and flexibility of the knee and muscle strength of the ankle entered the regression equations, the regression coefficients were not significant. These findings are somewhat consistent with those reported by other researchers that appropriate muscle strength (Nashner, 1987; Ring & Matthew et al., 1988) and ankle movement (Whipple et al., 1987) are important to balance. Additionally, these findings indicate factors other than those in the present study may have significant influences on balance.

Research Implications for Future Studies

The eight-week low intensity aerobic exercise program did significantly produce differences between the experimental and comparison groups for flexibility of the ankles and right knee, but not for muscle strength of the lower extremities. Even though the differences between the groups on balance was not significant, the experimental group experienced an increase in balance while the comparison group did not. The difference in flexibility and the increase in balance indicate movement in the right direction. However, a limitation of this study is the duration of the exercise program, which if of longer duration, may allow more time for change to occur.

In addition to the effect of exercise on elders, the effect of limited physical activity should also be considered. Elders in Western society decrease their activity as they age (Shepard, 1978). Such lack of activity leads to symptoms of disuse, such as decreases in muscle strength (Fiatarone et al., 1990) and flexibility (Munns, 1981). In the present study, a 23% attrition rate was experienced in the experimental group. Although there is not specific information to evaluate causes for this attrition, understanding why elders choose not to exercise or what factors motivate them to continue exercising would be important. Future studies should focus on determining the benefits and barriers to exercising among elderly persons.

Benefits of a low intensity aerobic exercise program for sedentary elderly not only vary among individuals, but also may have different effects on different populations of elders. Fiatarone and colleagues (1990) found great improvement in muscle strength among frail elders. This finding suggests that with greater frailty, exercise effect may be greater. Thus, future studies should examine the effect of this low intensity aerobic exercise program among frail elders living in a long-term care setting.

Not only different populations but also methodological limitations should be addressed by using random sampling and random assignment. These would avoid possible systematic bias that may have been present in this study.

Although not significant, the exercise group improved their balance in the present study. Since poor balance has been identified as a factor influencing falls among elders (Brocklehurst et al., 1978; Ring, Nayak et al., 1988; Sheldon, 1960), a question for future research is, do falls decrease among elders who are regularly engaged in an exercise program as compared to elders who are not regularly engaged in an exercise program?

Future research should include a replication of this study that would incorporate most of the recommendations cited earlier. Methodological modifications should be to improve the ability to generalize by using random sampling and random assignment and improve the power to detect significant differences, if present, by increasing the sample size. To allow more time for the exercise to affect muscle strength and balance, the duration of the exercise program should be extended to 12 weeks. To reduce the risk of testing effect, measurement of the variables would be done at several points to allow the subjects to adjust to the testing procedure. Testing should be done at week 1 (pretest), week 4, week 8, and week 12 (posttest). The intensity of the exercise program would be increased by encouraging the subjects to exercise to maximum range of motion. To determine if greater resistance is necessary to achieve an increase in the variables of interest among sedentary elders, a second experimental group should be included who exercise with weights on the ankles to increase resistance. Because the population of greatest risk of negative effects from disuse are sedentary, efforts that make the exercise program more attractive to people who tend not to engage in exercise should be implemented. For example, music could be utilized during exercise. Moreover, the exercise program should be promoted as fun and as a time for socializing.

Clinical Implications

As the number of elderly with their age-related problems and chronic illnesses grows, nursing will be increasingly involved in helping elders to adapt to changes in their physiological needs. As persons age they have a tendency to decrease their physical activity. Such a tendency results in disuse, which affects many physiological factors. Specifically, disuse decreases muscle strength, flexibility, and balance.

Nurses have frequent opportunities to provide nursing care to elders in all settings. This research has shown that physical activity in the form of low intensity aerobic exercise has important clinical implications for sedentary elders by improving flexibility. The exercise program in this study would take a minimal amount of time to teach to patients and supports health maintenance and prevention of disuse and disease. An important aspect of nursing care is that the nursing intervention be agreeable to the client and easily fit into the person's daily life style (American Nurses' Association, 1987). This research has shown that inactive elders will exercise if the exercise program is simple, safe, easy to do, and fits into their daily routine.

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APPENDIX C

MUSCLE TESTING--NICHOLAS HAND-HELD DYNAMOMETER

LEFT	MUSCLE	RIGHT
_______	GLUTEUS MAXIMUS	_______
_______	GLUTEUS MEDIUS	_______
_______	HIP ADDUCTORS	_______
_______	SOLEUS	_______
_______	HAMSTRINGS	_______
_______	QUADRICEPS	_______
_______	TIBIALIS ANTERIOR	_______

Number of times can raise on toes and back down (maximum of 10 times)

____

APPENDIX D

FLEXIBILITY

GONIOMETER MEASUREMENTS

TAKE MEASUREMENTS WITH SUBJECT IN THE SUPINE OR SIDELYING POSITION. RECORD THE MEASUREMENT.

LEFT KNEE

Flexion ____________

Extension __________

Limited motion _____

RIGHT KNEE

Flexion ____________

Extension __________

Limited motion _____

LEFT ANKLE

Plantar ____________

Dorsiflexion _______

Inversion __________

Eversion ___________

RIGHT ANKLE

Plantar ____________

Dorsiflexion _______

Inversion __________

Eversion ___________

APPENDIX E

VIBRATORY SENSATION

VIBRATION TEST--DO WITH SUBJECTS'S EYES CLOSED. TOUCH SUBJECT WITH TUNING FORK. ASK SUBJECT TO TELL IF SHE/HE FEELS THE VIBRATIONS AND TO INFORM YOU WHEN IT STOPS. CHECK APPROPRIATE REPONSE. OUTCOME IS RESULTS OF 3 OUT OF 5 TIMES.

START	YES(1)	NO(0)	STOP	YES(1)	NO(0)
RIGHT ANKLE	___	___		___	___
RIGHT KNEE	___	___		___	___
LEFT ANKLE	___	___		___	___
LEFT KNEE	___	___		___	___
			II		
RIGHT ANKLE	___	___		___	___
RIGHT KNEE	___	___		___	___
LEFT ANKLE	___	___		___	___
LEFT KNEE	___	___		___	___
			III		
RIGHT ANKLE	___	___		___	___
RIGHT KNEE	___	___		___	___
LEFT ANKLE	___	___		___	___
LEFT KNEE	___	___		___	___
			IV		
RIGHT ANKLE	___	___		___	___
RIGHT KNEE	___	___		___	___
LEFT ANKLE	___	___		___	___
LEFT KNEE	___	___		___	___
			V		
RIGHT ANKLE	___	___		___	___
RIGHT KNEE	___	___		___	___
LEFT ANKLE	___	___		___	___
LEFT KNEE	___	___		___	___
			OUTCOME/SCORE		
RIGHT ANKLE	___	___		___	___
RIGHT KNEE	___	___		___	___
LEFT ANKLE	___	___		___	___
LEFT KNEE	___	___		___	___

APPENDIX F

PROPRIOCEPTION

POSITION TEST--DO WITH THE SUBJECT'S EYES CLOSED. ASK SUBJECT TO IDENTIFY WHERE LIMB POSITIONED. CHECK APPROPRIATE RESPONSE. OUTCOME IS THE RESULT OF 3 OUR OF 5 TIMES.

LEFT ANKLE	I		II		III		IV		V		TOTAL	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y(1)	N(0)
Dorsiflexion	___	___	___	___	___	___	___	___	___	___	___	___
Plantar	___	___	___	___	___	___	___	___	___	___	___	___
Inversion	___	___	___	___	___	___	___	___	___	___	___	___
Eversion	___	___	___	___	___	___	___	___	___	___	___	___
LEFT KNEE												
Flexion	___	___	___	___	___	___	___	___	___	___	___	___
Extension	___	___	___	___	___	___	___	___	___	___	___	___
RIGHT ANKLE												
Dorsiflexion	___	___	___	___	___	___	___	___	___	___	___	___
Plantar	___	___	___	___	___	___	___	___	___	___	___	___
Inversion	___	___	___	___	___	___	___	___	___	___	___	___
Eversion	___	___	___	___	___	___	___	___	___	___	___	___
RIGHT KNEE												
Flexion	___	___	___	___	___	___	___	___	___	___	___	___
Extension	___	___	___	___	___	___	___	___	___	___	___	___

APPENDIX H

DEMOGRAPHIC INFORMATION

DATE______________
INVESTIGATOR______________________
GROUP______

DATA COLLECTION SHEET-PRETEST

ASK FOR THE FOLLOWING INFORMATION FROM THE SUBJECT

Birthdate: ____________________

Age: ___________

Sex: ____1-Male ____2-Female

Race: ____1-White ____2-Black ____3-Asian _____________Other

Have you experienced any of the following:

	1-Yes	0-No	Comments
Stroke	_____	_____	________________
Joint Replacement	_____	_____	________________
Other Joint Surgery	_____	_____	________________
Hip Fracture	_____	_____	________________
Ankle Fracture	_____	_____	________________
Leg Fracture	_____	_____	________________
Arthritis	_____	_____	________________
Peripheral Neuropathy	_____	_____	________________
Hypertension	_____	_____	________________

HAVE YOU FALLEN IN THE PAST SIX MONTHS?

_____1- Yes _____0-No

APPENDIX H--Continued

If yes, was the fall due to : (Check ONE only)
- 1- An environmental hazard. _____
- 2- No environmental hazard. _____
- 8- N/A _____

What major health problems do you have?________________________

____

____

____

APPENDIX I

CONCEPTS MEASURED

CONCEPT	MEASUREMENT	WHEN MEASURED	SCORE
Exercise	Log	8 weeks	1 interval
Balance	Roberts Balance Scale	Pre/Post	1 interval
Balance Perception	Roberts Balance Perception Questionnaire	Pre/Post	1 interval
Muscle Strength	Nicholas Manual Muscle Tester		
Quadriceps		Pre/Post	1. Quadricep and hamstrings, summed interval
Hamstrings		Pre/Post	
Soleus		Pre/Post	2. Soleus and tibialis anterior, summed interval
Tibialis Anterior		Pre/Post	
Gastrocnemius	Number of times raises up on toe	Pre/Post	3. Count 0-10
Flexibility			2 scores
Ankle	Goniometer		1. Ankle Plantar flexion, dorsiflexion, inversion, eversion--summed interval
Plantar flexion		Pre/Post	
Dorsiflexion		Pre/Post	
Inversion		Pre/Post	
Eversion		Pre/Post	
Knee	Goniometer		2. Knee Flexion and extension--summed interval
Flexion		Pre/Post	
Extension		Pre/Post	
Vibratory sensation	Tuning Fork	Pre/Post	Number of incorrect responses 1 interval
Proprioception	Position of extremity	Pre/Post	Number of incorrect responses 1 interval
Visual Acuity	Snellen Eye Chart	Pre/Post	1 interval
Physical Activity Level	Activity Questionnaire and Log	Pre/Post	1 interval

APPENDIX K

ACTIVITY JOURNAL FOR COMPARISON GROUP

ACTIVITY JOURNAL

NAME ______________________________

If you have any questions call Eugenia Mills 894-2492

APPENDIX K--Continued

Please record any physical activity you might happen to do that is more than your usual activity. Do not list the exercises we are having you do.

Date	What physical activity did you do? Describe it (briefly).	How long did you do activity?

APPENDIX L

CONSENT FORM: EXPERIMENTAL GROUP

I, ________________________, agree to participate in this research project. The purpose of this study is to learn about the effect of a simple set of exercises on balance, movement of the ankle and knee joints, and muscle strength in the lower legs. I understand there are some benefits for my health in participating in this project, but there is a slight risk of falling and a slight risk of tiring. The risk of falling will be minimized by someone standing very near me during the various positions required to measure my balance. Further, I will stop my activity if I become tired. I understand all information will be held in confidence and my identity will not be revealed. I understand I may withdraw from this project at any time.

I understand that participation in this project requires that I:

1. answer questions about my age and health.
2. remain in various positions while my ability to maintain them is timed.
3. participate in moving my knee and ankle to show how much movement I have in these joints.
4. participate in having the strength of my lower legs measured.
5. participate in an exercise program which is done while sitting in a chair and standing. The exercise program will last for eight weeks, and I will attend a group exercise class three times a week. I will do my best to do the exercises once each day between the exercise classes.
6. will not participate if I feel sick or very tired.
7. will stop taking part in the exercises if I feel very tired or my legs hurt.

I understand the first four items will take about 30 minutes of my time, and will be done twice, once before the exercise program begins and again at the end of the exercise program.

I talked with my physician about this exercise program and have his/her approval to do the exercises.

If I have any questions, I may call the researcher, Eugenia Mills, at home (894-2492) or at work (863-8833).

SIGNATURE____ DATE ____________

APPENDIX M

CONSENT FORM: COMPARISON GROUP

I, ______________________________, agree to participate in this research project. The purpose of this study is to learn about the effect of a simple set of exercises on balance, movement of ankle and knee, and muscle strength in the lower legs. I understand there are no benefits in participating in this project, but there is a slight risk of falling. This risk will be minimized by someone standing very near me during the various positions required to measure my balance. I understand all information will be held in confidence and my identity will not be revealed. I understand I may withdraw from this project at any time, and my participation will not affect services I receive from the management of this facility.

I understand that participation in this project requires that I:

1. answer questions about my age and health.

2. remain in various positions while my ability to maintain them is timed.

3. participate in having the strength of my lower legs measured.

4. participate in moving my knee and ankle to show how much movement I have in these joints.

I understand the above four items will take about 30 minutes of my time, and will be done twice in eight weeks.

If I have any questions, I may call the researcher, Eugenia Mills, at 863-8833.

SIGNATURE ______________________________
DATE ____________________