AN ABSTRACT OF THE THESIS OF

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Bone mass and falls are two determinants of fracture risk. The purpose of this study was determine if a 9-month resistance training intervention would decrease fracture risk and improve psychological variables in postmenopausal women. Participants (n=44, mean age=63y) were at least 5 years past menopause and community-dwelling. Dependent measures included bone mineral density (BMD), muscular strength and power, static and dynamic balance, self-concept, and global affect. Bone mass and body composition were assessed by dual energy x-ray absorptiometry (DXA, Hologic QDR-1000/W). Peak force was determined by isokinetic dynamometry (KinCom 500H) and muscular power by a modified Wingate anaerobic power test. The ProBalance Master (NeuroCom International, Inc.) was utilized to assess static and dynamic balance. Self-concept and affect were evaluated via the Physical Self-Perception Profile-A (PSPP-A) and Positive and Negative Affect Schedule (PANAS), respectively. Subjects were assigned to either a control or exercise condition. Exercisers participated in weight-bearing, lower body training 3 times per week, in which resistance was added with a weighted vest. Controls were instructed to maintain customary activity and dietary habits. Strength, power, balance, and psychological measures were assessed at three-month intervals. Bone mass was determined at baseline, 6 and 9 months. At the conclusion of the intervention, exercisers exhibited significant (p=0.01-0.0001) improvements in leg power (13%) as well as in knee extensor (16.6%), hip abductor (30.3%), and ankle plantar flexor (33.3%) strength. The dynamic balance assessment indicated improved lateral postural stability in the exercisers.

No improvements were noted for BMD, static balance, or psychological measures. Both groups maintained BMD at the femoral neck and lumbar spine during the 9-month trial. In conclusion, a practical resistance training intervention may decrease fracture risk in healthy, older women, by improving leg strength, power, and dynamic postural stability.

The Effects of Resistance Training on Fracture Risk and Psychological Variables in Postmenopausal Women

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Janet M. Shaw, Author

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INTRODUCTION

Osteoporosis represents a major health problem in this country. It is estimated that over a quarter million hip fractures occur annually, amounting to over 8 billion dollars spent on immediate and long-term medical care (Melton, 1993). Although the etiology of osteoporotic fractures is complex, it is evident that two factors play important roles - bone loss and falls. With age, women experience bone loss, particularly after menopause (Birkenhager-Frenkel, Courpron & Hupscher, 1988) and an increased risk of falling (Nevitt, Cummings & Hudes, 1991). Reductions in physical activity significantly impact bone mass and two determinants of fall propensity - muscle strength and postural stability. A decline in muscle strength and bone mass has been reportedly associated with an increase in falls and incidence of hip fracture (Anniansson, Zitterberg & Hedberg, 1984 and Nevitt, et al., 1991).

Bone mineral density (BMD) declines with age and low bone mass is associated with fracture (Hui, Slemenda & Johnston, 1988 and Ross, Davis & Epstein, 1991). Thus, BMD is an index of fracture risk. Physical activity is known to be beneficial to bone. This phenomenon is most dramatic in cases of bed rest and space travel where reduced forces on the skeleton result in marked bone loss (Donaldson, Hulley & Vogel, 1970, Krolner & Toft, 1983 and Mack, LaChance & Vose, 1967). Thus, mechanical loading is one of the three primary determinants of bone remodeling activity (Snow-Harter & Marcus, 1991). The type of exercise that best promotes bone strength is still in question, but evidence is accumulating to suggest that weight bearing exercise which increases muscular strength and mass may confer the best osteogenic stimulus. The two remaining determinants of remodeling activity include calcium nutriture and reproductive hormone status. Sound nutritional practices are important since calcium forms the necessary building blocks for mineral deposition (calcium hydroxyapatite) in bone. Lastly, the importance of reproductive hormones for bone health, notably estrogen, is well documented (Riggs & Melton, 1986, Raisz & Smith, 1989 and Drinkwater, Bruemner, & Chestnut, 1990). It has been proposed that the skeletal benefits of mechanical loading can only be realized in the presence of adequate calcium and estrogen levels (Dalsky, 1990). Evidence is mounting that BMD increases may be possible with optimal mechanical forces and calcium intake that meets the recommended dietary allowances, even in the absence of estrogen (Robinson, Snow-Harter, Taaffe, Gillis, Shaw, & Marcus, 1995 & Nelson, Fiatarone, Morganti, Trice, Greenberg & Evans, 1994)

Cross-sectional studies which report greater BMD among men and women with greater muscle strength and mass and who have been participating in muscle building exercise support weight training as exercise that is beneficial for bone (Bevier, Wiswell, Pyka, Kozack, Newhall & Marcus, 1989, Colletti, Edwards, Gordon, Shary & Bell, 1989, Pocock, Eisman & Gwinn, 1990 and Snow-Harter, Bouxsein, Lewis, Carter & Marcus, 1992). However, longitudinal investigations of weight training effects on bone mass are few and report mixed responses to weight training and bone loading activities (Nelson, et al., 1994, Gleeson, Protas, LeBlanc, Schneider & Evans, 1990, Pruitt, Jackson, Bartels & Lehnhard, 1992, Snow-Harter et al., 1992 and Ayalon, Simkin, Leichter & Raifmann, 1987). Although some report increased BMD with weight training (i.e., Nelson, et al., 1994, Snow-Harter et al., 1992, Pruitt et al., 1992) others have observed decreased BMD in women who engaged in the same type of exercise program (Rockwell, Sorenson & Baker, 1989). Methodological concerns make it difficult to draw specific conclusions from these studies especially since they have relied on machine-based weight training and other non-weight bearing activities to improve strength.

Fracture risk is also related to the likelihood of falling and fall severity. Common factors that distinguish fallers from nonfallers include reduced strength and power of the lower extremities and abnormalities in posture and gait (Whipple, Wolfson & Amerman, 1987 and Tinetti, Speechley & Ginter, 1988). Fast twitch muscle fibers, which are largely responsible for strength and power activities, were reduced in size in hip fracture patients when compared to age-matched controls (Anniansson et al., 1984). Whipple et al. (1987) reported that knee and ankle weakness were related to an increase in falls in nursing home residents. Additionally, those with a history of falls had significantly lower power in the major muscles of the lower extremity when compared to age-matched controls. Two risk factors identified in community dwelling fallers were disability of the lower extremities and abnormalities of balance and gait (Tinetti et al., 1988). Falling is a multifactorial problem which must also take into consideration the circumstance of the fall. Walking, turning and reaching activities and going up or down stairs have been associated with falls that result in injury (Nevitt, Cummings & Hudes, 1991). Lastly, Greenspan and coworkers (1994) have demonstrated that the severity of a fall (site and velocity of impact) may distinguish those that experience a hip fracture from a fall.

Strengthening exercises which require support and stabilization of the body in a standing, upright position emerge as one option to ameliorate the risk of falling. There is a strong line of evidence to support a favorable response to machine-based resistance exercise in this population (Nelson, et al., 1994, Fiatarone, Marks, Ryan, Meredith, Lipsitz & Evans, 1990, Brown, McCartney & Sale, 1990, Charette et al., 1991). Much of this work suggests that strength training in older populations may encourage independent living. Fiatarone et al. (1990) reported strength improvements in nonagenarians averaging 174% after 8 weeks of high intensity strength training (80% of 1-RM), after which two subjects no longer required the use of canes for ambulation. Hence, even very old individuals can engage in weight training, which can likely reverse muscular atrophy largely attributed to disuse. The benefits of participation in such activities outweigh the risks of immobility, decreased function and increased likelihood of falls.

Most of the studies which utilized weight training exercise programs in older adults have been of fairly short duration (8-12 weeks). While this program length may be appropriate for observation of changes in the characteristics of muscle, the potential benefit to bone mass may not be observed until 6 to 9 months of training due to the longer time required to detectably alter bone. Additionally, machine-based resistance training typically involves a seated posture, which isolates muscle groups, but reduces forces at some skeletal sites, particularly the hips and lower extremities. Further, relatively short programs may not promote a lifestyle change which incorporates the newly learned exercise routine.

It is widely accepted that regular exercise can have a positive influence on psychological variables (Morgan, 1985). Recent research in sport and exercise psychology has generated sound methodology to examine the influence of exercise on self-conceptions (Fox & Corbin, 1989 & Chase, 1991). Self-conceptions provide insight on how one perceives oneself, while the specific measure of self-esteem is the evaluative component of self-concept (Sonstroem, 1984). Individuals may describe or evaluate themselves differently depending on the specific domain of inquiry. For example, self-conceptions may be different in social settings than in physical settings, such as in sport and exercise. Relationships between fitness and physical self-conceptions have been demonstrated (i.e., Heaps, 1978 and Marsh & Peart, 1988), and there is limited research to suggest that self-conceptions within the physical domain can be improved with physical activity (Marsh, Richards & Barnes, 1986). However, global self-esteem, one important self-conception, is considered a stable trait and as yet, exercise interventions have not been shown to alter it. A change in physical self-conceptions with an exercise intervention may be mediated by the social aspects of the program, feelings of competence, goal achievement or increases in physical fitness (Sonstroem, 1984). While self-conceptions within the physical domain may improve over a short period of time, a longer exercise intervention may be required to influence the more stable, global measure of self-esteem. Sonstroem (1984) recommends that researchers improve methodology by investigating both global self-esteem as well as self-conceptions within the physical domain for longer periods of time (minimum of 15 to

20 weeks). To date, no study has attempted to experimentally determine the effects of a long term exercise intervention on physical self-conceptions or global self-esteem in older women.

Affect, or general mood state, has been related to self-esteem. Specifically, positive affect has been positively correlated and negative affect negatively correlated with self-esteem (Pelham & Swann, 1989). Although affect has been demonstrated to improve with exercise, most of the research has focused on aerobic exercise and college-aged populations (Willis & Campbell, 1992). In addition, the Profile of Mood States (POMS) (McNair, Lorr & Droppleman, 1971) has been used frequently to assess mood alteration with exercise. However, the POMS inventory was originally developed for use on clinical populations which includes only one positive and four negative mood states. The Positive and Negative Affect Schedule (PANAS, Watson, Clark & Tellegen, 1988), developed recently, allows for measurement of the basic positive and negative dimensions of mood.

Self-conceptions and affect are important psychological variables to consider with respect to quality of life. Although they may not be directly related to fracture risk, there is a need to assess the psychological as well as physiological correlates of exercise participation. Improving one's general disposition as well as how one feels about oneself may be the more enduring benefits of exercise participation that ultimately promote adherence.

Significance

In order to evaluate the efficacy of an exercise program as a fracture prevention strategy, it is necessary to incorporate multiple factors related to fracture and to examine these factors in a longitudinal manner. Previous studies have examined these factors separately and/or at one point in time. Strength training protocols which aim to decrease fracture risk should proceed over a long period of time and utilize exercises that afford significant mechanical forces at the hip and require maintenance of standing, upright posture. Strength training studies in older adults to date have relied on machine-based training and employed short training periods. The effects of long-term training on balance have not been examined. Previous studies have been cross-sectional or have used crude assessments of postural stability. Lastly, the effects of long-term training on indices of self-conceptions and affect have not been explored in older adults. Psychological effects of training are particularly important in older women due to the prevalence of depression and other psychological disorders among this population.

Purpose

The purpose of this study was to determine the efficacy of a 9 month lower body resistance training program on improving the fracture risk profile of postmenopausal women. Specifically, BMD of the hip and spine, strength and power of the lower extremities and indices of postural stability were assessed. In addition, self-perceptions and affect were evaluated in order to determine psychological effects of long term exercise participation.

Hypotheses

The specific hypotheses tested in this study included:

$H_0 1$: There would be no significant change in BMD of the lumbar spine and proximal femur after 9 months of lower body resistance training in postmenopausal women.

$H_A 1$: There would be a significant increase in BMD of the lumbar spine and proximal femur in postmenopausal women after 9 months of lower body resistance training as compared to control women.

$H_0 2$: There would be no significant change in strength of the ankle plantar or dorsiflexors, hip abductors or adductors or knee extensors after 9 months of lower body resistance training in postmenopausal women.

H_A2: There would be a significant increase in strength of the ankle plantar and dorsiflexors, hip abductors and adductors and knee extensors in postmenopausal women after 9 months of lower body resistance training as compared to control women.

$H_0 3$: There would be no significant change in indices of postural stability (maximum LOS, movement time, path sway and target sway) after 9 months of lower body resistance training in postmenopausal women.

H_A3: Maximum LOS, movement time, path sway and target sway would improve significantly in postmenopausal women after 9 months of lower body resistance training as compared to control women.

$H_0 4$: There would be no significant increase in mean or maximum power after 9 months of lower body resistance training in postmenopausal women.

H_A4: Mean and maximum power would increase significantly in postmenopausal women after 9 months of lower body resistance training as compared to control women.

$H_0 5$: There would be no significant change in self-conceptions (global self-esteem, physical self-worth, and perceptions of sports competence, physical appearance, health/disease state or functional capacity) after 9 months of lower body resistance training in postmenopausal women.

H_A5: There would be a signficant increase in self-conceptions in post menopausal women after 9 months of lower body resistance training as compared to control women.

$H_0 6$: There would be no significant change in affect after 9 months or lower body resistance training in postmenopausal women.

H_A6: There would be a significant increase in positive affect and a significant decrease in negative affect in postmenopausal women after 9 months of lower body resistance training as compared to control women.

Delimitations

The following were measures taken in order to confine the focus of the study:

1. Apparently healthy, community-dwelling women who were between 50 and 75 years of age and at least 5 years postmenopausal were recruited to participate. Women who smoked, took medications known to alter bone metabolism (eg., corticosteroid and thyroid medications) and who regularly participated in weight training within the past two years were excluded from the study.

2. Women taking estrogen were included in the study if they were on estrogen for at least one year and if their bone mass normalized for age at the hip was lower than the mean (z score = -0.5 or less).

3. Women included in the study were those with bone mass values at or below the mean for their age at either the hip or spine. This delimitation was important for complying with the training principle of initial values (Drinkwater, 1994). Those with initially high bone mass might not experience increases with exercise due to a ceiling effect.

4. Bone mineral density was the only index of bone strength.

5. Data collection took place immediately before, during (months 3 and 6) and after the 9 month training program. Subjects were not followed beyond this time frame.

6. The exercise program was a modified free weight training program, utilizing weighted vests to alter resistance in place of traditional equipment such as bar bells and dumbbells. This study only employed lower body exercises in the training program which specifically loaded the hips and spine. Therefore, the effects of traditional free weight training which includes upper body training was not investigated.

Limitations

The following may limit the findings of the study:

1. There was no control over the participant's adherence to the training program (treatment) or follow-up period (control). Subjects were volunteers and therefore free to

terminate participation at any time. Steps were taken to enhance adherence (creating an enjoyable, convenient exercise environment, making frequent contacts with control subjects, holding occasional social gatherings) in order to maintain subject compliance. Despite this, four women terminated participation in the exercise program, which may limit the findings and somewhat decrease statistical power.

2. There was no control over the effort exerted by the subjects during strength, power and balance assessments. Subjects were encouraged during all assessments that required maximal efforts as well as provided with detailed descriptions of test protocols to eliminate errors due to subject misunderstanding.

3. Assessments were not always conducted at the same time of day, due to equipment availability and participants' schedules. Strength, power, and balance assessments may be affected by the time of day in which they were conducted.

4. Assignment to groups was not totally random. Although every attempt was made to do so, some participants stated clearly that they would not complete the study if assigned to the exercise group. For example, one woman's job overlapped with both exercise sessions, another was the full-time caregiver for her ill husband. Four women were intentionally assigned to the control group due to these types of reasons. Seven women were assigned to the control group due to late enrollment into the study, after the start date of the exercise program.

5. The balance protocol did not allow for enough time to familiarize participants prior to testing sessions. It is likely that some of the subjects were still learning the skills necessary to complete the protocol with proficiency at the end of the study.

6. The majority of the participants in this study were quite active (average hours of weight-bearing exercise per week = 4.1) which contributes to selection bias. Studies that advertise for volunteers for an exercise program are not as likely to recruit those who are inactive. Initial values on dependent variables (particularly strength and power) were probably higher than average due to selection bias.

7. Participants in the control group were asked to complete activity logs in order to monitor their weight-bearing exercise during the 38-week intervention. While some were very diligent in recording this information, some were not. This limits the extent to which statements can be made about the control group's activity during the intervention.

8. There were more women on estrogen (n=7) in the control group than in the exercise group (n=1). Although this was likely to have an impact on BMD results, it is doubtful that hormone replacement had an effect on any of the other dependent measures, especially strength, power, and balance (Seely, Cauley, Grady, Browner, Nevitt & Cummings, 1995).

9. The mean weight and body composition of the exercise group was significantly higher ($p<0.05$) than that of the control group at baseline. These differences were primarily a result of higher fat mass in the exercise group. Whole body lean mass, however, was not statistically different between the groups. This was primarily an oversight in the group assignment process. It is noteworthy that neither body weight nor fat mass had any significant correlation with BMD at any sight.

Operational Definitions

1. Bone mineral content (BMC) - The absolute amount of calcium hydroxyapatite (g) in the bone region of interest as measured by dual energy x-ray absorptiometry.

2. Bone mineral density (BMD) - The amount of calcium hydroxyapatite (g) per unit area (cm^2) as measured by dual energy x-ray absorptiometry. BMD, therefore, is expressed as areal density and does not represent a volumetric measurement.

3. Dual energy x-ray absorptiometry (DXA) - A technique to quantify bone mineral as well as soft tissue by photon absorptiometry which uses an x-ray tube photon source and a detector made of tungsten. Two x-ray beams of different energies are pulsed alternatively at 70 and 140 kV peaks which allows for BMC measurement at axial skeletal sites (Kellie, 1992) as well as body composition determination.

4. Muscular strength - The peak amount of force a muscle or muscle group can generate. Peak force is expressed in kilograms and was assessed by isokinetic dynamometry (KinCom 500H).

5. Isokinetic dynamometry - A measurement technique used to determine peak force which uses hydraulic mechanisms and a load cell to match forces placed upon it while controlling the speed of muscular contraction. All isokinetic testing was conducted at a speed of 30 degrees/sec.

6. Muscular power - The rate of performing muscular work. Work is calculated as the product of force and distance per unit of time (seconds). Muscular power in this study refers to anaerobic power in which the limiting factor is the body's ability to convert chemical energy to mechanical energy (Bar-Or, 1987). Mean and maximum power output was measured by the Wingate Anaerobic Power Test.

7. Mean power - The average power output calculated during the 15 second Wingate Anaerobic Power Test. Absolute mean power is expressed in Watts and relative mean power is expressed in Watts per kilogram of body weight.

8. Maximum power - The highest power output calculated during the 5 second period with the highest flywheel revolutions recorded. This value is typically recorded during the first 5-7 seconds of the Wingate Anaerobic Power Test. Absolute maximum power is expressed in Watts and relative maximum power is expressed in Watts per kilogram of body weight. To control for its association with legs lean mass, maximal power is also expressed as watts/kg leg lean mass.

9. Wingate Anaerobic Power Test (WAPT) - A test designed to assess the anaerobic power of the muscles involved in a supramaximal bout of exercise performed on a cycle ergometer (Bar-Or, 1987). The work performed during the WAPT was calculated as the product of the resistance on the flywheel and the flywheel revolutions performed. The relative resistance setting on the flywheel was set between 8- 10.5% of lean body mass. The time

was recorded in seconds. An optical sensor mounted on the cycle ergometer was interfaced with a computer which contained software to calculate power output.

10. Balance - The ability to distribute body weight over the base of support while standing (the feet), in either static or dynamic postures such that position is maintained. Indices of static and dynamic balance were assessed on the Pro Balance Master.

11. Movement time - The time it takes (seconds) for a subject to shift her center of gravity (represented by a cursor on the video screen) from one target to the next as measured on the Pro Balance Master. At the beginning of a trial on this apparatus, the subject was cued via video monitor to shift the center of gravity cursor from one target to another. The computer calculates movement time as the time it takes the subject to reach the target from the moment of the video cue. Failure to reach a target resulted in a score of 10 seconds which was the pacing interval used in each dynamic balance trial.

12. Path sway - The amount of sway a subject displays during the excursion from one target to the next as measured by the Pro Balance Master. Deviations from a straight line during the excursion were calculated to express path sway as a percentage of path length. Since the shortest distance between two points is a straight line, 100% would be a perfect score for path sway. A score of 200 would indicate that the path taken toward the highlighted target was twice that of a straight line.

13. Target sway - The amount of movement a subject displays once the center of gravity cursor arrives at the target as measured by the Pro Balance Master. Target sway is expressed as a percentage of the subject's theoretical limits of stability. If a subject fails to reach a target, target sway cannot be calculated.

14. Patient position - The position achieved during a dynamic balance trial. During the test which cued the subject to move toward the target placed at 100% LOS, patient position was recorded to determine maximal functional LOS.

15. Limits of stability (LOS) - Refers to the angular distance from the center of the body which a subject can deviate without loss of balance. The anteroposterior LOS extend

approximately 12 degrees from the farthest backward to forward position while lateral LOS are approximately 16 degrees from side to side (Nashner, 1989). Limits of stability were calculated by the Pro Balance Master with knowledge of the subject's height, the primary anatomic variable that affects the LOS.

16. Self-concept (SC) - The extent to which an individual has positive feelings toward him or herself (Gergen, 1971). Global and physical self-conceptions as well as subdomains of physical self-conceptions were measured by the Physical Self Perceptions Profile for Older Adults (PSPP-A, Chase, 1991). The most global measure of self-concept is self-esteem.

17. PSPP-A - Physical Self Perception Profile - Older Adults. This is a questionnaire designed after the PSPP for young adults, which uses a four-choice structured alternative format (Harter, 1985). This scale measures physical self-concept as well as four subdomains: sports competence, physical appearance, health/disease status and functional capacity (Chase, 1991). In addition, six items which use the same response format were added in this study to assess global self-esteem (Harter, 1985).

18. Affect - Global mood or emotional state as measured by the Positive and Negative Affect Schedule (Watson et al., 1988). For general purposes, affect was divided into a two dimensional structure consisting of positive and negative factors.

19. PANAS - Positive and Negative Affect Schedule. The PANAS consists of a list of 20 adjectives, 10 that load on the positive factor and 10 that load on the negative factor (Watson et al., 1988). For each adjective, subjects were asked to note the extent to which they felt that way during the past few days using a five point Likert scale. An average score was calculated for each factor.

REVIEW OF THE LITERATURE

Bone Mineral Density

The function of the skeletal system is threefold; to aid in locomotion and support loads against gravity, to provide protection for vital organs (such as the spinal cord, brain, heart and lungs) and to serve as the primary repository of total body calcium to support blood levels when needed. The integrity of the system may be compromised if the strength of bone is reduced. Snow-Harter and Marcus (1991) suggest that one component of bone strength is bone mineral density (BMD), or the relative amount of calcium hydroxyapatite per unit area of bone. The relationship between decreased BMD and an increased risk of skeletal fracture is well documented (Hui, Slemenda & Johnston, 1988).

Approximately 60% of final bone mass is accumulated during the adolescent growth spurt and it is estimated that peak bone mass is achieved somewhere within the end of the second decade of life (Snow-Harter & Marcus, 1991). There is some disagreement with respect to when bone loss begins to occur. Estimates of the onset of loss have been anywhere between the second to the fifth decades of life. There is considerable evidence, however, to suggest that bone loss occurs earliest and is most dramatic at skeletal sites where trabecular bone is most abundant. Marcus, Kosek, Pfefferbaum, and Horning (1983) found that trabecular bone volume from iliac crest biopsies of premenopausal women (18-50 years) was negatively correlated with age. From this correlation, it was estimated that these premenopausal women were experiencing a loss of approximately 0.7% a year. Additionally, Birkenhager-Frenkel, Courpron, and Hupscher (1988) confirmed this rate of loss for premenopausal women within a sample of healthy men and women. This cross section included a group of postmenopausal women, in whom, an accelerated rate of trabecular bone loss was observed. Aloia, McGowen, Vaswani, Ross, and Cohn (1985) also suggest that bone loss is accelerated at the time of menopause. However, some cross sectional studies have not observed an increased rate of loss at menopause (i.e., Riggs, Wahner, Dann, Mazess, & Offord, 1981 and Mosekilde & Mosekilde, 1988). This discrepancy may be resolved once more longitudinal data are available to better understand the rates of bone loss at various stages of the lifespan. With respect to the patterns of bone loss, the National Osteoporosis Foundation (NOF) has identified advanced age and menopause (particularly early or surgical) as two major risk factors for osteoporosis (Peck, Riggs, & Bell, 1987).

Reproductive endocrine status has been established as a primary controller of bone remodeling, the dynamic interplay between bone resorption and bone formation (Snow-Harter & Marcus, 1991). Under normal conditions, bone remodeling is a coupled process whereby the cells involved are equally active in order to maintain relative balance in the system. However, alteration of the reproductive hormone status of the individual can modify this process, most notably by increasing the efficiency of resorption when hormone levels are significantly reduced. When the remodeling process favors resorption, declines in BMD result.

Estrogen is the primary reproductive hormone of interest with respect to BMD. As noted above, several authors report an accelerated rate of bone loss associated with menopause, and hence, declines in estrogen. Estrogen replacement therapy is recognized as an option to prevent bone loss particularly at the time of menopause (Peck, et al., 1987). However, the mechanism by which estrogen decreases bone resorption is not clearly understood. Raisz and Kream (1983) suggest that estrogen has an indirect effect on bone by increasing the intestinal absorption of calcium, improving the synthesis of vitamin D and increasing calcitonin secretion. In the absence of estrogen, Dalsky (1990) proposes that bone becomes more sensitive to the calcium mobilizing (resorption) effects of parathyroid hormone.

Hypoestrogenism has also been documented in young women with amenorrhea, primarily athletes and those with anorexia nervosa. Drinkwater, Nilson and Chestnut (1984) documented significantly lower spine BMD in amenorrheic athletes when compared to controls. Marcus, Cann, and Madvig (1985) replicated these findings in a group of elite distance runners. However, the athletes in the latter study were carefully matched for possible confounding variables such as body composition, aerobic fitness and age of menarche. The cyclic runners exhibited the highest BMD values, followed by nonexercising, age-matched cyclic women and finally the amenorrheic runners. The cyclic runners appeared to have the benefit of mechanical loading (running) as well as normal estrogen levels. However, in the absence of estrogen but in the presence of mechanical loading, the amenorrheic runners exhibited the lowest BMD values. Cann, Martin, and Genant (1984) reported spine BMD values of amenorrheic nonrunners with anorexia nervosa to be even lower than amenorrheic runners. Dalsky (1990) proposes that estrogen and calcium play a permissive role with respect to the benefits of mechanical stimuli on bone. That is to say that in the absence of adequate calcium or normal estrogen levels, the mechanical stimulus afforded by exercise may not be fully achieved.

Recently, two studies have contradicted the basic premise that mechanical loading cannot afford increases in BMD in hypoestrogenemic women (Robinson, et al., 1995 and Nelson, et al., 1994). Robinson, et al. (1995) have demonstrated that gymnasts exhibit higher bone mass than distance runners at the spine, hip, and whole body despite a similar incidence of menstrual cycle dysfunction. Bone mass in the runners was associated with menstrual status, that is, those with current amenorrhea and with a history of amenorrhea had the lowest bone mass at all sites. Regularly cycling runners with no history of cycle disruption exhibited the highest bone mass within that group. In contrast, menstrual status in the gymnasts was not related to bone mass and bone mass was remarkably higher than both the distance runners and the normally active controls. Further investigation has shown that BMD in the gymnasts increased over the period of a training cycle and decreased during the summer when the mechanical stimuli were no longer present (unpublished data, Bone Research Laboratory). These findings suggest that the loading patterns (i.e., takeoff and landing forces) in gymnastics may override the negative influence of hypoestrogenism and that bone responds to this type of training, exhibiting the principle of reversibility in it's absence.

Nelson, et al. (1994) recently reported increases in BMD at the spine and hip in estrogen deplete postmenopausal women engaged in resistance training. The participants in this study were previously sedentary. Training was performed on pneumatic resistance machines twice weekly for one year at approximately 80% of 1 RM. The exercisers evidenced an average of .9% and 1.0% increase in BMD at the femoral neck and lumbar spine, respectively, while controls exhibited significant losses in bone mass at both sites. The exercises employed were designed to increase strength of all major muscle groups. This is the first study to demonstrate increases at the hip in postmenopausal women not on exogenous hormone replacement.

Physical activity is known to be beneficial to bone in that it provides a mechanical stimulus which enhances bone mass, thus increasing bone formation over resorption. In general, those who engage in regular physical exercise tend to have higher bone mass than those who do not. Perhaps the best illustration of this is in athletes who participate in unilateral sporting events. Huddleston, Rockwell and Kulund (1980) demonstrated that radial BMC of the dominant arm was significantly higher than radial BMC of the nondominant arm in lifetime tennis players. These results were replicated in a younger group for BMD by Pirnay, Bodeux and Crielaard (1987). It is interesting to note that the *nondominant* arm had higher BMD than sedentary controls. On the opposite end of the continuum, bed rest and space travel are associated with reduced muscular activity and gravitational forces which result in marked bone loss and excessive calcium excretion (Donaldson, Hulley & Vogel, 1970, Krolner and Toft, 1983 and Mack, LaChance & Vose, 1967, Issekutz, Blizzard, Birkhead, & Rodahl, 1966).

The primary forces on bone which are thought to provide osteogenic stimuli are gravitational forces and forces from muscular pull. Weight bearing exercises, which provide both types of forces, are therefore recommended for bone health. However, the forces absorbed by the skeleton vary depending on the activity. To illustrate in numerical terms, the forces produced at the lumbar vertebrae during fast walking and jogging are approximately 1 times body weight (BW) and 1.75 times BW, respectively (Capozzo, 1983). However, during weight lifting activity, strains at the lumbar vertebrae as much as 5-6 times BW have been reported (Granhad, Jonson, & Hansson, 1987). In intervention trials to date, there appears to be little advantage of walking alone. Cavanaugh and Cann (1988) found that spine BMD actually decreased in postmenopausal women despite one year of brisk walking intervention. Dalsky, Stocke, and Ehsani (1988) reported a significant increase in spine mineral content after nine months of a combined program of walking, jogging, and non-weight bearing resistance exercises. It is likely that the higher intensity activities (jogging and resistance exercise), combined with the fact that the women were previously sedentary, conferred enough mechanical stimulus to alter bone mass.

Carter, Fyrie and Whalen (1987) and Rubin and Lanyon (1985), have developed models based upon theoretical and animal cycles or repetitions to explain why certain mechanical stimuli are more beneficial to bone than others. Carter (1984) postulates that fatigue from mechanical stress stimulates remodeling. However, when stress is gradual, bone formation processes are stimulated. When stress is continual, such as in activities like running, walking or aerobics where multiple repetitions are performed over a long period of time, the remodeling process may not keep up with the rate of damage. Therefore, activities such as weight training are thought to provide a large degree of stress yet provide adequate recovery time in which bone mass may adapt. This theory is supported by cross-sectional studies which report positive relationships between BMD and muscle strength and higher BMD values for those involved in muscle-development programs (Bevier et al., 1989, Colletti et al., 1989, Pocock et al., 1990 and Snow-Harter et al., 1992).

Early cross-sectional work which examined relationships between muscle strength and mass and bone emphasized specificity of muscle-bone interactions and tested only limited muscle groups (Sinaki, Wahner & Offord, 1988). More recent studies report significant relationships between specific skeletal sites and muscles distant from those sites (Pocock et al., 1990 and Snow-Harter et al., 1992). The few cross-sectional reports in men have shown important relationships between bone mineral density and both muscle strength and mass. Block, Genant & Black (1986) found that paraspinous muscle cross-sectional area to be significantly related to vertebral bone density in men. Snow-Harter et al., (1992) reported that back strength was the most robust predictor of lumbar spine, femoral neck, and whole body BMD ($r=0.52-0.62$) in adult men. Data recently collected on 90 postmenopausal women (aged 48-72 years) at the Bone Research Laboratory (Oregon State University) has shown strength (measured by isokinetic dynamometry) to be correlated with BMD of the proximal femur (femoral neck), lumbar spine and whole body (Snow-Harter, et al., 1993). Hip abductor and biceps strength exhibited the highest correlations at the femoral neck ($r=0.31$, $p<0.01$), biceps and quadriceps strength were best correlated with whole body BMD ($r=0.33$, $p<0.01$) and biceps, back and hip abductor strength had similar associations at the lumbar spine ($r=0.24-.27$, $p<0.05$).

Muscle weight has been associated with bone. Early research (Doyle, et al., 1970) demonstrated relationships between bone and muscle with a strong correlation ($r=0.72$) between psoas weight and vertebral ash weight. Fast twitch muscle fibers, which are largely responsible for strength and power activities, were reduced in size in hip fracture patients when compared to age-matched controls (Anniansson, et al, 1984). In addition to the association to bone, greater tissue mass surrounding bone help absorb forces from a fall and reduce fracture risk. Significant relationships between body composition measures and bone mineral density in postmenopausal women have been found in research efforts conducted within the Bone Research Laboratory at Oregon State University. Specifically, whole body lean mass ($r=0.27$, $p<0.01$) was significantly related to femoral neck BMD (Snow-Harter, et al., 1993). In contrast, whole body fat mass was not related to BMD at the hip. Age, years past menopause, whole body lean mass and whole body fat mass were found to be significantly correlated with whole body BMD in postmenopausal women

(Wegner, et al., 1993). However, when entered into a multiple stepwise regression model, only lean mass and years past menopause proved to be independent predictors of whole body BMD. Others have supported the relationship between lean mass and BMD in older women. In a large cross section of both pre- and postmenopausal women, Aloia, et al. (1991) concluded that total body potassium was positively correlated with BMD of the spine, radius, femoral neck and total body calcium, which is reflective of whole body BMD. In contrast, Reid and colleagues (1992) suggest that fat mass, however, is an important determinant of whole body, hip and spine BMD in postmenopausal women. These studies are all based on cross-sectional data, which makes it difficult to draw specific conclusions with respect to relationships between body composition and bone health. The proposed project intends to examine not only the relationships between BMD and body composition in a longitudinal fashion, but also to observe if the training techniques employed can favorably alter body composition, specifically by increasing lean mass.

While the cross-sectional studies are convincing with respect to the relationships between muscular strength, mass, and BMD, longitudinal investigations of resistance training effects on bone mass are limited (e.g., Gleeson, Protas, LeBlanc, Schneider & Evans, 1990, Nelson et al., 1994, Pruitt et al., 1992, Snow-Harter et al., 1992, Ayalon et al., 1987, Prince, Smith, Dick, Price, Webb, Henderson, & Harris, 1991). Studies to date have varied with respect to training regimens and bone density results. Snow-Harter and colleagues (1992) reported a significant 1.2% increase in lumbar mineral density in young women following 8 months of resistance training. Gleeson, et al. (1990), found that one year of weight training produced a marginal, but insignificant increase in lumbar spine density in premenopausal women. Although a significant difference in spine mineral was found between weight trainers and controls, the observed increase of 0.8% in bone mass over baseline values did not achieve statistical significance. Rockwell et al. (1989) reported a 4% loss of vertebral mineral density in premenopausal women following a one-year weight training regimen.

A somewhat different intervention conducted in England has evidenced improvements in bone mass at the hip in premenopausal women (Bassey, 1994). This group implemented a 6-month trial in which two groups of women participated in an aerobic dance program. In addition to the aerobic dance, half of the women were assigned to a jumping condition, in which participants jumped shoeless, in place for 50 repetitions. The other half of the group performed upper body calisthenics, such as push ups. Those in the jumping condition exhibited a 3.4% increase in BMD at the trochanter, although no changes were observed at the femoral neck. A recent follow-up to this study in premenopausal women has demonstrated increases in femoral neck BMD, which suggests that jumping may realize favorable changes at this site (unpublished data, personal communication with E.J. Bassey).

More resistance training interventions designed to alter bone mass have been conducted in postmenopausal women probably due to their increased risk for osteoporotic fractures. Pruitt et al. (1992), reported that early postmenopausal women who engaged in a 9-month intervention exhibited an increase in lumbar spine BMD (1.6%) compared to a decrease (-3.6%) observed in the control group. Most of the exercises were performed on Universal Gym equipment which targeted all major muscle groups. The training stimulus was fairly light, however, which was administered three times per week and included only one set of 8-12 exercises at an intensity of 10RM. The increase in spine BMD is noteworthy, considering the participants were not on exogenous hormone therapy and their relative proximity to the menopause (all were 1-7 years postmenopausal). Bone loss is known to be accelerated during the first 5-7 years of the menopause (Birkenhager-Frenkel et al., 1988), which was demonstrated by the control group. There were no changes observed for the proximal femur, distal radius, or serum markers of bone remodeling for either group.

Notelovitz and colleagues (1991) examined the effects of estrogen therapy and variable-resistance weight training on BMD in women who were surgically menopausal (mean age=43y). The women on estrogen alone maintained BMD during the one-year trial while those on estrogen plus resistance training increased spine (8.3%), radial midshaft (4.1%) and whole body (2.1%) BMD. Unfortunately, there was not an exercise only group in order to evaluate the efficacy of exercise without estrogen. Compliance in this study was questionable in that 7 women dropped out of the hormone-only group and 6 terminated participation in the hormone plus exercise group. This calls into question the potential bias that may have factored into the study results, although the authors noted there were no initial differences between those who completed the trial and the dropouts.

Ayalon et al. (1987) administered a program to osteoporotic, postmenopausal women that targeted the forearm, since fractures often occur at the distal radius. The women participated in exercises that loaded the forearm with only muscular activity and bone weight for three times a week. Distal radium BMD was increased significantly over controls after the five month program. This work demonstrates the importance of specificity of skeletal load. However, the radius is not a weight-bearing bone and it does not encounter large forces on a regular basis. It is therefore easier to isolate the radius and subject forces to it that are larger than what it typically experiences. Application of a site-specific load is more difficult at the other primary fracture sites, the hip and spine. One case in point is the work of Smidt and colleagues (1992) who administered trunk exercises to specifically load the spine via muscular contraction in postmenopausal women. One third of the women in the exercise and control conditions were on estrogen replacement. After one year of training, there was no change in lumbar spine BMD although the target muscle group which attached directly at the vertebra under investigation evidenced a 30% increase in strength. The spine likely experienced loads on a regular basis that were much larger than that afforded by the training which therefore lacked adequate stimulus to uncouple bone remodeling in favor of increased formation.

The most promising study to date is that of Nelson and coworkers (1994) discussed earlier. This group confirmed that resistance training in a machine-based program afforded skeletal benefits in postmenopausal women not on estrogen replacement. The use of a machine-based intervention has been unsuccessful prior to this published work in demonstrating bone mass increases at the hip. Perhaps this finding was due in part to careful attention to study design. Participants at the onset of the study were sedentary. In addition, they reported excellent adherence (87.5%) to the training program, and compliance to the study as a whole. The exercise intensity was fairly high (80% of 1RM), which is a necessary component to realize changes in bone mass. One factor that may be overlooked is the physical activity level of the participants over the course of the trial. Those in the exercise program increased their level of physical activity outside of the intervention trial, while controls decreased overall energy output. There is no description of the type of activities those in the exercise group engaged in, however, this may have contributed to the BMD changes.

In all of the intervention studies cited above, the protocols designed to improve muscular strength and enhance bone mass relied on machine-based training or non-weight bearing strength exercises for muscle strength changes. While machine weights effectively isolate muscle groups, most lifts require a subject to be seated. This posture reduces gravitational loads at some regional sites, particularly the hip, which may be one reason that bone changes were minimal at that Nelson et al. (1994) has been the only group to realize changes at the hip. According to Hodge, Carlson, Fuan, Burgess, Riley, Harris & Mann (1989), forces at the hip are greatest upon rising from a chair. Data were generated from a force transducer implanted in the prosthesis of a 73-yr old women. Results demonstrated that forces at the femoral neck were greatest when rising from a chair (1.5 times, 2 times, and 3 times stair climbing, jogging, and walking, respectively) and increased as the height of the chair was lowered. In none of the investigations to date have any researchers used exercises which simulate the action of rising from a chair or include stair climbing (which produced forces closest to that of rising from a chair). These activities (with loads increasing over time) were central to the exercise program in the present study.

Fall Risk

The etiology of falls is multifactorial (Lord, Ward, Williams & Anstey, 1994 & Tinetti et al., 1988). Most epidemiological research which has focused on ambulatory, community-dwelling, older populations without specific neurological impairments (i.e., Parkinson's disease, hemiparesis from stroke) has consistently found that lower limb strength, reaction time, sensory dysfunction, and postural instability are important risk factors for falls. Greenspan et al. (1994) have proposed that not all falls are potentially injurious and that fall severity in combination with bone mass at the hip are the two primary determinants of hip fracture in ambulatory elderly. Specifically, those who fall to the side and have no ability to alter fall direction or speed of impact and land directly on the hip, are more likely to fracture, particularly if BMD at that site is low (Hayes, Myers, Morris, Gerhardt, Yett & Lipsitz, 1993). Therefore, it is important to consider whether or not a fall occurs, in addition to the characteristics of a fall to determine whether or not a fracture will result.

Impaired musculoskeletal function associated with aging and disuse ultimately results in decreased mobility (Vandervoort, Hill, Sandrin & Vyse, 1990). In addition, these declines in musculoskeletal function have also been associated with an increase in falls and incidence of hip fracture (Anniansson et al, 1984 and Nevitt et al, 1991). Vandervoort et al., (1990) reports that once function has declined to the point where mobility is significantly reduced, older individuals may refuse to ambulate due to a fear of falling, which is the beginning of a downward spiral which ultimately results in loss of independence. This situation, in which very few physical attempts are made, leads to marked reductions in strength and power of the lower extremities which have specifically been linked to fall risk. Whipple, et al. (1987) reported that knee and ankle weakness (measured by isokinetic dynamometry) were related to an increase in falls in nursing home residents. Additionally, the researchers found that individuals in a nursing home with a history of experiencing falls had significantly lower power in the major muscles of the lower extremity when compared to age-matched controls. Risk factors associated with falling have been identified in community dwelling elderly persons (Tinetti, et al., 1988). Two of the risk factors identified were disability of the lower extremities and abnormalities of balance and gait. The authors note that the likelihood of falling increases dramatically when an individual has multiple risk factors.

The link of muscular strength and power to fall risk is most logically in the stabilization and control required for voluntary movements. Fiatarone et al. (1990) reported a 48% increase in tandem gait speed in nonagenarians who experienced strength improvements averaging 174% after 8 weeks of high intensity strength training (80% of 1-RM). Tandem gait speed is a task that reflects muscle strength, power, and balance (Fiatarone, 1991). Considerable dynamic postural adjustments are made during a tandem gait speed test, in which the individual is required to walk as quickly as possible in a heel-toe fashion. The circumstance of a fall must also be considered with respect to its strength requirements (Nevitt, et al., 1991). In a prospective study of injurious fall risk, Nevitt and colleagues (1991) suggest that predictors of minor injury after nonsyncopal falls included walking, turning and reaching activities and going up or down stairs of any sort. Although these activities require minimal strength and coordination, it has been proposed that many older individuals are at a strength and/or power threshold thereby increasing the risk for injury due to a lack of functional reserve from which to draw (Young & Skleton, 1994). This idea is supported by the finding that leg extensor power in older men and women was closely related to functional performance assessed by gait speed, standing from a seated position, and speed in stair climbing (Bassey, Fiatarone, O'Neill, Kelly, Evans & Lipsitz, 1992).

Recent research suggests that muscle strength training in older populations may encourage independent living (i.e., Brown, et al., 1990 and Fiatarone, et al., 1990, Evans & Campbell, 1993). There is little question that older individuals can improve muscular strength as a result of training (Charette, et al., 1991, Fiatarone, et al., 1990 and Brown, et al., 1990). Charette and colleagues (1991) administered a 12 week training program to older women (mean age=69y) that focussed on the lower extremity. The training program was performed three times a week on weight machines. Maximal strength values increased with training 28-115%. Additionally, cross sectional area of type II (fast twitch) muscle fibers of the vastus lateralis increased by 20%. Controls neither increased strength nor demonstrated hypertrophy. Brown, et al. (1990), found similar results in men of similar age (mean=63y).

One of the most encouraging studies demonstrated that individuals in their 90's can improve strength. Fiatarone, et al. (1990), trained 10 subjects living in a long-term care facility. The subjects performed leg extension exercises while seated on a weight machine three times a week at fairly high intensities for 8 weeks. At the end of the 8 weeks of training, strength improvements averaged 174-180%, with no plateau in strength gains. After the training, subjects significantly improved gait speed, which the authors report, requires primarily strength and balance. Two subjects no longer required use of canes to walk after training. However, 32% of the maximal strength was lost after four weeks of detraining. The authors concluded that even very old individuals can engage in weight training, which can likely reverse muscular atrophy largely attributed to disuse. The benefits of participation outweigh the risks of immobility, decreased function and increased likelihood of falls.

There is a limited amount of research which has focused on long-term strength training in older adults (Pyka, Lindenberger, Charette & Marcus, 1994, Nelson, et al., 1994, Pruitt, et al., 1992, Notelovitz et al., 1991). It is interesting to note that all but one of these studies (Pyka et al., 1994) were conducted to determine the effects of strength training on bone mass. All reported significant improvements in strength, with one exception. Notelovitz et al. (1991), did not document changes in muscle strength, even though the intervention was conducted on Nautilus variable resistance equipment. Indices of cardiovascular fitness increased.

Pruitt et al. (1992) implemented a 9-month, weight-training program in early postmenopausal women (mean age=54.6y; 3-4y postmenopausal). Participants performed one set of 10-15 repetitions at fairly low intensity (50-60% of 1RM) three times per week. The exercises employed weight machines and emphasized all major muscle groups. Strength improvements (1RM) were between 22 and 36%. Unfortunately, no measures of functional ability were made, probably because of the relatively young age of the participants. Nelson et al. (1994), however, did include backward tandem walk as a measure of dynamic balance, within the course of a one-year resistance training study in a somewhat older group (mean age=61y). They utilized higher exercise intensity in their program (80% of 1RM) which included 3 sets of 8 repetitions on a twice weekly basis. Strength gains were between 35 and 76%. In addition, time to perform the backward tandem walk decreased 14% and the number of errors committed during this task were greatly reduced. The authors attributed this improvement in functional performance to the training, since controls exhibited a decrease in performance. Lastly, Pyka and colleagues (1994) conducted a similar training regime to Nelson et al. (1994), in men and women with a mean age of 68 years. They utilized an intensity of 75% of 1RM for 3 sets of 8 repetitions 3 times per week. Strength improvements (30-97%) and muscle fiber cross-sectional area increases were documented. Strength increased rapidly at the beginning of the training, then reached a plateau after 3 months. Increases in type I fiber area were found at both 15 and 30 weeks of training, while type II fiber area increased at 30 weeks only. This group concluded that neural mechanisms, evidenced by the rapid increase at the onset of the program, and hypertrophy, documented by increase in fiber cross sectional area, were responsible for the observed strength gains. Although no assessment of physical function was included, it is likely that improved neural pathways and increased muscle mass help explain improvements in functional ability following resistance training in the elderly.

These studies and others (i.e., Frontera, et al., 1988 and Agre, et al., 1988) demonstrate that older individuals respond favorably to resistance training. However, like any other fitness parameter, strength gains are reversible and will decline with cessation of training. It is therefore important to implement more long-term training programs which will likely lead to maintenance of strength and foster habitual activity patterns. While these studies have clearly focused on strength improvements, little if any research has attempted to increase power in older adults. Measurements of power (isokinetic dynamometry and time to rise from a chair) have distinguished fallers from nonfallers (Whipple, et al., 1987 and Fleming, Wilson & Pedergast, 1991). Muscular power plays an important role with respect to control during voluntary movements and reaction to external disturbances. In a biomechanical analysis of induced stumble in a group of young individuals, recovery was dependent on the lower limb power and the ability to return to an upright posture after considerable trunk flexion (Grabiner, Koh, Lundin & Jahnigen, 1993). The role of power in functional abilities is documented (Bassey et al., 1993) and it's assessment should not be neglected in older individuals.

Human balance is a complex task which is maintained by sensory detection of body position and motion, integration of sensorimotor information and appropriate musculoskeletal responses (Nashner, 1989). Conceptually, a fall can occur when any one of these factors are not maintained. For example, if a person's center of mass exceeds his/her limits of stability, that person will either have to take a step or stumble and fall if there is inadequate musculoskeletal function to compensate for this situation. Vestibular or central nervous system input are also important factors when considering the multifactorial nature of balance. Lord, Clark and Webster (1991) reported that sensation, muscle strength in the legs and reaction time were all important factors involved in postural stability in a group of older men and women (mean age=83 years).

Nguyen, Sambrook, Kelly, Jones, Lord, Freund, & Eisman (1993) documented numerous lifestyle and physical factors in a longitudinal manner in order to determine major risk factors for fracture in men and women over the age of 60. They identified postural instability, quadriceps strength, and femoral neck BMD as major risk factors for osteoporotic fractures. This provides support for the notion that postural stability is an important clinical measure with respect to fracture risk. One report suggests that the direction of instability is the best predictor of falling behavior in the elderly (Maki, Holliday & Topper, 1994). Maki and coworkers (1994) performed numerous tests of balance in a group (n=100) of independent, elderly men and women (mean age=83y) living in self-care (retirement) facilities. Spontaneous and induced postural sway were recorded for anterior-posterior and medial-lateral directions, after which falls were recorded in a prospective manner for one year. The best predictor of falling was*lateral* instability. This finding has important implications given that the most severe falls occur to the side (Hayes et al., 1993).

Of the three primary components of balance (maintenance of a position, stabilization for voluntary movement, and reaction to external disturbances), stabilization for voluntary movement appears to be a primary concern, especially since falls are often associated with voluntary actions (Nevitt, et al., 1991). During resistance training which requires stabilization of the body, dynamic postural adjustments are continually required in order to perform an exercise. Consequently, neuromuscular improvements in strength are expected to increase maximum limits of stability and improve postural control within the sway envelope, or the theoretical range in which an individual can shift the center of gravity. This idea was tested within a strength intervention trial in older women in which one of the primary outcome variables was balance. Judge, Lindsey, Underwood, and Winsemius (1993) administered a 6 month combined walking and resistance training protocol to 12 women with a mean age of 68 years. Postural sway during a double stance static trial did not change after six months of training. Single stance sway improved by 17% after the trial, although, this was not significantly different from the control group. These marginal results are probably due to multiple factors. First, the resistance training intervention was performed on weight machines, which do not require the individual to support and control body posture during the lifting activity. Second, the features of balance measured were static in nature, while the intervention involved dynamic activities. It is possible that aspects of dynamic balance were favorably altered, yet not measured.

In another exercise intervention, Sauvage and colleagues (1992) demonstrated significant improvements in balance and gait speed after 12 weeks of exercise training. Subjects were older males (n=8, mean age=73y) who participated in 3 supervised exercise sessions a week, including work on a cycle ergometer and dynamic strength training. The strength training protocol utilized machines (weight and pulley systems), yet required subjects to maintain a standing position during the exercises. After the program, the exercise group exhibited significant improvements in mobility assessment (p=0.004, which includes performance-oriented indices of balance, Tinetti, 1986) as compared to controls. In addition, kinematic analyses of walking gait indicated significant increases in stride length (p=0.02 to p=0.03), and velocity (p=0.04) in the exercise group only. Interestingly, static balance (double stance, eyes open and eyes closed) as measured by center of pressure deviations on a force plate, was not significantly altered by the exercise intervention. Again, this may be due to inappropriate assessment in that double stance balance is an index of static balance while the intervention was dynamic in nature. Similarly, strength was not favorably altered as a result of training (when the results of the exercise group were compared to that of the controls), probably attributable to a mis-match of assessment (isometric) and training (concentric) techniques.

Methodological concerns of the studies above make it difficult to draw specific conclusions with respect to the intervention best suited to improve balance. In addition, some research suggests that resistance training may decrease gait speed yet improve balance. Topp and associates (1993) administered a 12 week program utilizing rubber tubing to improve strength of the primary muscles (upper and lower body) involved in balance and gait. Exercisers exhibited significantly slower gait speed and improved single leg stance (eyes open), after the intervention period, although, these changes were not different from controls. Isokinetic strength of the knee extensors and flexors, however, was significantly improved in the exercising individuals. These researchers proposed that older individuals often have an increased gait speed due to improper, anteriorly oriented center of gravity and therefore, a need to "catch-up" and walk more quickly. The observed decreases in gait speed with training may therefore be associated with improvements in center of gravity alignment and ultimately beneficial. Unfortunately, the balance and gait speed results of the exercisers were not significantly different from the controls, thus, a solid conclusion about why these changes occurred (training or spurious finding) cannot be made.

Static balance has traditionally been assessed in older populations by a single leg stance. The ability to assess dynamic balance is somewhat more difficult, although tandem gait speed and a backward walking test have been used for this purpose (Fiatarone, et al., 1990 and Gehlsen & Whaley, 1990). Fiatarone, et al. (1990) reported significant improvements in tandem gait speed which she has linked to improvements in balance as well as strength and power. However, Gehlsen and Whaley (1990) found no differences in backward walking performance between fallers and nonfallers. These researchers did find that static balance performance distinguished fallers from nonfallers, which was most likely related to the reductions in leg strength and flexibility in the group of fallers. Yack and Berger (1993) proposed a measure of trunk acceleration to distinguish those with and without postural stability problems. This new assessment technique involves placing an accelerometer over the spinous process of the second thoracic vertebrae and then recording trunk acceleration during walking. In their initial study, Yack and Berger (1993) found that older individuals with a history of falling and those who reported having stability problems were distinguished by the pattern of accelerometer data. In particular, those who were classified as unstable demonstrated much greater difficulty controlling the trunk during walking. This new technique may offer insight with respect to gait abnormalities, however, it does not allude to the importance of lower limb stability, which may precede trunk movements during walking.

Recently, new technology has made the assessment of dynamic balance more detailed to better understand the components of voluntary movements within the sway envelope (Nashner, 1989). Work with this new apparatus (Pro Balance Master, Neurocomm International, Inc.) has been conducted primarily within clinical and rehabilitation settings. Hamman, et al. (1992) administered a specific intervention on the Pro Balance Master to young (20-35yrs) male and female subjects (n=17). Subjects were trained either once a week for five consecutive weeks or once a day for five consecutive days. The training involved static balance determination which measures body sway in a double stance position, with eyes open, eyes closed and eyes open and visual feedback. The dynamic protocol involved the standard dynamic limits of stability test in which a subject must shift his/her center of gravity from a center target to each of 8 targets that form a circle placed at 45 degree angles from one another. The targets represented 75% of each subject's LOS. In addition, a dynamic protocol in which subjects excursioned between peripheral targets only was utilized. There were no difference in either training group after the intervention in any of the three static balance measures. Results of the dynamic balance assessments suggested that transition time, path sway, and sway area (target sway) improved (20-64%) in both groups and that daily and weekly intervention groups performed similarly. While these results are interesting, it has not been demonstrated that indices of dynamic balance on this apparatus can be favorably altered with long term exercise intervention trials aimed at improving strength and power of the lower extremities.

Psychological Aspects of Exercise Training

Many of the physiological benefits of exercise are well-documented. It is estimated, however, that only 10% of the adult population engages in regular, vigorous exercise, without which the benefits of training do not persist (Caspersen, Christenson &

Pollard, 1986). It may be that the psychological benefits of training are important to consider with respect to adherence to training programs. In addition, these psychological benefits may be viewed as an important facet of training, independent of the physical benefits. This notion is particularly important in older populations, given the trend toward increasing psychological and mental health problems such as depression, that are associated with the aging process (Blazer, Hughes, & George, 1987).

Self-concept is often used interchangeably with self-esteem and self-worth. For purposes in this discussion and hereafter, self-concept will be used as the primary measure of interest, which relates to how an individual describes oneself. Global self-esteem may be defined as an evaluation of how one feels about oneself (Gergen, 1971), or the evaluative component of self-concept. Individuals may describe themselves differently depending on the specific domain of inquiry. For example, self-concept may be different in social settings than it is in physical settings, such as in sport and exercise. The hierarchial model proposes that self-concept within four basic domains of academic, social, emotional, and physical feed into a global measure of self-concept (Shavelson, et al, 1976). Relationships between perceptions of fitness and self-concept have been demonstrated (i.e., Heaps, 1978 and Marsh & Peart, 1988). Marsh and Peart (1988) found a significant relationship between physical self-concept and physical fitness as measured by performance on various calisthenics. There is limited research to suggest that self-concept within the physical domain can be improved with physical activity (Marsh et al., 1986). However, global self-esteem is considered a stable trait and as yet, exercise interventions have not been shown to alter it.

There are many proposed psychological benefits of exercise participation (Willis & Campbell, 1992). Research efforts to support these benefits have been conducted primarily in college-aged populations and within the context of aerobic exercise interventions. Improvements in psychological well-being, mood state, self-concept, reaction to stress, cognitive processes, decreases in stress, anxiety, and depression, have been associated with exercise participation (Rodin & Plante, 1989). Recent research in sport and exercise psychology has generated sound methodology to examine the influence of exercise on self-concept which was previously thought to be too vague a characteristic to operationalize. Additionally, measurement of this construct within the physical domain in older populations has been established (Chase, 1991). Understanding of self-concept and how it may change with an exercise intervention is an attractive prospect due to the large number of other variables it tends to influence. For example, self-concept has been linked to various aspects of social, academic, and professional achievement (Sonstroem, 1984). There is also considerable value in improving global self-esteem, simply to improve the quality of one's life.

A change in physical self-concept with an exercise intervention may be mediated by the social aspects of the program, feelings of competence, goal achievement or increases in physical fitness (Sonstroem, 1984). While self-conceptions within the physical domain may improve over a short period of time, a longer exercise intervention may be required to influence the more stable, global measure of self-esteem. Sonstroem (1984) recommends that researchers improve methodology by investigating both global self-esteem as well as subdomains of self-concept within physical settings for longer periods of time (minimum of 15 to 20 weeks). To date, no study has attempted to experimentally determine the effects of a long term exercise intervention on physical self-concept or global self-esteem in older women.

Limited research has demonstrated some positive effects of exercise participation in older adults. Emery and Blumenthal (1990) confirmed that exercise participants perceived many positive changes in areas associated with quality of life (i.e., overall health status, self-confidence, energy level, mood). The interventions utilized in this study included aerobic exercise and yoga. Both groups experienced improved perceptions of psychological well-being over controls. The original investigation examined the effects of these interventions on several psychological variables, including anxiety, depression, and more clinical measures such as obsessive-compulsive and phobic tendencies (Blumenthal et al., 1991). The authors concluded that there were very few objective improvements in psychological variables which they attributed to the sample, which was generally healthy and active at the start of the intervention. However, one alternative conclusion may be that the exercise intervention was not geared toward improving the functional status of this population. Improvements in strength may be more salient to older adults with respect to optimal function, whereas aerobic interventions may be more meaningful to younger populations.

One early report documented improvements in self-concept with aerobic training (Sidney & Shephard, 1976). In this study, a group of 26 older men and women (mean age=66y) exercised for one hour, 4 times per week for 14 weeks. After an initial phase-in period, during which the participants were encouraged to exercise at moderate intensity (at a heart rate of 120-130 bpm), the instructors encouraged a higher intensity (at a heart rate of 140-150 bpm). Those who exercised with high frequency (>2 times per week) and at the recommended intensity experienced significant improvement in self-concept, most notably with respect to body image. It is interesting to note that these psychological benefits did not extend to those who had less regular participation or lower intensities.

Other published reports have suggested that weight training can significantly impact self-concept (Tucker, 1983 and Tucker, 1987). Tucker investigated the effects of weight training on self-concept in college-aged men (mean age=21y). They participated in a beginning weight-training class which met 2 times per week for 16 weeks. Most exercises were performed on Universal Gym equipment and in some cases with free weights. At the conclusion of the program, the participants evidenced 10-20% improvement in strength. Of the numerous psychological measures assessed, changes in neuroticism, body cathexis, and strength were the best predictors of increases in self-concept. It is interesting to note that those who perceived that they had muscular body types (mesomorphic somatotype), did not experience as much of an increase in self-concept as those who did not have this body type perception at the the onset of the training. Tucker concluded that the potential improvements in self-concept with weight training is mediated by perceptions of body image prior to the intervention. This is in line with the idea that those with high baseline levels of self-concept are less likely to experience improvements with physical training due to a ceiling effect (Sonstroem, 1984). The sociological implication for improved self-concept in men with weight training (i.e., more masculine, muscular body) is probably much different than that in older women. It is likely that older women may experience improved self-concept with resistance training due to an increase in functional ability and perhaps beneficial changes in body composition (Berger & McInman, 1993). Due to the lack of empirical research in the area, this hypothesis remains speculative.

Affect, or mood, has been related to self-concept. Specifically, positive affect has been positively correlated and negative affect negatively correlated with self-concept (Pelham & Swann, 1989). As in the case with self-concept, there is considerable reason to examine this psychological construct within the context of an exercise intervention. General improvement in mood may relate to enhanced exercise adherence. Most of the research which supports improved mood states with exercise participation has focused on acute bouts of exercise (Rodin & Plante, 1989). Although it has been demonstrated to improve with exercise, most of the research has focused on acute bouts of aerobic exercise in college-aged populations (Willis & Campbell, 1992). In addition, the Profile of Mood States (POMS) (McNair, et al., 1971) has been used frequently to assess mood alteration with exercise. However, the POMS inventory was originally developed for use on clinical populations which includes only one positive and four negative mood states. The PANAS, which measures the two global dimensions of positive and negative affect, may be a more appropriate choice of inventories to assess affect in healthy populations.

Sidney and Shephard (1976) have reported that aerobic training in a group of 26 older men and women signficantly impacted mood state. However, only those who exhibited improvements in maximal oxygen consumption experienced favorable changes in mood state. In contrast, those who didn't realize increases in maximal oxygen consumption revealed a shift toward a more negative mood state. Changes in mood, along with the discussion above on changes in self-concept, indicate that psychological improvements with exercise may be dependent on participation characteristics such as frequency and intensity of exercise. Clearly those who participated more regularly and with vigor are those who increased maximal oxygen consumption. Those are also the individuals who registered significant increases in body image.

One of the most common areas of interest with respect to exercise-induced affective changes in the elderly is decreasing the problems of depression. Uson and Larrosa (1982) implemented an exercise program for 9 months in a group of men and women between the ages of 60-80 years. Their program included warm-up and cool-down stretches, as well as jogging and calisthenics. A 70% decline in depression was recorded in the exercisers compared to a 40% increase in symptoms of depression in age-matched controls. It is interesting that the controls were involved in other group activities which involved social and recreational pursuits. Perhaps the physical aspects of training provide a unique psychological benefit beyond the social interaction which also occurs within the context of group exercise. Bennet, Carmack, and Gardner (1982) demonstrated similar improvements in depression symptomology in nursing home residents with a much less vigorous program including light stretching and postural exercises. It is important to note, however, that a decrease in depression with exercise is only realized in those with existing symptomology (Willis & Campbell, 1992). Much less is known about global positive and negative affective responses to long-term training in older women without pre-existing psychological symptoms. To date, affective responses to long term resistance training in older women have not been documented.

METHODOLOGY

Sample

Forty eight women who were at least five years postmenopausal and between 50-75 years of age were recruited from Corvallis, OR and the surrounding area. Subjects were screened for coronary heart disease, respiratory disease, metabolic disease (diabetes, thyroid conditions, etc.) and orthopedic problems (significant disability of ankle, knee or hip) by health history questionnaire (Appendix B). Participants were screened for smoking and medication use known to alter bone metabolism (with the exception of estrogen, those on thyroid or glucocorticoid medications were excluded). Women taking estrogen were included in the study if they had taken hormones for at least one year and if bone mass at the hip was less than the mean of age-matched controls (z score < -0.5). Initial bone mass at the spine or hip for all participants had to be below age-matched controls (z score <-0.5). In addition, women who recently (previous year) participated regularly in weight training as a form of exercise were not included in the study. Four women were excluded at baseline due to high initial bone mass values (z-score >.5 at the hip and spine). Four women discontinued participation in the exercise program. Therefore, 40 women completed the 9-month study.

Prior to participation, all subjects gave written, informed consent (Appendix A) according to the policies outlined by the OSU Institutional Review Board. All testing and training procedures were approved by the same. Subject data were kept confidential by assigning each participant a number for purposes of identifying information within the data base.

Instrumentation

Bone scans were performed on the whole body, the proximal femur (hip) and the lumbar spine (L_{2-4}). The coefficients of variation (CV) for these procedures at the OSU Bone Research Laboratory are 1.0% for whole body BMD and <1.0% for BMD of both the proximal femur and the lumbar spine. Body composition, bone-free lean and fat mass was determined from the whole body scan. The CV for body composition analysis with DXA at OSU is 1.2%.

Radiation exposure from DXA is minimal. Subjects experience an entrance dose of approximately 2-5 mrem during the femur and spine scans. The entrance dose for the whole body scan is approximately 1.5 mrem. Radiation exposure on a daily basis from background sources is estimated to be 1 mrem. Bone scans were performed by personnel trained according to the requirements of the Oregon Board of Radiologic Technicians.

Bone mineral density was assessed by dual energy x-ray absorptiometry (DXA, Hologic QDR 1000/w, Hologic, Inc. Waltham, Mass.). This noninvasive technique involves passing a narrowly collimated x-ray beam of two alternating energies (70 and 140 kvP) through the subject while she lies in a supine position on the scanning table. The dual energy beam is necessary in order to assess bone sites within the axial skeleton (i.e., the proximal femur and spine) since these areas are surrounded by a significant amount of soft tissue. The x-ray source is located below the table while the scanning arm, positioned above the patient, contains the x-ray target made of tungsten. When the beam is first emitted, it passes through a calibration wheel which has reference density values for bone, soft tissue and air. Upon passing through the subject, tissues with the highest densities attenuate the greatest number of photons. When the beam is detected by the target, the computer housed within the table performs various algorithms in order to convert the analog information to a digital format. The information is analyzed for bone mineral content in grams (BMC), bone area (cm^2) and areal density (BMD, g/cm^2).

Lean and fat mass (independent of bone) was quantified from the whole body scan. This was accomplished by use of a reference "tissue bar" comprised of lucite and aluminum. The percentage of water in lean tissue was assumed to be 73.2%. Validation of this procedure for body composition analysis has recently been conducted in the OSU Bone Research Lab. These results demonstrated that DEXA is comparable to two and four component body composition models.

Peak force was assessed by isokinetic dynamometry (KinCom 500H, Chattex Corp.). This apparatus employs hydraulic mechanisms in order to match the forces applied to it while maintaining a constant speed of contraction. The lever arm is affixed to the motor head to which a load cell is attached. Various positioning devices are used in order to isolate the muscle group of interest. The pad to which the subject applies force is directly connected to the load cell in order to assess force output. For each strength test, the anatomical axis of rotation is aligned with the proximal end of the lever arm which is attached to the motor head. Strength assessment protocols were programmed into the KinCom which set parameters for testing (i.e., start and stop angles and speed of contraction).

Strength values determined at relatively slow speeds of contraction (15-30 degrees per second) are considered to be most representative of maximal strength due to recruitment of the greatest number of fast twitch fibers. Protocols employed previously at OSU have revealed good reliability with CVs of 5% for the hip abductors and adductors, 3.6% for ankle dorsiflexors, 8% for ankle plantar flexors, and 4% for quadriceps (all at 30 degrees per second).

Static and dynamic balance was evaluated using the Pro Balance Master (Neurocom International, Inc.). The machine is equipped with dual force plates which house four load cells to detect pressure. The force plates are installed within a platform flush with the surrounding surface and a color monitor mounted at eye level directly in front of the subject is used to guide subjects through test protocols. A standardized foot position was used for all test protocols on the Pro Balance Master.

The Pro Balance Master is used to measure several indices of postural stability. The theoretical maximum LOS is calculated by the machine based on the subject's height and age. The standardized foot position (the medial malleoli are aligned with a horizontal stripe which centers the subject with respect to the force plates), allows the Pro Balance Master to detect the location of the subject's center of gravity (COG). Protocols which involve the subject shifting the COG from a center target to peripheral targets placed at various percentages of the LOS, determine the movement time, path sway and target sway during that excursion. These variables assess postural control during voluntary movements. Maximum LOS is calculated from a trial in which the subject is directed to make an excursion to a target at 100% LOS. Maximal distance achieved during the excursion is recorded as patient position.

The reliability of this machine has been established for some of the standardized test protocols (e.g. the sensory organization test used for static balance assessment) by the manufacturer at test sites around the country. It was determined that at least one familiarization session was required on a separate day in order to achieve a true baseline in healthy adults. Therefore, one familiarization session was provided prior to baseline data collection. Coefficients of variation for the dynamic balance assessment used in the present study ranged from 7.6 to 9.3%.

Muscular power was assessed by the Wingate Anaerobic Power Test (WAPT) for older individuals (Bar-Or, 1992). The WAPT was performed on a bicycle ergometer and is designed to assess power of the lower extremities. A Monark 814E cycle ergometer equipped with pedals with plastic toe straps, adjustable seat, adjustable handle bars and a weight basket were used for this test. Weights of one kilogram, one-half kilogram and one-tenth kilogram were placed in the weight basket to apply a breaking force to the fly wheel. The weight applied to the fly wheel (force), the circumference of the fly wheel

(1.615 meters, distance) and the time during the test (seconds), were used to calculate power from the following equation:

$$\text{Power} = \frac{\text{force} * \text{distance}}{\text{time}}$$

Power output results from the WAPT were obtained with the assistance of a computer interface designed by Sports Medicine Industries, Inc. (SMI, Inc., St. Cloud, MN). Sixteen reflective markers were placed equidistant from one another along the outer boarder of the fly wheel. An optical sensor was mounted approximately one-half inch from the fly wheel which detects the markers as the fly wheel rotates. The optical sensor was interfaced to an IBM compatible computer with software from SMI, Inc. to calculate the power outputs from each second of the 15 second test. Before the test, the subject's weight, belt resistance (calculated as a percentage of whole body lean mass), fly wheel circumference and test duration were provided within a subject biography format. The printed output provided the individual power outputs per second of the test, the mean power (average power throughout the 15 second test) and the maximum power (average of the three highest one-second power readings). Mean and maximum power were provided in both absolute (Watts) and relative measures (Watts/kg). The C.V.s for the WAPT are 4.7% for mean and 4.4% for maximum power.

Participants completed two psychological inventories designed to assess self-concept (SC) and affect. The Physical Self-Perception Profile-A (PSPP-A, Appendix C) was used to assess how the subjects evaluate themselves with respect to sports competence, physical appearance, functional capacity, health/disease state and self-worth within the physical domain. This scale was patterned after the original PSPP designed for college-aged adults (Fox & Corbin, 1989). Items were added to the scale in order to assess global self-esteem, which employed the same response format (Harter, 1985). In addition to assessing these self-conceptions, twelve items within this scale were designed to determine the relative importance of each area to the subject. For example, two items were provided to assess how important sports competence was to the subject. There were six items that loaded on each of the six SC measures of interest, plus the twelve questions to assess importance, making a total of 48 items. The psychometrics of the PSPP-A and the global self-esteem items for older adults have been established (Chase, 1991 and Harter, 1985a).

The PSPP-A employs a structured alternative format. The subject responded to one of two statements that depicted how she viewed herself with respect to any of the six SC measures and the importance of each. One response is generally positive or designed for the subject to respond in the affirmative while the other is negative. For example: Some people feel they are among the best when it comes to participating in sports (positive) OR Others feel that they are not so good when it comes to participating in sports (negative). The subject chose the response that best described herself in that context and then replied whether that statement was "sort of true" for her or "really true" for her. Therefore, there was only one possible response for each statement. The negative responses were scored as a 1 or 2 (really true and sort of true, respectively) while the positive responses were scored as a 3 or 4 (sort of true and really true, respectively). All items that loaded on each of the six SC measures were totaled and then divided by 6 to arrive at an average score for each. Lastly, each of the four averaged subdomain scores were multiplied by the corresponding average importance score to result in the final value. This process ensures that how the subject values each of the subdomains is taken into consideration in the scoring.

Positive and negative affect was assessed with the Positive and Negative Affect Schedule (PANAS, Watson et al., 1988, Appendix D). This scale consisted of a checklist of 20 items, equally divided into 10 positive and 10 negative adjectives. For each adjective, subjects noted to what extent they had felt that way during the past few days, using a 5 point Likert format (1=not at all to 5=extremely). The items loaded on a general positive and negative affect score. The positive scores were added and then divided by 10 in order to arrive at the positive affect score. The same procedure was used to calculate the negative affect score. The psychometrics of this scale have been established for older adults (Kercher, 1992).

Diet was assessed during the third month of testing. Participants were given the Block Food Frequency questionnaire which assesses past year nutrient intake (Block, Hartman, Dresser, Carroll, Gannon, & Gardner, 1986). Participants noted the foods they ate regularly (number of times per week) as well as the quantity of each food. This scale has been validated for assessing calcium intake and was used primarily for that purpose in this study (Cummings, Block, McHenry, & Baron, 1987).

Procedures

Table 1 depicts the relative time in which the procedures were performed. The training program began on February 28, 1994, which was considered the start date from which future testing sessions were scheduled. Each participant was tested every three months (+/- two weeks).

Women who were previously enrolled in studies at the OSU Bone Research Laboratory and who met the inclusion criteria were called to determine interest in participation. Other subjects were recruited from Corvallis, OR and the surrounding area through various media announcements. Approximately 75 inquires were made in response to a press release published in the Corvallis Gazette-Times in December, 1993. Potential subjects who met the inclusion criteria and who were willing to take part in the study after hearing a full description of the time line and procedures, were informed that they would be randomly assigned to either an exercise group or a control (non-exercise) group. After providing an explanation of the role of each group and the importance of randomization to the two groups, potential subjects were asked if they were still interested in participating in the study. Subjects in the control group were offered participation in training following the 9 month trial.

Those interested in participating were sent copies of the two informed consent forms (Appendix A), the health history questionnaire (Appendix B) and the physician clearance form (Appendix A). Subjects were asked to complete the health history form and to read the informed consent forms. The latter, which outlined the study in lay terms, was reviewed by the potential subject's personal physician. If the physician agreed that his/her patient was a good candidate for the study, he/she signed the clearance form. All women in the study received clearance from their personal physicians prior to participating in the study, regardless of the group to which they were assigned. The health history, informed consent and physician clearance forms were collected from the participants upon their first visit to the OSU Bone Research Laboratory (BRL). At that time, subjects were requested to provide written, informed consent.

Participants who completed baseline testing by the end of February, 1994 (n=37) were matched for BMD of the femoral neck and lumbar spine, age, and years postmenopause. More women (n=23) were assigned to the exercise group since the full contingent of participants was not screened and tested at the onset of the training program. One woman assigned to the exercise program declined to participate in that group, so she was intentionally assigned to the control group. This resulted in a total of 22 women in the exercise condition. Three women were unable to participate in the exercise group due to conflicting work schedules with the exercise classes or other excessive time committments. Therefore, four participants were intentionally assigned to the control group at the onset of the training program. Seven women were enrolled into the study after the exercise program began. These women were not matched for BMD and were automatically assigned to the control condition. A total of 22 participants were assigned to the control group.

Table 1. Time Line of Testing and Training

Month(s)	Date	Training and/or Testing
Pre-study	Dec.,1993	Participant recruitment
	March, 1994	**Baseline testing** SC & Affect BMD WAPT Balance Strength
Month(s)	Date	Training and/or Testing
1	March, 1994	**Begin Training**
3-4	May-June, 1994	Diet (calcium) SC & Affect Balance WAPT Strength
6-7	August-Sept., 1994	SC & Affect BMD Balance WAPT Strength
9	Nov. 18, 1994	**End Training**
9-10	Nov.-Dec., 1994	SC & Affect BMD Balance WAPT Strength

During the pre-test session, participants reported to the Bone Research Laboratory two to three times for baseline testing and reliability assessment of ankle strength, the WAPT, and the balance protocol. Day one testing includeed completion of the psychological questionnaires, BMD determination, the WAPT and familiarization on the Pro Balance Master. Day two testing included the balance assessment followed by strength determination. Twenty women returned a third day to repeat ankle strength, power, or balance protocols to determine reliability of those measures. Seven participants returned for ankle strength, nine for the WAPT, and four for the balance protocol. The test and retest scores were used to generate coefficients of variation for the testing procedures since they did not exist prior to that time. Testing days one and two were separated by at least 24 hours but not more than one week, while testing days two and three were separated by 2-7 days.

During the third month of training or follow-up (control), all participants were retested for SE, affect, balance, strength, and power. At this testing session, subjects were provided with the Block Food Frequency questionnaire to complete and return via U.S. Mail (controls) or at the next training session. Control subjects provided completed logs documenting physical activity for the first three months of the study.

During the sixth month of training or follow-up, all subjects were retested for SE, affect, BMD, balance, strength, and power. This testing session required one to two visits to the laboratory, depending on facility and participant schedules. Results of these intermediate testing sessions were used to establish a progression in dependent measures in association with the progression of the training program and/or change in seasons (control).

At the completion of the 9-month training program or follow-up, all subjects were retested for all dependent measures. Testing procedures were performed in the same order as in the pre-training testing period and month 6. All participants in the exercise group were tested within two weeks of the last day of training.

All subjects were tested for BMD of the spine ($L_{2\text{-}4}$), proximal femur and whole body using standardized procedures. Participants were reminded to wear non-denim clothing free of metal buttons, zippers, or ornaments that were likely to interfere with the BMD measures of interest. The whole body was scanned first, which required the participant to lie in a recumbent position on the densitometer for approximately 13 minutes. Participants' feet were taped together during the whole body scan to help eliminate movement artifact. For the spine and hip scans, positioning devices from the manufacturer were utilized to isolate the specific area of interest. These devices also reduced the likelihood of a subject moving during a scan.

Bone scans were analyzed for BMD of the whole body, lumbar spine (average value for L_{2-4}) and the hip and its subregions (femoral neck, trochanter and Ward's triangle), using standardized techniques recommended by the manufacturer. In addition, scan results were compared to normative values supplied by the manufacturer. The whole body scan was analyzed immediately since body composition measures (whole body lean mass) were required for determining the WAPT resistance setting. Bone mineral density was assessed on the first day of testing (pre-training, training/follow-up month 6 and post-training). On repeated BMD assessment, compare analysis was used to improve reliability and to compute the percent change from the original scan. Results of BMD testing were provided to the subjects at pre-training and post-training only.

Peak force was determined on the KinCom 500H. Strength was assessed for ankle plantar and dorsiflexion, hip abduction and adduction and knee extension. The test administrator began all strength assessments by demonstrating the positioning and movements involved. Positioning required that the anatomical axis of rotation (eg., the knee for knee extension, the greater trochanter for hip strength and the lateral malleoli for ankle strength) was aligned with the axis of rotation of the KinCom (the proximal end of the lever arm, at its site of attachment to the motor head). After correct positioning and gravity correction procedures were completed, initial joint position, start and stop angles were established. The subject was instructed to perform 3-5 trials of the exercise at an intensity much below maximum which served as the warm-up activity prior to maximum strength assessment. After the warm-up, subjects performed 3-5 maximal efforts in order to determine peak force. Each maximal effort was separated by approximately 30 seconds to one minute of rest.

The protocols for each of the five strength measures were programmed into the KinCom and therefore kept consistent across all testing sessions. All tests were conducted at a speed of 30 degrees per second. The left ankle was tested for ankle plantar and dorsiflexion. The subject was seated in a semi-recumbent position with the left leg supported at the knee. The initial joint position was set at 90 degrees with the start and stop angles set at 85 and 120 degrees, respectively. The left leg was utilized for knee extension strength determination. In a seated position, the initial joint position was 90 degrees with the start angle set at 85 degrees. The stop angle for the quadriceps protocol was close to 150 degrees, depending on how far the subject could comfortably extend the lower leg. Lastly, the right hip was used for hip abductor and adductor strength determination. The subject was positioned lying on her left side. The initial joint position was set at 0 degrees. For hip abduction, the stop angle was 30 degrees. The starting position was at whatever angle (typically -16 to -10) created when the right leg was lying comfortably on top of the left leg. For hip adduction, the start angle was 45 degrees and the stop angle was set at approximately 0 degrees.

Subjects were familiarized with the Pro Balance Master on the first day of testing of the pre-training session. After recording their height (without shoes), subjects were oriented to the machine and placed in the standardized foot position on the force plates in stocking feet. They were allowed to simply move the COG cursor by shifting their body weight while standing on the force plates. All subjects completed the entire testing protocol during the familiarization session. The familiarization data were used to determine the intermediate target in the dynamic LOS test as well as the strategies used while moving to the posterior target. The strategy was then kept constant during repeated testing sessions. Other than these points, the familiarization data were not saved or recorded.

The static balance protocol (sensory organization test) consisted of four tests which required the subject to maintain a steady, standing position for 20 seconds under varying sensory conditions. These included: (1) stable platform surface with eyes open; (2) stable platform surface, eyes closed; (3) dynamic platform surface, eyes open; and (4) dynamic platform, eyes closed. The subject's average position and amount of body sway was recorded during each test and expressed as a percentage of their LOS.

The dynamic LOS test required participants to move as quickly and accurately as possible from a center target to each of six peripheral targets, two each in the anterior, posterior, right and left lateral positions. For each direction, one target was positioned at a distance which the subject could achieve and the another at 100% LOS. The first target was set at 65-75% LOS (depending on individual ability). This target placement was determined during the familiarization period. Once the subject aligned the COG cursor within the peripheral target, they were instructed to hold the cursor there until the video cued them to come back to center. In the case of targets placed at 100% LOS, subjects were instructed to move as close as possible to the highlighted target without losing balance. There were two excursions to each of the peripheral targets in all directions, which began from the center target. A ten-second pacing interval was used for this test. The dependent variables of maximum LOS, path sway, movement time and target sway were measured during the dynamic balance assessment. The mean of the values obtained from the two excursions were used for scoring purposes.

The balance protocol was the first assessment conducted which required physical activity on any given testing day. Placing the balance assessment first was necessary in order to decrease potential interference of the strength and WAPT tests on balance performance. The only exception to this was when the subjects were familiarized on the first day of testing at the pre-training session.

The WAPT was conducted on a Monark bicycle ergometer and consisted of a 5 minute warm-up, a 15 second bout of fast pedalling at increased resistance and a 5-10 minute cool-down. The warm-up portion of the test consisted of pedalling against very light resistance (approximately .5-1kg) at a slow to moderate pedal cadence (40-60 rpm). During this time, the subjects were instructed to pedal as fast as they could for approximately 5-7 seconds, with the goal to reach 100 rpms. The subjects performed two short sprints in order to practice increasing the speed of pedalling. The two practice sprints were spaced approximately one minute apart. Once the practice session was complete and a heart rate of 110 beats per minute was reached, the subject continued on to the 15 second trial.

The resistance for the 15 second trial was a relative workload representing 8-10.5% of whole body lean mass, as determined by the whole body bone scan. Most participants were assigned a workload of 9.5% of lean mass, however, there were a few women who required slightly lighter or heavier workloads. Those who had difficulty reaching 100rpms during practice sprints and/or who participated in very little structured exercise were assigned a workload between 8-9%. There were three women who required a higher workload (10-10.5%) due to high fitness levels and/or regular training on a bicycle. At the onset, the weight was placed in the weight basket, yet held off the fly wheel. The subject was instructed to pedal as fast as she could, and upon exceeding 100 rpms, the basket was released and the weight engaged on the fly wheel. The 15 second trial began the moment the weight was engaged. At the end of 15 seconds, the weight was released from the fly wheel and the subject continued pedalling at a reduced rate. The cool-down continued for 5-10 minutes. Measures obtained from the WAPT included absolute (watts) and relative (watts/kg body weight) mean and maximum power.

The PSPP-A and PANAS questionnaires were completed by participants at the beginning of all four testing sessions. Prior to administration, instructions on the questionnaires were reviewed by the investigator and the subject. They were cued to answer each question as honestly as possible and it was recommended that they not ponder any question too long.

The exercise training sessions were held within the Department of Exercise and Sport Science at Oregon State University. The first two weeks consisted of a pre-training period, designed to bring all subjects to certain level of fitness and to familiarize the participants to the exercises. During this time, subjects performed the exercises without added weight. The full training program was designed to increase strength and power of the lower extremities. Training sessions were based on principles of resistance training and were held three times per week, with at least one day of rest between sessions. Traditional weight equipment was not used. Resistance was altered by having the subjects wear a weighted vest. The amount of weight assigned to each participant was calculated as a percentage of body weight. Subjects completed the number of sets and repetitions at the relative intensities outlined below for six different exercises. Due to individual variation, progression through the program was tailored to the abilities of the participants (particularly with respect to intensity). Therefore, the range of values for intensity represents this variation in ability.

An 8 inch wooden step was used for stepping exercises. Using an up-up-down-down cadence, one cycle equaled one repetition for stepping. Stepping was conducted such that a dominant leg did not develop. On occasion, other tasks were added to stepping exercises, such as a high knee raise, or a toe raise. These stepping variations were added to provide variety as well as to challenge the participant's ability to coordinate these skills while standing on one leg.

Jumping in place was added to the training during month four. After the fifth month of training, jumping off a 4 inch step was added. Participants were instructed to stand on the step and jump onto a padded surface, landing on both feet. In the latter stages of the training program (weeks 22 and 28), subjects jumped from the 6 and 8 inch benches in addition to jumping in place on the floor. Vests were not worn during jumping exercises.

Table 2. Exercise Training Program Outline

Weeks	Sets	Reps	Intensity*	Jumps
1-2	1-3	15	body weight	0
3-6	1-3	15	3-9%	0
7-10	2-4	12	7-12%	0
11-12	3	15	6-10%	0
13-16	3-4	10	9-13.5%	1-4
17-20	4-5	10	10-15%	5[1]
21-24	3-4	10-12	11-16%	6[2]
25-26	4	10-12	9-12%	8-10[3]
27-30	4-5	10-12	12-16.5%	12-14
31-34	4	10-12	12-18%	16-20
35-36	3	10-12	13-18.5%	22-24
37-38	3	10-12	14-20%	26-28

*Intensity was expressed as a percentage of body weight.
[1]Jumping from 4-inch step (starting week 19)
[2]Jumping from 6-inch step (starting week 22)
[3]Jumping from 8-inch step (starting week 28)

Subjects began the squat with feet slightly wider than shoulder width apart in a toe-out position. This wide stance places less stress on the knee and involves hip musculature to a greater extent than knee extensors. A full squat was recommended, in which the thighs reach a position parallel with the floor (~90 degree knee angle). However, at the beginning of the program, few could achieve a full squat, and therefore, a half squat was performed. The knee angle achieved in a half squat is about 120 degrees. As the program progressed, more and more participants were able to achieve a full squat.

Subjects sat in an armless chair that allowed for ~90 degree knee angle. Starting in a seated position, subjects stood up then sat down for one repetition. Hands were not used in this exercise, to emphasize use of the lower extremities. There were two women in the study who had knee pain in association with chair exercises. These women substituted squats when chair raises were indicated.

Lunges were performed in three directions: forward, right and left lateral. The lunges began with a step in one of the three directions, a shift in body position, a bend in the stepping leg no less than 90 degrees and a return to the original standing position. Initially lunges were performed onto the 8 inch step, to lessen strain on the knee. In month 4, the last set of lunges was performed without the step.

Subjects stood with flat feet on the floor. They began the exercise by rising up to the toes, returning to flat feet, rocking back to the heels while lifting the toes, and then returning to flat feet for one repetition. Occasionally, toe raises were performed on a single leg.

Before the training sessions, subjects were led through a 10 minute warm-up, including light walking or cycling and stretching for the lower extremity (calves, quadriceps and hamstrings). After the training sessions, subjects were led through a cool-down period consisting of 10-15 minutes of stretching. The cool-down included stretches for the calves, hamstrings, quadriceps, hip, back, chest and shoulders.

Two exercise sessions were offered, one in the morning and one in the evening, to accommodate participants' schedules. Training was consistent between the sessions (i.e., the morning sessions was replicated in the evening). Attendance was recorded at each session. At the conclusion of each exercise period, participants recorded the number of sets, repetitions, and jumps in a training log. In addition, they noted their activity outside the supervised sessions. Participants were frequently reminded to maintain their pre-study level of exercise during the trial. Exercisers were provided with written instructions for times when they were absent from the training program more than two days in a row. The instructions included the specific exercises, sets, repetitions, jumps, and stretching planned during the absence.

Women in the control group were reminded to maintain and record their physical activity during the study. In addition, they were asked to refrain from engaging in any new form of exercise, particularly weight training. They were also asked to maintain dietary practices and to notify the investigator in the event that medications were added and/or dosages were altered.

Descriptive statistics (means and standard deviations) were generated for subject characteristics. In addition, simple ANOVAs were run on matching variables (age, BMD, and years postmenopausal) and anthropometric and nutritional data (height, weight, body composition, and past year calcium intake) to determine group differences at baseline. The overall design employed a 2 (group) X 2 (time) repeated measures format. Uni- and multivariate repeated measures techniques were conducted to determine time and group main effects and time x group interactions. Lastly, multiple stepwise regression analyses were utilized to define independent predictors of improvements in balance measures.

Univariate statistics were computed for BMD, static balance, maximal LOS, and power. Separate repeated measures ANOVAs were utilized to determine changes in femoral neck and lumbar spine BMD. All women were included in the femoral neck analysis while only 31 were analyzed for lumbar spine. Some of the spine data were not entered into the analysis due to the presence of extravertebral calcification (i.e. osteophytes). Those on estrogen were included in the BMD analyses since they were stabilized on hormones and their bone mass values did not reflect a change that was significantly different from their estrogen deficient counterparts.

A 2 x 2 x 2 x 2 ANOVA with repeated measures was employed for static balance (body sway) to account for three within factors: visual orientation (eyes open or closed), surface condition (fixed or swayed), and time. To determine changes in maximal LOS, a 2 x 4 x 2 ANOVA with repeated measures was conducted. The two within factors were direction (anterior, posterior, right, and left lateral) and time.

Maximum power was the only measure analyzed from the WAPT, since mean and maximum values were highly correlated (r>0.70). In addition, lean mass of the legs (kg) was significantly associated with maximum power at baseline (r=0.557, p=0.0001). To correct for this association, the dependent measure of max watts/kg (legs lean mass) was entered in the repeated measures analysis.

Five separate comparisons were made using univariate statistics, which can inflate the experimentwise error rate. Therefore, the Bonferroni technique was utilized to adjust the alpha level for these univariate statistics (Thomas & Nelson, 1985). The alpha level (0.05) was divided by the number of comparisons (5) to calculate the final acceptable signficance level of 0.01.

Subject numbers were determined from formal power calculations. It was hypothesized that BMD of the lumbar spine and proximal femur would increase significantly over the 9-month period. The most demanding comparisons to test these hypotheses are Student's t analyses of BMD measures to compare changes within groups with respect to zero. With a power=0.8, alpha=0.05, and an expected difference between groups of 1% at the proximal femur and lumbar spine, 17 subjects per group were needed in order to determine signficance. Twenty-two subjects were recruited for each group at the onset of the study. At the conclusion of the nine month trial, eighteen women remained in the exercise group while all twenty-two were in the control group.

Multivariate techniques were employed to determine the effects of the training on self-perceptions, affect, strength, and dynamic balance. Specifically, multivariate mixed model analyses (MMM MANOVA, Schutz & Gessaroli, 1987) were employed. Prior to analysis, the dependent measures were assessed for multicollinearity. If two or more measures were highly correlated (r>0.70), only one of the measures was entered into the analysis. The Huynh-Feldt (H-F) procedure was used for estimating epsilon, the degree to which the data meet the assumption of sphericity (Schutz & Gessaroli, 1987). The MMM MANOVA repeated measures technique was chosen since there were no violations of sphericity (epsilon <0.70, Schutz & Gessaroli, 1994). Univariate follow-up analyses were conducted to determine which dependent variables within the analyses contributed to significant findings.

The dependent measures within self-perceptions, affect, and strength, were entered into separate MMM MANOVA analyses in which the repeated measure is treated as a univariate variable. Five of the six dependent variables from the PSPP-A were utilized to determine if the exercise training had an impact on self-perceptions. The physical self-esteem and attractive body subscale measures were highly correlated ($r>0.70$), and therefore only the latter was entered into the multivariate analysis. The subscales of attractive body, sports competence, physical function, and extent of medical problems were weighted with the importance scale of each. The weighted scores were obtained by taking the product of the actual subscale score and its corresponding importance score (Marsh, 1986). The weighted scores, which account for the extent to which the subject values each self-perception subscale, were used in a second analysis. The positive and negative affect scores, and all five strength scores, were entered into separate MMM MANOVA analyses.

A 2 x 2 MMM MANOVA was conducted for dynamic balance. Only the trial conducted at the intermediate LOS was analyzed for path sway and movement time. In most cases, the subjects were not able to reach the target during the trial at 100% LOS. Because of this, movement time is automatically scored as 10 seconds (even though movement to the subject's maximal position may have been much quicker) and target sway data are not provided. Target sway was not included in the analysis for the intermediate target, due to many missing data points. In addition, the anterior-posterior (AP) scores were collapsed (as a sum of the two), as were the right and left lateral (LAT) scores for movement time and path sway, and entered into the analysis as four separate variables. The grouping of the data seems most appropriate since the movements required excursions in different planes and therefore utilized distinct strategies and muscle groups. This grouping is supported by the fact that over 70% of the individual values for movement time and path sway between AP and LAT targets had very low correlations ($r<0.30$).

The number of subjects required per group for multivariate statistics can be estimated by using a subject-to-variable ratio. Schutz and Gessaroli (1987) suggest that the following equation be used to determine the total number of subjects: $[p(k-1) + j]$, where p is the number of dependent variables in the analysis, k is the number of repeated measures, and j is the number of groups. The largest number of subjects would be required for the strength and self-perception analyses since each of these utilized five dependent variables. The total number of subjects based on the equation above would be seven. There were 18 and 22 women in the exercise and control groups, respectively, which should afford adequate statistical power.

Lastly, multiple stepwise regression analyses were conducted to identify independent predictors of significant change in balance measures. It has been proposed in cross-sectional studies that strength and power are important for balance and that these factors contribute to the risk of falling. To determine if these elements confer balance improvements in an intervention setting, percent change in strength and power were added to the stepwise regression as independent variables while percent change in lateral movement time, path sway, and maximal left lateral LOS were the dependent variables in separate analyses. The independent variables were only those strength and power measures that exhibited significant time by group interactions demonstrating a training effect.

RESULTS

Baseline characteristics of participants were very similar with the exceptions of body weight, composition, and estrogen use. Mean baseline characteristics (±SD) are outlined in Table 3. The difference in body composition was attributed to higher fat mass in the exercise group since there was no difference in whole body lean mass. The number of estrogen users was higher in the control group than in the exercise group. There were no differences in lumbar spine (Lu) or femoral neck (Fn) BMD, age, years postmenopause (PM), average hours of weight bearing (WB) activity, or past year calcium intake. Strength, power, balance, and psychological measures were comparable at the onset of the study.

Table 3. Baseline Characteristics

	CONTROL n=22	EXERCISE n=18
Age (yrs)	62.5 (6.6)	64.2 (5.8)
Years PM	12.0 (6.1)	14.1 (5.7)
Height (cm)	162.9 (4.9)	164.8 (7.2)
Weight (kg)	63.7 (7.7)	70.2 (11.3)*
Body Composition (%)	28.6 (4.5)	33.3 (6.6)*
Lean Mass (kg)	43.3 (4.3)	44.2 (5.6)
Fat Mass (kg)	18.4 (4.8)	23.8 (7.6)*
LuBMD (g/cm^2)	.871 (.126)	.893 (.100)
FnBMD (g/cm^2)	.651 (.083)	.683 (.062)
W-B Activity (hr/wk)	4.4 (2.9)	4.1 (3.6)
Calcium (mg/d)	895.7 (478)	900.4 (367)
Number on Estrogen	7	1

* exercise higher than control $p<0.05$

Training Program

Average attendance (adherence) to the training program was 80.7% with a range of 63.4 to 94.6%. Four of the original participants discontinued involvement in the exercise group resulting in a compliance rate of 82%. Two women terminated participation within the first 3 months due to the time commitment associated with the training. The other two women left due to knee strain at months 5 and 6. Both had knee pain prior to entry into the program and the combination of exercises and progression increased symptomology. No injuries resulted directly from the training.

Physical activity completed outside of the exercise program was analyzed in combination with activity completed within the training intervention. At the onset of the study, the exercise group averaged 4.1 hrs/wk of weight-bearing exercise vs an average of 4.4 hrs/wk at the end of the 9-month trial ($p>0.05$). Participants were asked to maintain activity levels such that the intervention would have an additive effect. Assuming that activity logs were accurately maintained, it is apparent that many replaced previous exercise with the intervention program.

Control Follow-Up

Control participants were reminded at testing appointments to keep physical activity and diet as consistent as possible with recent past habits. Physical activity logs kept by control subjects confirmed that weight bearing exercise did not change over the course of the study (4.4 to 4.7 hrs/wk, $p>0.05$). The primary activities reported by controls were walking, hiking, gardening and miscellaneous yard work, golf, and tennis. Compliance among controls was 100%.

Body Composition

Body composition and weight changed in the exercise group, notably in the lower body where leg lean mass increased and leg fat mass decreased. Changes observed in the control group were not statistically significant. Mean (±SD) body composition for both groups at baseline and month 9 are presented in table 4.

Table 4. Body Composition at Baseline and Month 9

	CON BASE	CON M9	EX BASE	EX M9
Fat Mass (kg)				
Arms	2.3 (.6)	2.4 (.6)	2.6 (.7)	2.6 (.9)
Legs	7.9 (2.0)	7.9 (2.0)	10.1 (2.8)	9.5 (3.1)[2]
Trunk	7.4 (2.8)	7.4 (2.6)	10.2 (4.6)	9.4 (5.0)[1]
Whole	18.4 (4.8)	18.5 (4.6)	23.8 (7.6)	22.3 (8.5)[1]
Lean Mass (kg)				
Arms	3.8 (.5)	3.9 (.6)	3.9 (.6)	3.9 (.6)
Legs	12.6 (1.3)	12.8 (1.4)	12.9 (1.7)	13.4 (1.8)[1]
Trunk	23.6 (2.5)	23.5 (2.6)	24.1 (3.4)	23.8 (3.1)
Whole	43.3 (4.3)	43.4 (4.5)	44.2 (5.6)	44.3 (5.4)
Percent Fat	28.6 (4.5)	28.5 (4.4)	33.3 (6.6)	31.6 (7.1)[2]
Body Weight	63.7 (7.7)	63.9 (8.0)	70.2 (11.3)	68.7 (12.2)[1]

[1] Significantly different at month 9, $p<0.05$
[2] Significantly different at month 9, $p<0.01$

Bone Mineral Density

Bone mineral density in both groups was very close to the aged-matched mean for the spine and hip at the onset of the study. Results of repeated measures ANOVAs revealed no significant changes in BMD at the spine or hip in either the exercise or control group after the 9-month trial. Therefore, the first null hypothesis which stated there would be no changes in BMD with the exercise intervention was not rejected. There was a trend, however, for the exercisers to increase and the controls to decrease, particularly at the spine. The percent change (±SD) from baseline to month 9 and values as a percent of normals at baseline for LuBMD and FnBMD by group and estrogen status are presented in

Table 5. Values of LuBMD and FnBMD in g/cm^2 for baseline, month 6 and month 9 are presented in Appendix Table A.

Table 5. Percent Change in Bone Mineral Density from Baseline to Month 9 and Percent of Normals at Baseline Only

	CONTROL	EXERCISE
FnBMD		
All		
% Change	-.063 (3.263)	.173 (2.861)
% Normals	91.8 (11.0)	97.4 (7.6)
	n=22	n=18
No Estrogen		
% Change	.275 (3.487)	.008 (2.859)
% Normals	92.2 (12.7)	97.1 (7.7)
	n=15	n=17
LuBMD		
All		
% Change	-.275 (3.463)	.515 (2.889)
% Normals	97.3 (11.6)	101.2 (11.0)
	n=15	n=16
No Estrogen		
% Change	-1.002 (3.909)	.466 (2.983)
% Normals	100.2 (9.8)	101.7 (11.1)
	n=9	n=15

Strength

The repeated measures MMM MANOVA for strength revealed a significant group by time interaction (F_m=6.43, p=0.0003). Univariate follow-up analyses generated for each dependent variable revealed that hip abduction, knee extension, and ankle plantar flexion accounted for the significant strength increases attributable to the training program. The second null hypothesis which stated that no difference in strength would be observed with exercise training was rejected. The exercise group experienced a 30.3% increase in hip abduction (range=0-110%), a 16.6% increase in knee flexion (range=0-56%), and a 33.3% increase in ankle plantar flexion (range=2-81%). There were no observable changes in strength for hip adduction or ankle dorsiflexion. The control group exhibited no increase in any of the five strength measures beyond the coefficient of variation for each test. Mean strength in kilograms of force (±SD) for the exercise (EX) and control (CON) groups at baseline (BASE) and month 9 (M9) are presented in Table 6. Mean strength values for baseline, month 3, month 6, and month 9 are presented in Appendix Table B.

Table 6. Strength at Baseline and Month 9

	CON BASE	CON M9	EX BASE	EX M9
Hip AB (kg)	29.1 (4.9)	31.0 (6.0)	26.4 (6.8)	32.9[2] (4.1)
Hip AD (kg)	22.5 (5.9)	21.9 (4.3)	23.0 (5.0)	23.9 (5.3)
Knee Ext (kg)	41.6 (8.0)	43.3 (6.7)	41.9 (6.7)	48.5[1] (8.2)
P Flex (kg)	23.1 (5.7)	24.3 (6.2)	26.0 (4.3)	34.3[3] (5.7)
D Flex (kg)	15.5 (3.0)	15.7 (3.1)	16.1 (3.7)	17.3 (3.8)

[1] significantly different from control at month 9 p=0.01
[2] significantly different from control at month 9 p=0.003
[3] significantly different from control at month 9 p=0.0001

Balance

Results of the univariate analyses indicated that there were no changes in static balance (sensory organization test, SOT) in either group after the intervention or 9-month follow-up (p>0.05, Figure 1). There was a significant surface by vision interaction across groups which was expected. This indicates that the most body sway detected during the SOT was in the eyes-closed swayed-surface condition (Figure 2).

Figure 1. Static Balance Across Test Conditions at Baseline and Month 9

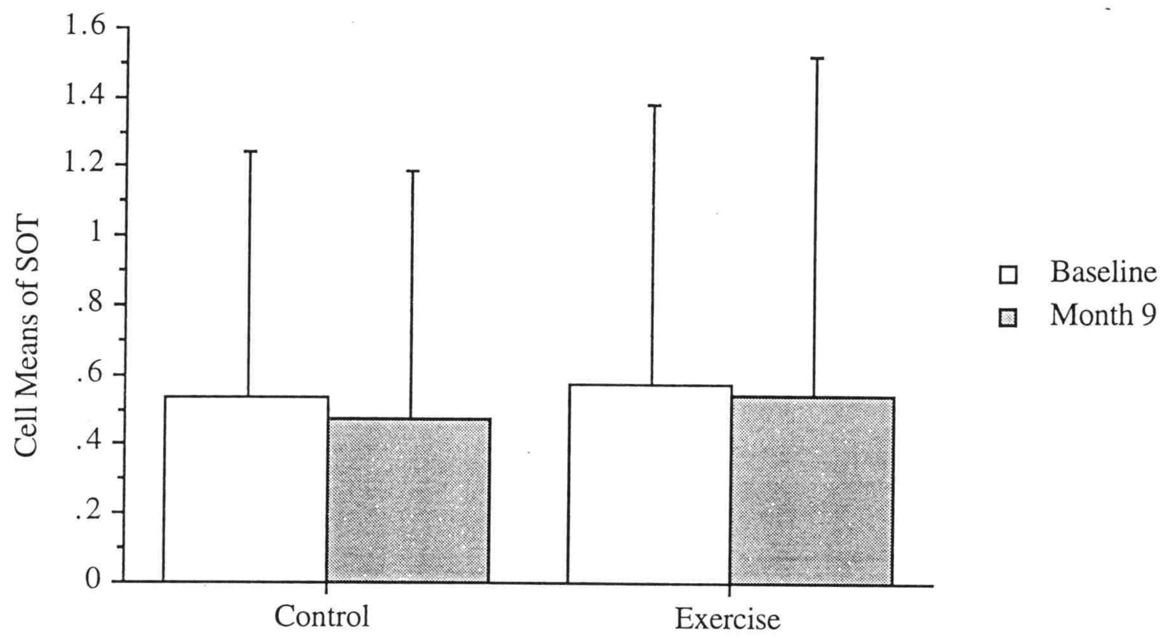
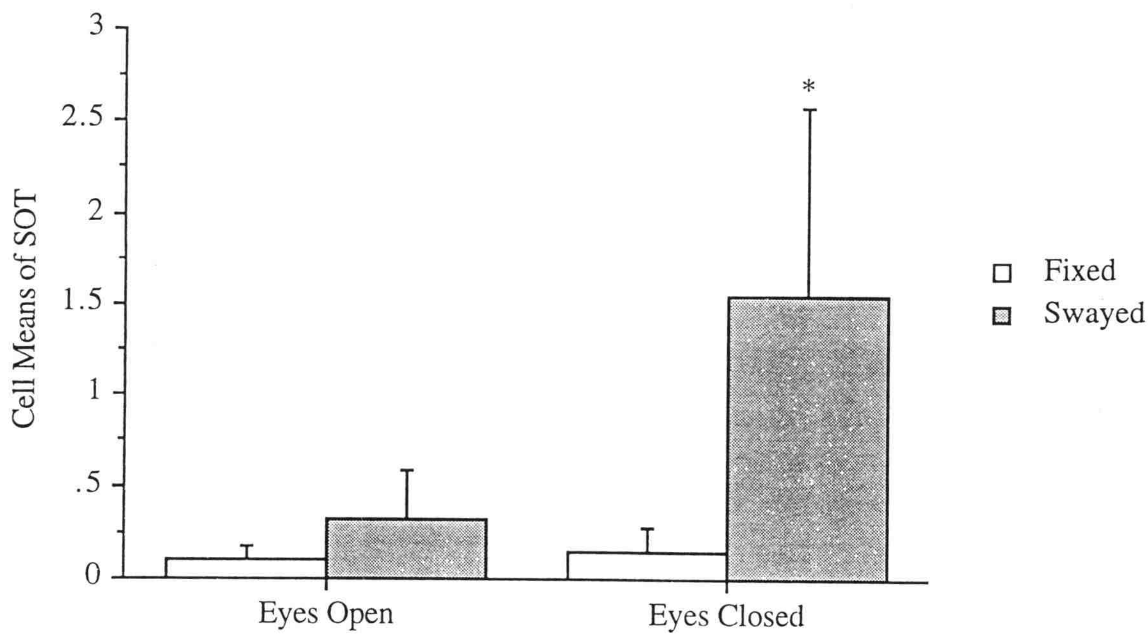


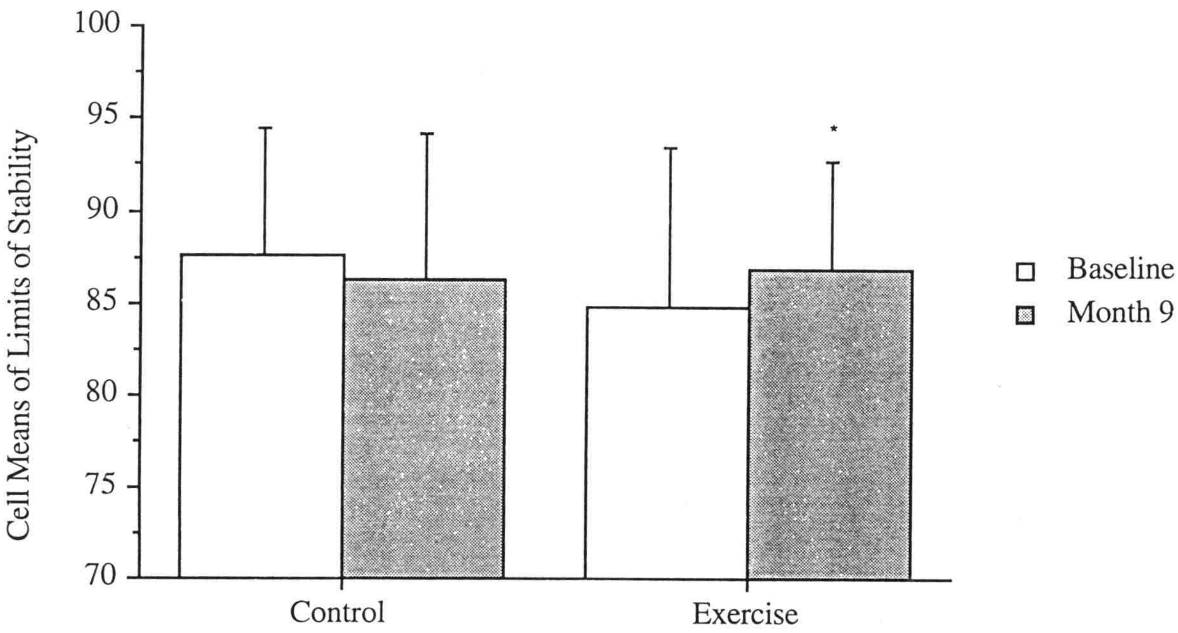
Figure 2. Static Balance Across Groups for Vision and Surface Condition



*significantly greater than all other conditions p=0.0001

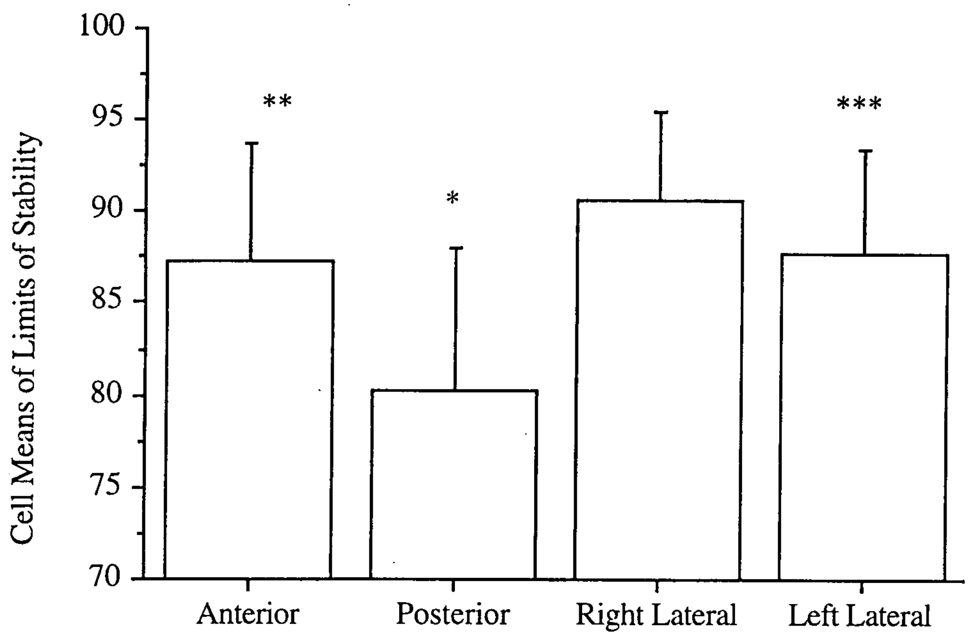
For maximal LOS, there was a significant time by group interaction. This result suggests that the women in the exercise group increased maximal LOS, while the women in the control group decreased maximal LOS, across all test directions (anterior, posterior, left or right lateral). Overall, maximal LOS in the control group decreased by 1.6% while in the exercise group it increased by 2.2% (Figure 3). In addition, there was a main effect for direction (Figure 4). Linear contrast analyses determined that for all participants, maximal LOS was lowest in the posterior direction, followed by the anterior and left lateral directions. Regardless of the group to which they were assigned, the participants in this study exhibited the greatest LOS in the right lateral direction.

Figure 3. Maximal LOS at Baseline and Month 9



*significantly different from control at month 9 p=0.0168

Figure 4. Maximal LOS Direction for All Participants



*significantly different than Anterior, Right, and Left Lateral p=0.0001
**significantly different than Right Lateral p=0.0013
***significantly different than Right Lateral p=0.0054

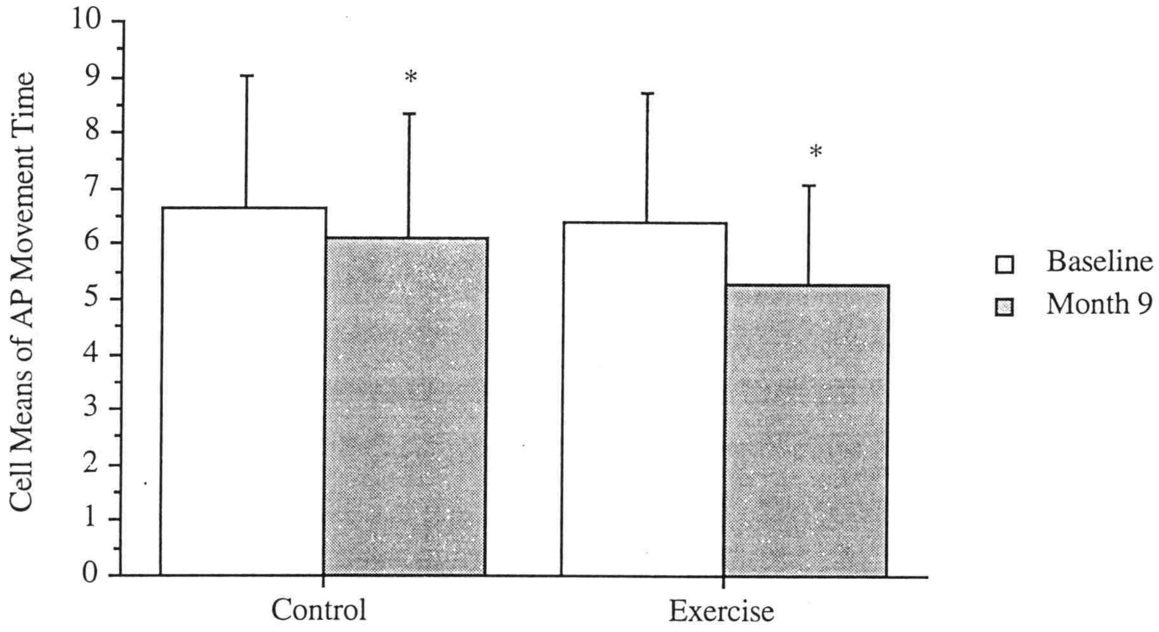
Results of the balance multivariate repeated measures analysis revealed a significant time by group interaction (F_m=3.466, p=0.0184). Univariate follow-up analyses indicated that AP movement time (MT) and LAT path sway (PS) contributed to the interaction (Table 7, Figures 5-8). In addition, there was a significant time effect across groups noted for AP MT, indicating that the exercise and control groups improved similarly on this measure. No significant changes were observed for PS in the LAT direction. These findings suggest that the women in the exercise group were able to move more quickly in the medial-lateral direction and more accurately in the anterior-posterior direction, as compared to the women in the control group after the 9-month trial. Both groups, however, improved in MT in the AP direction. The third null hypothesis, which stated there would be no significant change in balance measures associated with the training program was rejected.

Table 7. Anterior-Posterior and Lateral Movement Time and Path Sway at Baseline and Month 9

	CON BASE (n=20)	CON M9	EX BASE (n=17)	EX M9
AP MT (sec)	6.7 (2.4)	6.1[1] (2.2)	6.4 (2.3)	5.3[1] (1.8)
LAT MT (sec)	5.6 (1.7)	5.7 (2.4)	5.9 (1.6)	4.6[2] (1.2)
AP PS (%path length)	273.6 (31.7)	283.9 (25.0)	314.7 (56.3)	290.9[3] (35.3)
LAT PS (%path length)	335.3 (55.9)	329.6 (82.7)	370.5 (115.4)	334.2 (70.9)

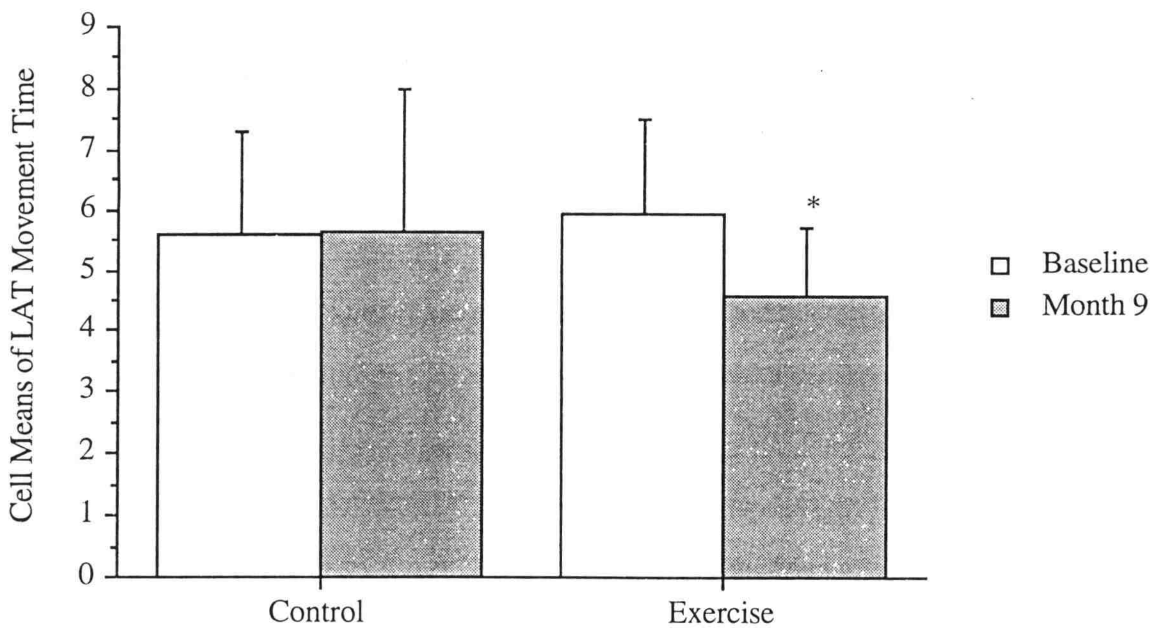
[1]significantly different from baseline at month 9 $p=0.0412$
[2]significantly different from control at month 9 $p=0.0034$
[3]significantly different from control at month 9 $p=0.0124$

Figure 5. Anterior-Posterior Movement Time at Baseline and Month 9



*significantly different from baseline p=0.0412

Figure 6. Lateral Movement Time at Baseline and Month 9



*significantly different from control at month 9 p=0.0034

Figure 7. Anterior-Posterior Path Sway at Baseline and Month 9

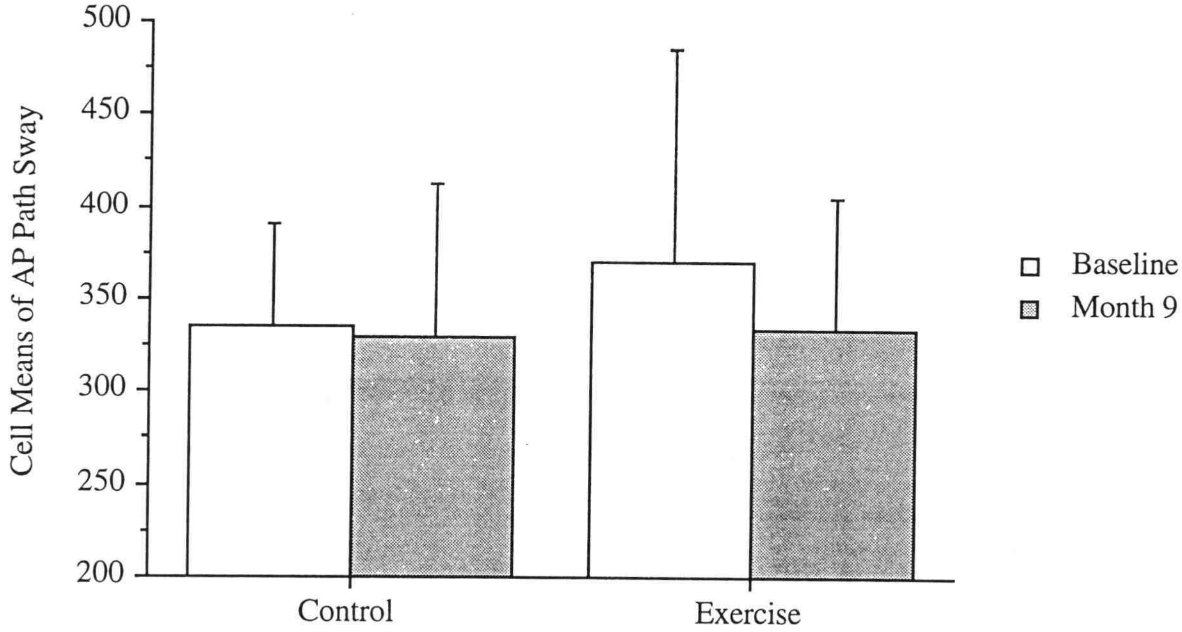
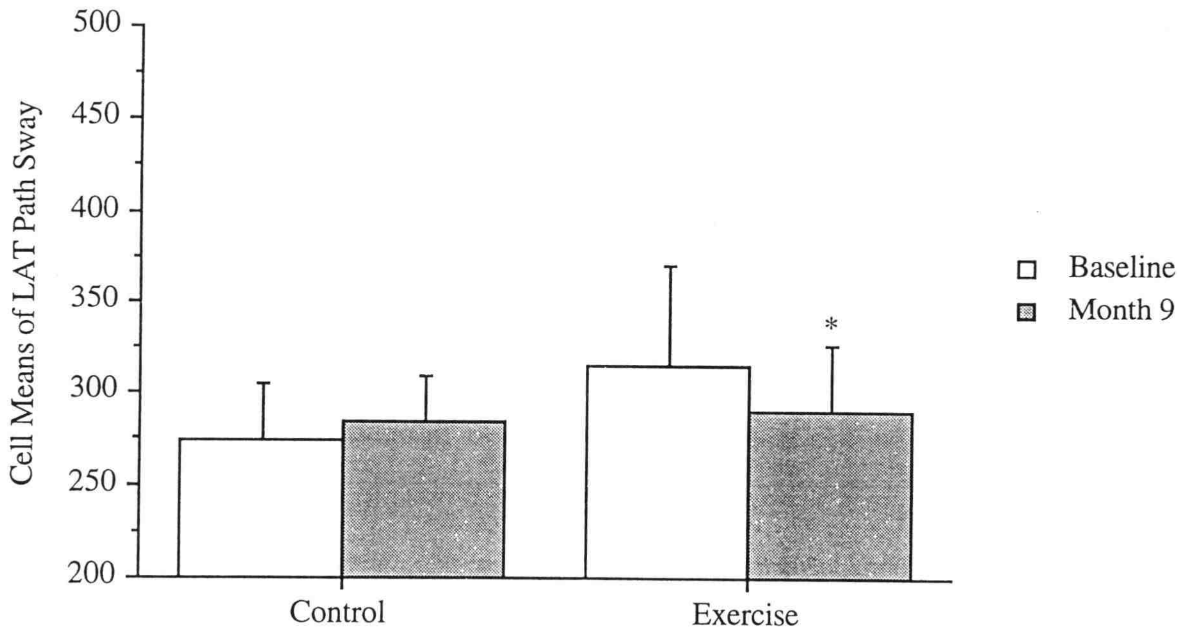


Figure 8. Lateral Path Sway at Baseline and Month 9



* significantly different from control at month 9, p=0.0124

In multiple stepwise regression analyses, independent predictors of change in dynamic balance indices were determined. Percent change in LAT MT (-20% vs +.04%, p=0.0054) and LAT PS (-6% vs +4.5%, p=0.0113) was found to be significantly different in exercisers versus controls. Percent change in hip abductor strength was the only independent predictor of LAT MT (R=.352, p=0.0328). The only predictor of LAT PS was maximum power (watts/kg), which accounted for approximately 20% of the variance (p=0.0049). The regression equations for percent change in LAT MT and LAT PS are displayed in Figures 9 and 10, respectively. Complete mean values for all balance data (±SD) at baseline, months 3, 6, and 9 can be found in Appendix Table C.

Figure 9. Percent Change in Lateral Movement Time vs Percent Change in Hip Abductor Strength

% Change LAT MT = -3.924 - .313 (% Change Hip Abductor Strength); R^2=.124

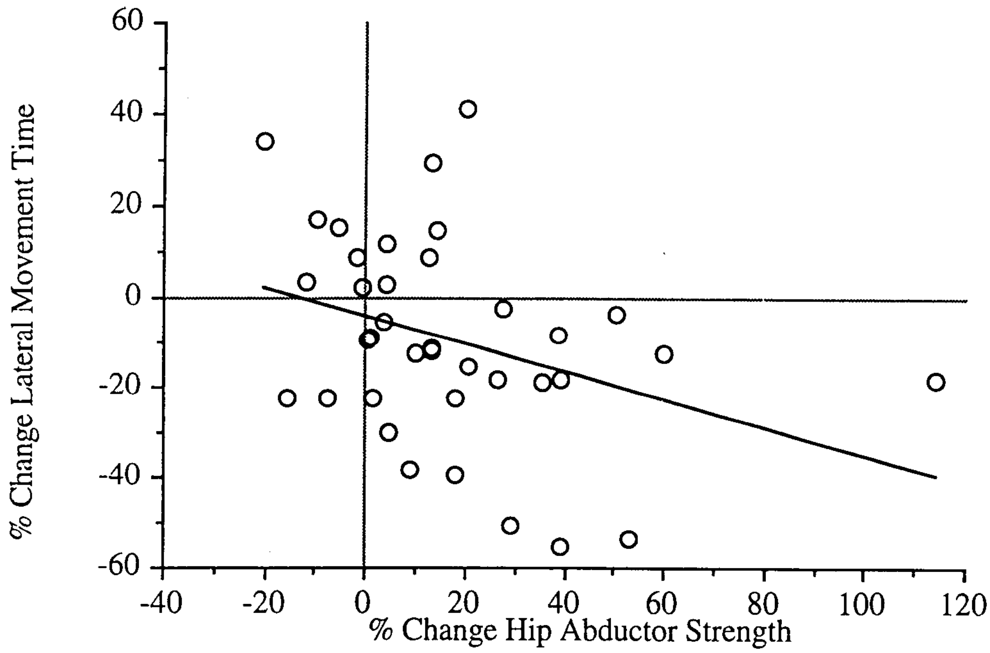
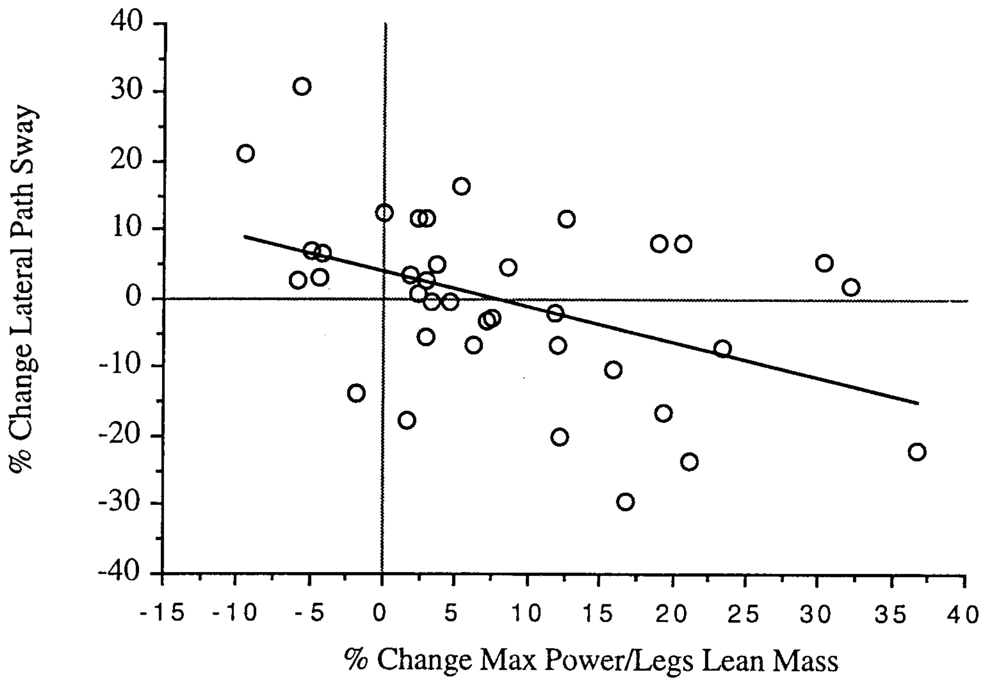


Figure 10. Percent Change in Lateral Path Sway vs Percent Change in Maximum Power

% Change LAT PS = 4.081 - .521 (% Change Max Power); R^2 = .205



Power

Maximum power (watts/kg leg lean mass) increased significantly in the exercise group, but not in the control group after the 9-month study period. The exercise group exhibited a 13% increase in power, even when corrected for the 3.5% increase in leg lean mass (p=0.02). Power did not change in the control group. The fourth null hypothesis, which stated there would be no significant difference in power associated with the exercise training, was therefore rejected. Mean values (±SD) for both groups at baseline and month 9 are presented in Table 7. Complete mean values for maximum power (±SD) at baseline, months 3, 6, and 9 can be found in Appendix Table D.

Table 8. Maximum Power at Baseline and Month 9

	CON BASE	CON M9	EX BASE	EX M9
Watts/kg	23.4 (4.7)	24.2 (4.7)	22.5 (4.7)	25.1* (4.1)

*Significantly different from control at month 9, p=0.009

Self-Concept

Multivariate repeated measures analyses conducted on both importance-weighted and non-weighted self-concept subscales yielded the same findings, therefore only those from the weighted subscales are reported. Results revealed a significant time effect for self-concept after the 9-month intervention and follow-up period (F_m=3.336, p=0.0147). The interaction, however, was not significant, which indicates that self-conceptions in the exercise group did not change in a different manner from those in the control group. These data indicate a failure to reject the fifth null hypothesis, which stated there would be no difference in self-conceptions after the 9-month trial between the groups. The univariate follow-up analyses suggest that the only dependent variable which contributed to this time effect was the attractive body subscale (p=0.002). The whole group improved their conceptions of the extent to which they described their bodies as attractive. The results of this finding (mean±SD) are displayed in Table 8.

Physical self-worth was highly correlated with the attractive body subscale. A separate univariate repeated measures ANOVA was conducted to determine if the results for that measure were similar to those for attractive body. This analysis replicated the attractive body findings (significant time effect, F=11.2, p=0.0019). To corroborate the redundancy of the attractive body and physical self-worth findings, regression analyses determined that over 60% of the variance in physical self-worth was explained by the attractive body subscale (R=.780, p=0.0001). In addition, percent change in attractive body was the only predictor (compared to the other self-concept subscales) of percent change in physical self-worth (R=.498, p=0.0011). Complete data for all self-conceptions at baseline, month 3, 6, and 9 can be found in Appendix Table E.

Table 9. Attractive Body Subdomain of Physical Self-Concept at Baseline and Month 9

	CON BASE	CON M9	EX BASE	EX M9
Attractive Body	6.8 (3.2)	7.1* (3.6)	5.9 (2.7)	7.0* (3.2)

*significantly different from baseline p=0.002

To determine if high initial values contributed to the lack of effect on self-concept, repeated measures MANOVAs were performed for those with high or low global self-esteem. Low global self-esteem was operationalized as a score below the mean value of 3.4, while high global self-esteem was a score greater than or equal to 3.4. For the low self-esteem subgroup, there was a significant time by group interaction for the attractive body subscale (p=0.0245). The results indicate that those in the exercise group with low global self-esteem increased on the attractive body subscale while controls remained the same. For the high self-esteem subgroup, there was a significant time effect across groups (p=0.0277). This was the same result as that for the group as a whole, in that the exercise program failed to produce a unique effect.

Multiple stepwise regression analysis was conducted to determine independent predictor(s) of change in attractive body. The predictor variables entered into the model were percent change for all strength measures (entered as a sum of change in plantar flexion, change in hip abduction, and change in knee extension), maximal leg power, leg lean mass, and leg fat mass. The only independent predictor of change in this model was change in leg fat mass. This analysis was conducted with and without the presence of one major outlying score. With the outlier in the analysis, 14.4% of the change in attractive body was explained by change in fat mass of the legs (R=-.379; p=0.0158). The analysis conducted without the outlier resulted in 29.6% of the variance accounted for by change in fat mass of the legs (R=-.544; p=0.0003). Regression equations and graphs for each analysis with and with the outlier are depicted in Figures 11 and 12.

Figure 11: Percent Change in Attractive Body vs Percent Change in Fat Mass of the Legs (with outlier score)

% Change Attractive Body = 10.541 - .379 (% Change Leg Fat Mass); $R^2 = .144$

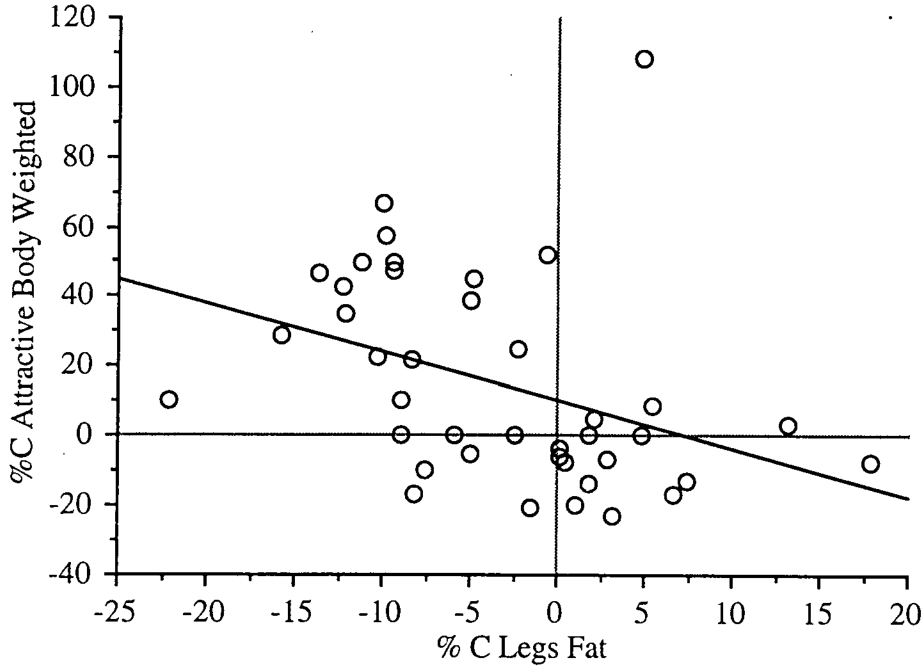
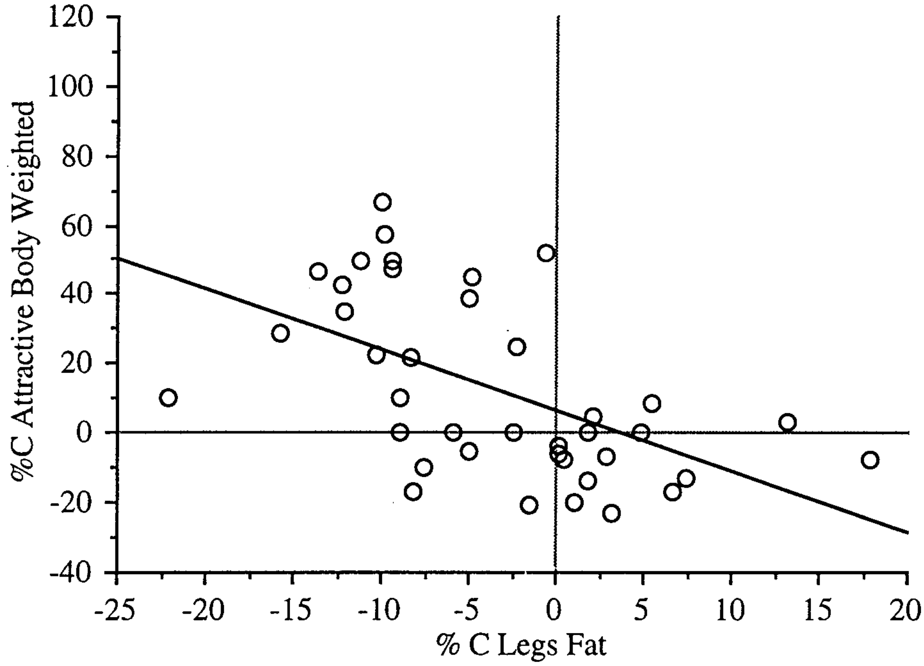


Figure 12: Percent Change in Attractive Body vs Percent Change in Fat Mass of the Legs (outlier removed from analysis)

% Change Attractive Body = 6.630 - .544 (% Change Leg Fat Mass); R^2 = .296



Affect

Results of multivariate repeated measures analysis suggest that there was no change in positive or negative affect in either group (p>0.05, Figures 13 and 14). The sixth null hypothesis stated there would be an increase in positive affect and a decrease in negative affect in the exercise group, but not in the control group after the study period. Because there were no differences in either affect measure, this hypothesis was not rejected. Complete mean values for affect (±SD) at baseline, months 3, 6, and 9 can be found in Appendix Table F.

Figure 13. Positive Affect at Baseline and Month 9

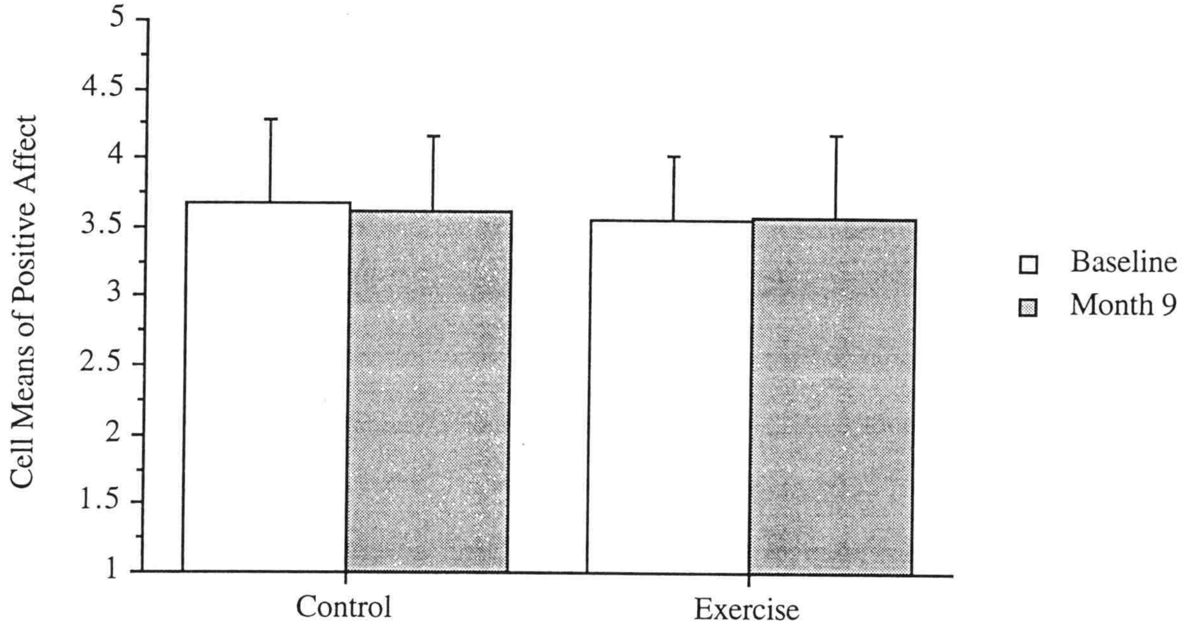
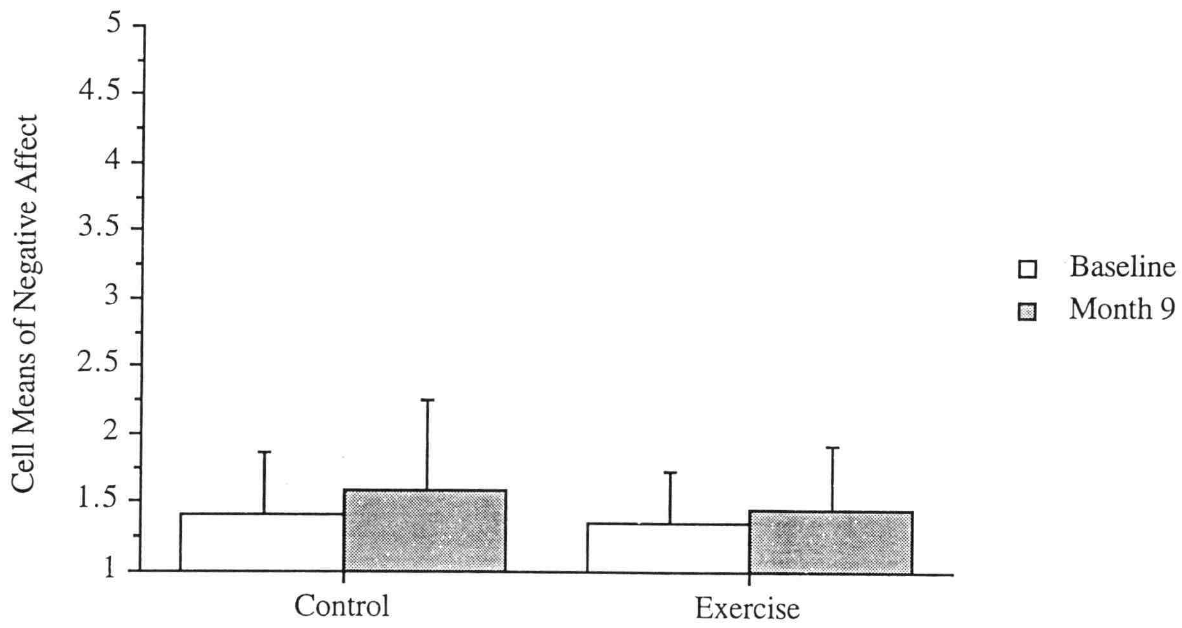


Figure 14. Negative Affect at Baseline and Month 9



DISCUSSION

The purpose of this study was determine if a 9-month resistance training intervention would decrease multiple indices of fracture risk and improve self-concept and affect in a group of healthy, community-dwelling, postmenopausal women. The findings indicate that the program was successful with respect to decreasing fracture risk, but not so for improving self-conceptions and mood state. The exercise group exhibited improvements in lower body strength and power, and dynamic balance, which are all factors associated with the risk of falling. Although a trend was observed for bone mass to increase in the exercise group and decrease in the control group, this finding did not achieve statistical significance.

Subject compliance and adherence to the training intervention was comparable to other published reports among this age group (Pruitt, et al., 1992, Nelson, et al., 1994). Absences were a result of illness, occasional conflict with personal schedule, or vacation. Compliance was much higher than would be anticipated for a general, non-research oriented, supervised exercise program, in which attrition rates are typically 45% (Dishman, 1988). Although age would seem to be a contributor to participation characteristics, this has not been confirmed in the exercise adherence literature (Dishman, Sallis, & Orenstein, 1985). Therefore, it is likely that compliance and adherence were enhanced since the participants had a personal stake in the subject matter being investigated. In addition, those in the control group were given the opportunity to participate after completion of the 9-month trial.

Increasing BMD via mechanical loading requires that the forces applied to bone be substantially higher from that experienced during activities of daily living. The specific exercise included in the intervention which likely imposed the greatest loading was jumping. However, jumping was not added until the fourth month of the program, and this may be one reason why improvements in bone mass were not observed. Bassey et al.

(1994) demonstrated increases in BMD at the hip in premenopausal women who participated in a six-month aerobic dance program plus a home jumping regimen. Participants performed 50 jumps per day, three days per week. Jumps were performed in place without shoes. Those who participated in the same aerobic dance program but who performed upper body exercises at home, did not exhibit any improvement in hip BMD. Participants in the present study began jumping only once per session and progressed up to 28 per session. Half of the jumps were performed in place, while the others involved jumping off a raised surface. The primary differences between the studies are that Bassey's group performed more jumps, the jumps were performed without shoes, and the women were estrogen replete. Further investigation will determine if adding more jumps will realize bone mass improvements in postmenopausal women not on hormone replacement.

The spine appeared to be more responsive to the exercise program as compared to the hip. This has been reported in previous studies (i.e., Pruitt et al., 1992, Snow-Harter, 1992). The jumping exercises may have provided the greatest stress at the hip, while the others (squats, lunges, stepping, etc.) may have loaded the spine, particularly since these exercises were performed while wearing the weighted vest. Anatomically, the spine experiences less mechanical loading than the hip, which may explain why it may be more responsive to additional loads. However, in the present study, the improvements observed did not reach statistical significance. The exercise progression was fairly conservative, given the paucity of research on free-weight training in this population and the relatively new approach taken (i.e., additional loading based on a percentage of body weight). It is plausible that the intensity necessary to achieve significant and meaningful changes was reached toward the middle of the program. Perhaps if the program were extended, the trend observed for an increase in spine BMD would have been significant.

Another factor to consider with respect to the lack of BMD changes is the initial level of activity. At the onset of the program, the average amount of weight-bearing activity for the whole group was approximately 4.5 hours per week. The exercises may have made more of an influence on bone if the participants were less active. Nelson et al. (1994) observed significant increases in BMD at the spine and hip in estrogen-deplete postmenopausal women after one year of weight training. The program involved two supervised training sessions per week on pneumatic resistance machines. The participants in this program were minimally active prior to the onset of the study. In addition, Dalsky et al. (1986) demonstrated improvement in spine mineral content after a walk to jog program that also included calisthenics and rowing. The subjects in Dalsky's program were previously sedentary. The participants in the present study were different from those in Nelson et al. and Dalsky et al., in that they were not sedentary. Hence, the initial level of mechanical loading likely influenced the magnitude of response to the present intervention program. In addition, it appears from the activity data as though the exercise group replaced previous exercise with the intervention, potentially due to the time requirements of the program. The intervention was therefore not an additive component to the exercise group's loading regime.

Estrogen status did not affect the statistical outcome of the BMD results at either bone site. The spine, however, appeared to be more sensitive to estrogen status. Four of the six controls who demonstrated >1% increase in spine BMD after the 9-month trial were on estrogen replacement. On the other hand, four controls who were estrogen-replaced exhibited a >1% decrease in BMD at the femoral neck and two demonstrated similar decreases at the lumbar spine. Two controls had remarkable increases (6-7.5%) in bone mass at the hip. One gained approximately 6.8 kg over the course of the study, while the other had no change in physical characteristics, activity, or nutritional habits. Neither were estrogen-replaced. Without these values in the group data, percent change in BMD at the hip in non-estrogen replaced controls is negative (-.77%). These findings are somewhat unexpected given the demonstrated anti-resorptive effects of estrogen replacement (Ettinger, Genant, & Cann, 1987 and Christiansen, 1981). However, most of the published reports on hormone replacement in postmenopausal women have focussed on the spine and radius (i. e., Christiansen, 1981 and Lindsay, Hart, Forrest, & Baird, 1980). Thus, effects at the hip are not well-documented. Activity levels of both groups remained high during the course of the study (~4.5 hrs/wk), and this may be one reason why the controls did not exhibit significant declines. In addition, past year calcium intake was similar between groups and since the participants were reminded to maintain nutritional habits throughout the study, there is no reason to believe this influenced the BMD results. Calcium intake was above the RDA for adults (800 mg/d) yet below the recommended levels proposed by the National Osteoporosis Foundation (12-1500 mg/d, Peck et al., 1987).

Although the intervention did not induce changes in bone mass, the strength, power, body composition, and balance changes are indicative of a training effect. Strength improvements were only noted for three of five muscle groups. The ankle dorsiflexors were a target muscle group due to their importance in balance. This is a difficult muscle group to isolate in training, and although the participants routinely rocked back onto their heels, lifting their toes off the floor, this motion involved no additional loading. This is most likely why that muscle group was not altered with training. On the other hand, hip adductor strength might have increased, yet the effect may not have been detected by the assessment protocol. The pad attached to the lever arm for that assessment was quite narrow and irritated the leg being tested. Consequently, several participants complained that the test caused pain at the site where the pad came in contact with the leg (just proximal to the knee on the inner thigh). It is possible that participants did not provide a maximal effort during the test. All squats and chair raises were performed in a wide, toe-out stance, which engaged the hip musculature more than a narrow, straight stance. Changes in hip adductor strength were therefore expected.

Knee extensor, hip abductor, and ankle plantar flexor strength exhibited significant increases of 16.6%, 30.3%, and 33.2%, respectively. These improvements were likely a combined result of improved neural mechanisms muscular hypertrophy. Lean mass of the legs increased 3.5% in the exercise group, which was beyond the 1.5% CV for regional soft-tissue assessment of in-house DXA equipment. Hypertrophy of type I and type II muscle fibers in response to resistance training in older adults has been documented by muscle biopsy (Charette, et al., 1991, Pyka, et al., 1994). Type IIB muscle fibers are associated with strength and power, and these fibers appear to be selectively lost with aging (Aniansson, et al., 1993). Perhaps these fibers exhibited hypertrophy in response to the training, which would result in greater muscle mass. Fiatarone, et al. (1990) attributed much of the strength gain in nursing home residents engaged in high intensity lower body training to hypertrophy based on CT scan results. In the present study, however, only 10-14% of the variance in strength change can be explained by the increase in leg lean mass. This indicates that neural factors played a large role in the contribution to strength gains in the exercised women.

The strength improvements in the present study were reasonable, considering the high initial values of the group, type of overload during training and method of strength assessment. Much higher changes in strength with long-term training in older women have been reported most likely due to the fact that the same testing equipment was used for training (e.g., Nelson, et al., 1994, Pyka, et al., 1994). Nelson and colleagues (1994) demonstrated a 72.4% increase in knee extensor strength after one year of training on pneumatic resistance machines. Strength was assessed using the 1RM (repetition maximum) method on the same equipment used for training. In a machine-based program, muscles are isolated in a non-weight-bearing fashion. This facilitates exercise progression since other joints (e.g., ankle, hip) are not involved and it does not require the individual to overcome the resistance of body weight. The trained participant becomes more familiar with the equipment during exercise sessions and more skilled at performing the task during testing sessions, placing those in the training group at an advantage. In addition, the participants in Nelson's group were not active at the onset of the study. Their baseline values were probably much lower than those in the current study. It is difficult to compare initial values since the current study employed isokinetic dynamometry vs 1RM testing to quantify peak force.

Pyka and coworkers (1994) employed a machine-based training system and the 1RM method for strength determination. After one year of training, knee extension strength increased by 95.4%, and hip abductor strength increased by 91.4%. The participants prior to the onset of training were either sedentary or moderately active. Again, the same equipment was used for both testing and training. It is interesting to note that strength increased rapidly at the beginning of training, yet demonstrated a plateau effect after approximately three months. There was little difference between strength values at month three than at the conclusion of the program. In the present study, isokinetic strength improvements were observed after jumping was added to the intervention and the amount of weight in the vest was between 10-15% of body weight. This is indicative of the high initial level of fitness of the participants and the overload necessary to observe strength gains. The power necessary for jumping was probably instrumental in facilitating the neural component of strength development. In addition, this may have contributed to increased lean mass due to eccentric loading.

The work of Agre et al. (1994) is similar to the present study in that the testing protocol was different from the training stimulus and the program utilized weight-bearing forces. Moderate improvements (9-20%) in upper and lower body strength were observed in older women (mean age=71y) who engaged in 25 weeks of low impact aerobics. Some participants performed the exercise sessions while wearing ankle and wrist weights, although this did not affect the strength outcomes. Peak force was assessed by isokinetic dynamometry. Improvements were noted for knee flexors but not for knee extensors, as in the present study. Since this program emphasized endurance and activation of type I muscle fibers, it is not surprising that strength gains were moderate. The lack of change in knee extensor strength was probably due to insufficient overload of the type II muscle fibers.

One of the key ideas of the present intervention design was to create a regimen which would transfer to activities of daily living. Rising from a chair is frequently cited as a difficult task for older individuals (Weiner et al., 1993). Time to rise from a chair is therefore used as a test of function in older adults (Fiatarone et al., 1990 & Judge et al., 1994) and it has been highly correlated with quadriceps strength (Fiatarone et al., 1990). The intervention trial of Judge et al. (1994) demonstrated 13 - 21% increases in lower body strength over three months in elderly adults (mean age=80y), yet there was little clinical relevance to these improvements. Time to rise from a chair and gait speed were not altered with the training program. Chair rise time would not have been an appropriate assessment in the current study since one of the exercises involved standing from a seated position multiple times and those in the exercise group would have been at a distinct advantage. However, the functional specificity of the training was noticed by the participants based on their anecdotal comments. They frequently reported how much easier it was to climb stairs, to stand from a seated position, to get out of a tent while camping, or to hike in the mountains. Inclusion of function-based exercises was a strength of this study.

Leg power increases in the trained group were similar to the strength results and were probably a result of the same basic mechanisms, i.e., improved neural components increased leg lean mass. At baseline, leg power was correlated with leg lean mass (r=0.60), so it was important to take this into consideration, given the increase in leg lean mass in the trained group. However, lean mass increases only accounted for 7.5 - 8% of the variance in power changes. Once again, the neural adaptation to the training appears to have made a major impact on the physiological outcomes of the training regimen.

There are no published reports of leg power changes assessed by the WAPT with an exercise intervention in older adults. The only WAPT data on older individuals is that associated with the reliability of the test protocol (Bar-Or, 1987). Muscle power is clearly an important measure to assess given that it has been distinguished as determinant of falling (Whipple, et al., 1987). Tests of functional power have been evaluated, such as gait speed and time to rise from a chair. As mentioned previously, neither of these improved after three months of either a resistance training program or a combined resistance and balance training program in elderly males and females (Judge, et al., 1994). Fiatarone, et al. (1990) demonstrated 48% improvement in tandem gait speed after 8 weeks of resistance training in nursing home residents. Habitual level of function did not change, however, during the course of the short-term intervention. Participants in one intervention utilizing rubber tubing to increase strength, exhibited slower gait velocity after 12 weeks of home training (Topp, et al., 1993). It is difficult at best to compare these results to the present study due to the major differences in assessment techniques.

The primary changes in balance were demonstrated in dynamic movements in the lateral directions. The findings indicate that the exercisers gained more control and could move more quickly in the frontal plane. This has clinical meaning given that fall severity is greatest when one falls directly to the side and lands on the greater trochanter (Hayes, et al., 1993 & Greenspan, et al., 1994). Stepwise regression analyses revealed that hip abductor strength and maximal leg power were independent predictors of lateral movement time and lateral path sway, respectively. Given that only 12.5 - 20.5% of the variance in balance changes were explained by these models, some other mechanisms not assessed contributed to these improvements. Nashner (1989) states that sensory input (e.g., visual, vestibular, and proprioceptive), integration of sensory information by the central nervous system, and appropriate musculoskeletal response are all essential mechanisms required for balance. Results of the static balance assessment (sensory organization test), which manipulated visual, vestibular, and proprioceptive input, revealed that no apparent sensory changes occurred with the training program. The regression models explained mechanisms that were likely involved in the musculoskeletal response, namely increases in hip abductor strength and leg power. Improvements in central nervous system integration are not well-explained. It is important to note that the balance assessment, compared to all others, had the greatest skill component. It is possible that participation in the training program helped the exercisers to "learn" the task better. For example, some of the exercises involved movements that were similar to the those utilized during the balance assessment. This is a necessary consideration, in light of the insufficient practice time allowed prior to testing sessions.

It is difficult to compare these findings with other reports of intervention-induced balance improvements since no other published studies has assessed balance on the ProBalance Master in conjunction with a long-term intervention. However, after 5 balance-specific intervention sessions on the ProBalance Master, young, healthy individuals (20-35y) demonstrated a 24% decrease in path sway and movement time, yet static balance was unaltered (Hamman, et al., 1992). Since the 24% change was considered a "true change" in ability, it is probable that the 20% decrease in lateral movement time in the present study is meaningful. The smaller change (-6%) in path sway is less convincing, although the lack of normative, longitudinal data makes it difficult to evaluate. Maximal limits of stability were generally greater in the exercisers at the end of the current study, although it is not known what clinical relevance that may have, especially given that the improvements observed were quite small.

Most research investigating changes in balance has utilized more functional tests of balance, such as tandem gait speed, or tests of static balance, such as a timed single leg stance or double leg postural sway. Nelson, et al. (1994) described a 14.3% decrease in backward tandem walk time in older, trained women, which they claimed demonstrated an improvement in dynamic balance. As reported earlier, nursing home residents exhibited a 48% decrease in maximal (forward) tandem gait speed. Static balance, assessed by double stance postural sway, was not affected by six months of tai chi exercises plus walking or machine-based resistance training in older women (Judge et al., 1993). The lack of change in static balance in the present study or in others does not seem surprising considering the dynamic nature of training programs. Perhaps dynamic balance is the preferred assessment technique when considering fall risk, especially given the importance of normal mobility in maintaining functional independence (Vandervoort, et al., 1990).

There were no differences in the psychological variables assessed over the course of the 9-month trial that could be attributed to the training intervention. Considering the baseline responses to the PSPP-A and PANAS questionnaires, it is probable that the lack of a unique response in the training group was due to a ceiling effect. This demonstrates the selection bias within the sample. In general, the participants were physically healthy and active at the onset of the study, which probably had some bearing on the presence and/or magnitude of the physiological outcomes of the intervention. The PANAS and PSPP-A data indicate that this bias extended to the psychological findings as well.

The range of possible scores for positive and negative affect was 1 - 5. Scores for negative affect never rose above 2 and those for positive affect never fell below 3. Generally speaking, both scores demonstrated remarkable stability as all participants exhibited low negative affect and moderate to high positive affect. Affect, or mood state, is often described as a state characteristic, which is considered malleable given various life circumstances. The emphasis in previous research on exercise-induced affect changes in older individuals has been in the area of depression. Physical exercise has been shown to decrease depression in this population (Uson & Larrosa, 1982), and this effect is logically limited to those who have been diagnosed with some form of mild to moderate depression at the onset of the intervention. However, given the negative affect scores in the present study, it is unlikely that participants were depressed. The results suggest that global affect was robust to the introduction of the training intervention, which was probably influenced by the participant's positive disposition. Another explanation to this finding may be that the measure was too global. Perhaps in future studies, affect should be measured with respect to participation in physical activity as opposed to life in general. This may prove to be a helpful strategy in future investigations, particularly in subject populations whose baseline level of affect is high.

The possible scores of the four self-concept subscales ranged from 1 - 16 and for global self-esteem from 1 - 4. The average value for global self-esteem across groups at baseline was 3.45. The baseline scores for the subscales of attractive body (5.7-6.5) and sports competence (3.6-4.2) were lower than physical function (13.3-14) and medical problems (11.9-13). This was the result of most participants describing themselves high on physical function and medical problems (meaning they did not rely heavily on medical care) in addition to rating these two self-concepts as very important. The increase in the attractive body subscale in both groups is interesting to note, yet difficult to explain in the control condition. It has been proposed and reported that "body concept" improves with weight training interventions, although this has not been addressed specifically in older women (Tucker, 1983, Berger & McInman, 1993). Two early studies in older adults demonstrated improvements in body image after relatively short interventions. Olson (1975) observed increases in body image in nursing home residents after 8 weeks of a low intensity program involving stretching and rhythmic breathing. Sidney and Shephard (1976) described similar findings for a somewhat younger group (mean age=66y) after a 14-week aerobic exercise program. The observed increase in the exercise group was therefore expected. Those in the control group, however, may have felt "special" for simply being a part of the research project and reported higher on this subscale as the study progressed or perhaps they reported unusually low at baseline. Given that physical activity patterns and measures of fitness did not change in the control group, it is unlikely that their sense of attractiveness was influenced via physical pathways. Perhaps in future studies, it would be helpful to introduce a separate control group which simply completes the PSPP-A to remove the effects physical testing and potentially influential feedback.

The exercise intervention was aimed particularly at improving physical function, and therefore the physical function and medical problems subscales were anticipated to change in addition to attractive body in the exercise group. However, the high initial values likely played a role in the lack of change therein. It is interesting to note that when the group as a whole was divided into high and low global self-esteem subgroups, the results of the repeated measures analysis was somewhat different. Only those in the exercise group demonstrated an increase in attractive body within the low self-esteem subgroup. However, in the high self-esteem subgroup, the result was the same as that for the whole group, a significant time effect for attractive body. In either subgroup, the attractive body subscale was still the only self-concept measure which demonstrated increases. This may indicate the need to use high self-concept as an exclusion criteria for future investigations.

It is important to view the findings of this study in light of its limitations. Selection bias, i.e., as demonstrated by initial levels of health, physical activity, and general disposition, has definitely played a role in the physiological and psychological outcomes of the study. Probably the major limitation was the nonrandom assignment to groups. Although baseline values were similar for most subject characteristics, it is still possible that some systematic error was factored into the results. This has been a consistent criticism of longitudinal research which is very difficult to avoid, especially in human subjects. There is a delicate balance between attention to research design and the necessity for statistical power, which is highly influenced by sample size. If a completely random design had been utilized in the present study, it would have been necessary to drop 11 participants from the study (4 that were automatically assigned to the control group for time conflict purposes and 7 that entered the study late), and proceed with a sample of 33. Assuming similar compliance, a total of 29 women would have been expected to complete the trial. This would have resulted in 5 fewer participants required to determine significant change in bone mass. In hindsight, this may have been the prudent choice to make. Since subject assignment was not random, the results will have to be considered with this shortcoming in mind. The control participants have since been phased into the exercise program and if they exhibit improvements similar to those observed in the original exercise group, this will provide further credence to these findings.

Future research in this area should take the aforementioned discussion points into consideration. With respect to group assignment, all efforts should be made to do so randomly prior to the beginning of the training program. This will allow for an optimal matching strategy, ensuring comparable groups at the onset of the study. Changes in the exercise program itself should include earlier introduction of jumping exercises to ensure optimal skeletal loading. The program itself should continue for a longer period of time, such as 18 to 24 months. To compliment the BMD results, urinary and serum measures of bone turnover (i.e., urinary pyridinoline cross-links and serum osteocalcin) sould be taken to confirm differences in bone remodeling between groups. More practice trials should be given prior to the balance assessment to ensure a true baseline is achieved and that all participants are sufficiently familiar with the apparatus and test protocol. With respect to psychological variables, global affect should be replaced by a measure specific to physical activity. Although it may be impractical, attempts should be made to use low to moderate self-concept as an inclusion criteria. In addition, a separate control group which only takes the psychological questionnaires would be helpful to deliniate natural changes in self-concept and affect over time in this population.

In conclusion, the intervention proved to be practical, appropriate, and beneficial with respect to decreasing fracture risk in postmenopausal women, even in those who are generally healthy, active, and fit. The exercises are easily adaptable to a home exercise program and require little equipment. Those in the exercise condition clearly enjoyed the program, from both a fitness and social perspective. The incidence of falls and hip fractures increases dramatically in women between the age of 70-75, and interventions such as this that target lifestyle behaviors may be especially important just prior to this stage of increased risk (Melton, 1993). In 1990, nearly 250,000 hip fractures occurred in the United States, which amounted to over 8 billion dollars in health care costs (Melton, 1993). Given that the population is aging and these figures are expected to increase, the preventive potential of programs such as presented in this study may decrease hip fractures as well as improve the quality of life in women as they grow older.

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APPENDICES

APPENDIX A

IRB PROPOSAL, CONSENT FORMS AND PHYSICIAN CLEARANCE FORM

EFFECTS OF RESISTANCE TRAINING ON FRACTURE RISK AND PSYCHOLOGICAL VARIABLES IN POST MENOPAUSAL WOMEN

1. Brief Project Description

As the general population grows older, it is important to understand the factors related to functional capacity of the elderly, and whether those factors can be altered (Brown, et al, 1990). Strength and stability of the lower extremity are necessary for performing basic tasks of daily living. In fact, risk of falling in the elderly has been associated with poor sense of balance and reduced leg strength and power (Whipple, et at, 1987). Falls in this population present the risk of soft tissue injury and possibly fracture, leading to compromised functional capacity. The purpose of this study is to implement an exercise intervention aimed at increasing bone mineral density of the spine and hip, the strength and power of the lower extremity as well as improving postural stability. Associations between strength, power, balance and bone mineral density will be addressed as well as psychological effects of the exercise training. Specifically, self-esteem and affect will be evaluated. Exercise has been shown to have various positive psychological effects, which in this population, may also relate to functional capacity and improved quality of life.

2. Methods and Time Line

Subjects will be tested for bone mineral density (BMD), strength, balance, muscular power, self-concept (SC) and affect, before, during and after an exercise training program. All testing procedures have been approved previously by the OSU Institutional Review Board (Spring 1993), however, the time frame for testing and the exercise training program have been altered slightly. The training program will last 9 months and the time line for testing will be as follows:

Pre-Training	Month 3	Month 6	Post Training
BMD		BMD	BMD
Strength	Strength	Strength	Strength
Balance	Balance	Balance	Balance
Power	Power	Power	Power
SC & affect	SC & affect	SC & affect	SC & affect

Bone mineral density will be assessed at month 6 during the training while the other measures will be repeated at months 3 and 6. A brief description of the test protocols and the training program follows. Prior to pre-training testing, all subjects will complete a health history questionnaire and obtain personal physician clearance to participate.

A. **Bone Mineral Density**

Bone mineral density (BMD) will be assessed by dual energy x-ray absorptiometry (Hologic QDR 1000/w). The lumbar spine (L2-4), hip (proximal femur) and whole body will be scanned for BMD determination. Bone scans will be performed by personnel trained according to the requirements of the Oregon Board of Radiologic Technicians.

B. **Strength**

The KinCom 500H will be used for isokinetic strength determination. Strength will be assessed for the, hip (abductors and adductors), quadriceps (knee extensors) and ankle (plantar and dorsiflexion).

C. Balance

Static and dynamic balance abilities will be evaluated using the Pro Balance Master (Neurocom International,Inc.). The static balance protocol will consist of four tests which require the subject to maintain a balanced standing position for 20 seconds under varying sensory conditions. These include: (1) stable platform surface with eyes open; (2) stable platform surface, eyes closed; (3) dynamic platform surface, eyes open; and, (4) dynamic platform, eyes closed.

The dynamic limits of stability (LOS) test will be used to assess dynamic balance. This protocol will require subjects to move as quickly and accurately as possible to each of nine targets placed at 50%, 75% and 100% of the subject's theoretical limits of stability. Three targets will be placed anterior, posterior, lateral right and lateral left to the subject's initial position in a highlighted center target positioned at 0% of their LOS. Each excursion to the three outer targets in each of the four directions will begin from the center target. A ten second pacing interval will be used for this test.

D. Muscular Power

Muscular power will be assessed by the Wingate Anaerobic Power Test (WAPT) for older individuals. The WAPT is performed on a bicycle ergometer and is designed to assess power of the lower extremity. The test consists of a five minute warm-up (40-60 rpm pedalling cadence), 15 seconds of fast pedalling against 9.5% of lean body mass, and a 5-10 minute cool-down.

E. Psychological Measures

Subjects will complete two psychological inventories designed to assess self-concept and affect. The Physical Self-Perception Profile will be used to assess how the subjects feel about themselves with respect to sports competence, appearance, functional capacity and health/disease state. General self-worth within the physical domain and global self-esteem will also be assessed. Positive and negative affect will be assessed with the Positive and Negative Affect Schedule. This scale is a checklist of twenty adjectives. The subjects simply note to what extent they have felt this way (not at all to extremely) during the past few days. The items load on a general positive or negative affect score.

F. Exercise Training Protocol

The exercise training will take place on the campus at Oregon State University. Individuals administering the training program will have current CPR certification. The training protocol to be administered was the subject of a 10 week pilot study/exercise class taught at River's Edge Athletic Club, Lake Oswego, OR. The training protocol was well tolerated by 9 women between the ages of 56 and 72 years.

The exercise training period will last nine months. The first two to four weeks will consist of a pre-training period, designed to bring all subjects to certain level of fitness at the onset of training. The training is designed to increase strength and power of the lower extremity. Training sessions are based on principles of resistance training and will take place three times a week, with at least one day of rest between sessions. Traditional weight equipment will not be used. Resistance will be altered by having the subjects wear a vest which will be loaded with known resistance (expressed as a percentage of body weight). Subjects will perform the number of sets and repetitions outlined below for six different exercises (see

EXERCISES). The following outline of the training program is specific with respect to the number of sets and repetitions, however, the instructors will attempt to tailor the sessions to the individual subjects.

Month(s)	Sets	Reps	Intensity	Rest
1	1-3	10-15	up to 4% of body weight	1 min
2-3	3-4	10-15	4-9% of body weight	1 min
3-4	3-4	8-12	6-12% of body weight	1 min
5-6	3-5	7-10	8-15% of body weight	1 min
7-8	3-5	5-10	8-20% of body weight	1 min
9	3-5	5-7	10-20% of body weight	1 min

EXERCISES: Bench stepping and jumping, Squats, Chair exercises, Lunges and Calf raises.

Bench stepping and jumping: Four, 6 and 8 inch wooden steps will be used for stepping as well as jumping. These steps are stable, with a wide base of support and non-slip ground contacts. Using an up-up-down-down cadence, one whole cycle will equal 1 repetition for stepping. Subjects will be required to alternate the leg which originates each sequence, so that a dominant leg will not develop. The 8 inch step will be used for stepping. After the third month of training, jumping off the lower steps (4 inches) will be added to the training. Subjects will be instructed to stand on the step and jump onto a padded surface, landing on both feet.

Squats: Subjects will begin the squat with feet shoulder width apart with arms stretched out in front. While looking forward, the subject performs a motion similar to sitting down in a chair. A full squat will be recommended, where the thighs reach a position parallel with the floor (~90 degree knee angle). However, if a subject cannot achieve a full squat, a half squat will be performed. A half squat uses the same motion, however, the knee angle achieved is about 120 degrees. If necessary, subjects will be allowed to use their hands for support (ie, holding on to the back of a chair) during the beginning stages of the intervention.

Chair exercises: Subjects will sit in an armless chair that allows for ~90 degree angle in the knee. Starting in a seated position, subjects will stand up then sit down for one repetition. Hands will not be used in this exercise, to emphasize use of the lower extremities.

Lunges: Lunges will be performed in four directions: front, back, right and left lateral. The lunges will begin with a step in one of the four directions, a shift in body position, a bend in the stepping leg no less than 90 degrees and a return to the original standing position.

Calf raises: Subjects will stand with flat feet on the floor. They will begin the exercise by rising up to the toes, return to flat feet, rock back to the heels and return to flat feet for one repetition. This will encourage development of both the plantar and dorsiflexors in the lower leg.

To encourage an increase in power, subjects will occasionally (3-5 times a month) perform sets of the exercises with quick repetitions.

Warm-Up and Cool-Down: Before the training sessions, subjects will be led through a 10 minute warm-up, including light walking or cycling and stretching for the lower extremity (calves, quadriceps and hamstrings). After the training sessions, subjects will be led through a cool-down period consisting of light walking and ~15 minutes of stretching. The cool-down will include stretches for the calves, hamstrings, quadriceps, hip, back, chest and shoulders.

3. Benefits/Risks of Participation

A. **Benefits**

Subjects will gain information with respect to their physical strength and power, bone mineral density and postural stability as a result of participating in this study. Many of these assessments are performed in clinical and/or professional settings yet are very expensive. Although we cannot provide diagnostic information, the subjects may choose to give the results of their assessments to their personal physician. Participation in the training program may improve three components thought to contribute to falls (strength, power and balance). For continued exercise of this nature, or for participation in a longer study of this nature, there may be an increase in lean mass, particularly in the hips. Therefore, the training program may help prevent falls in the subjects in the future. Disuse is often cited as a problem in older individuals and participation in training may not only improve physical but also psychological aspects of functional capacity.

B. **Risks**

The women who participated in the 10 week pilot study experienced no injuries or discomfort as a result of either the testing or training procedures. However, there are risks of participation. Those will be minimized by having trained personnel administering test protocols. All test and training administrators will be trained in the particular assessment protocols and certified in standard adult CPR. In all cases, the test and training protocols have warm-up or practice trials and where applicable, cool-down procedures to minimize the risk to subjects. The risks of participation for subjects in all procedures have been outlined previously in greater detail.

Risks of participation include exposure to a very low dose of radiation from the bone densitometer. The maximum radiation received from a regional scan (hip and spine) is between 2-5mRem, which is about 1/10th of a standard chest x-ray. The whole body scan results in an x-ray dose of approximately 1.5mRem, which is about the amount of radiation exposure an average individual experiences from background sources (sun, etc.) in two days.

Strength assessments may result in some acute muscle soreness. This will be minimized by giving the subject five practice, submaximal, warm-up trials before attempting the maximal efforts.

The risk involved in the balance assessment is minimal, although there is a slight chance that a subject may fall during the test protocol. Subjects will be screened for orthopedic (knee, ankle and hip in particular) problems which may affect performance. If a subject feels particularly uneasy on the Balance Master, there is a harness available for use, which will catch the subject should she lose her balance and stumble during the course of testing. The risk of falling will be minimized by providing practice sessions.

Anaerobic power determination with the WAPT is considered maximal exercise, yet it is not testing the cardiovascular system. However, this test is contraindicated for individuals with known cardiovascular and/or respiratory disease. Only apparently healthy individuals (with one or no major coronary risk factors) will be included in the subject pool. Risks associated with the WAPT include acute muscular soreness during and venous pooling and dizziness at the conclusion of the test. Muscular soreness will be minimized by providing a five minute warm-up prior to the 15 seconds of all-out pedalling. Venous pooling and dizziness may result after the test if the subject stops pedalling. However, very strict cool-down procedures will be maintained. Subjects will be required to continue pedalling for at least five minutes after the 15 second test with reduced resistance (similar to the resistance used during the warm-up), and at a reduced rate (40-60 rpms). Pedalling will continue until a heart rate under 100 bpm is achieved.

The training program may result in acute and delayed onset (one to two days post training) muscle soreness. There is also a slight chance of injury. The acute soreness will be minimized by providing a thorough warm-up period with dynamic activities and light stretching. After each training session, subjects will instructed to cool-down with a complete stretching program, which is thought to reduce the incidence of soreness and injury. The training protocol will be administered in the form of a class to assure adherence to warm-up and cool-down procedures. The risk of injury is also minimized by the warm-up and cool-down procedures, as well as by the conservative nature of the training program.

Using a weighted vest to alter intensity will minimize the risk of injury in that the subject will not have to hold onto traditional weight training equipment such as dumbbells and/or barbells. The vest allows for equal distribution of weight on the upper torso without subjecting the individual to undue stress on the shoulders or chest. The vest is padded in the shoulder region and the size is adjustable. To minimize soreness, weight is added to the vest in very small increments.

There is no physical risk associated with completing the psychological measures. However, completed questionnaires will be kept confidential.

4. Subject Population

Subjects will be apparently healthy, post-menopausal women between the ages of 55 to 75 years. Subjects will be screened for coronary heart disease, respiratory disease, metabolic disease (diabetes, thyroid conditions, etc.) and orthopedic problems (significant disability of ankle, knee or hip) by questionnaire. Subjects who are taking estrogen will be excluded from the study. Approximately 40 women will be recruited from Corvallis, OR and the surrounding area. Twenty of the subjects will be randomly assigned to the treatment (training) group and an equal number to the control group. All testing procedures will be the same for the control group, except they will not participate in the training program. At the onset of the study, potential subjects will be informed that they will be randomly assigned to one of the two groups. All subjects will be required to obtain a personal physician's clearance for participation in both the exercise testing and the exercise training.

Only women will be studied in this research project, particularly because they are at a higher risk of experiencing fracture with a fall. Women have lower bone and lean mass than men. Women also have lower strength values than men, particularly in older populations. Therefore, only women will be selected as participants due to the differences in potential gain from the study results.

5. Informed Consent

Please see attached form.

6. Method of Obtaining Consent

Subjects will be recruited from the Corvallis area via newspaper advertisement. When they are notified, they will be given a verbal description of the testing and training procedures. If the individual meets the inclusion criteria and is interested in participating in either the training or control group, she will be given a copy of the informed consent to read and sign. The subject will be responsible for showing the informed consent document with testing and training descriptions to her physician. An additional form will be provided for the physician to sign, indicating that he/she understands the procedures involved and approves of his/her patient to be part of the study (see attached). At the time of the pre-testing period, subjects will draw a number (1-40) to determine group assignment (even=training or odd=control).

7. Subject Confidentiality

All subjects will be assigned a code number which will be used for subject identification on all data collection forms as well as within the computer data base. Only the investigators will be aware of the subject's code number.

8. Copies of Questionnaires

Please find attached the Physical Self Perception Profile, the Positive and Negative Affect Schedule and health history questionnaire.

9. Additional Approvals

Not applicable.

10. Funding Proposal

Funding will be sought from the American Association for Retired Persons (AARP) and the American Association of University Women (AAUW). However, applications for funding are not complete at this time.

REFERENCES

Brown, A.B., McCartney, N. & Sale, D.G. (1990). Positive adaptations to weight-lifting training in the elderly. Journal of Applied Physiology, 69, 1725-1733.

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

EFFECTS OF RESISTANCE TRAINING ON FRACTURE RISK AND PSYCHOLOGICAL VARIABLES IN POSTMENOPAUSAL WOMEN

CONSENT FORM

I understand that I will be participating in a study designed to provide understanding about the relationships between muscular strength, power, balance, bone mineral density, self-concept and affect and how these variables may change with an exercise training program.

Prior to any testing, I will complete a health history questionnaire. I understand that I will sign a separate form for bone density testing.

I understand that I will be tested to determine the strength of my legs, hip and ankle. I will have to push against a lever arm with as much force as I can. For each test, I will be given five warm-up trials, followed by five individual maximal efforts, each separated by a rest period. Although there is a very slight risk of discomfort or injury, I understand that this risk is minimized by the warm-up activities and that the test will be administered by trained personnel.

I understand that static and dynamic balance determination will be conducted on the Balance Master. While on this equipment, I will be asked to stand as still as possible, as well as move my weight forward, backward and side to side as far as I can. There is a very slight chance that I may fall during this testing, however, a harness is available for additional support if needed.

To determine how fast I can move my legs, I will participate in the Wingate Anaerobic Power Test (WAPT). I understand that this test will be performed on a stationary bicycle. The test will consist of a warm-up period, followed by 15 seconds of fast pedalling (as fast as I can), and completed with a 5-10 minute cool-down. I understand that anaerobic power determination with this test is considered hard exercise, yet it is not testing my heart and lungs. Risks associated with the WAPT include muscular soreness and dizziness. I understand that the administrator of this test has been trained and will follow very strict procedures to minimize these risks. Muscular soreness will be minimized with a warm-up. Dizziness may result after the test <u>if</u> I stop pedalling. However, I will continue to pedal during the cool-down period as instructed by the test administrator to prevent any dizziness.

I understand that I will complete two questionnaires. These will be used to assess how I describe myself in various situations and my general emotional state. I understand that there is no physical risk associated with completing these questionnaires.

If I am assigned to the training group, the exercise training that I will participate in will take place within the Department of Exercise and Sport Science at Oregon State University. The exercise training period will last nine months. Training sessions will take place three times a week. All sessions will include a warm-up and cool-down. Each session will last approximately 50 to 60 minutes. I will wear a weighted vest during the training sessions. I will perform the number of sets and repetitions described by my instructors for bench stepping and/or jumping, squatting, getting in and out of a chair, lunges and toe raises. I understand that the training program may result in muscle soreness, especially at the beginning. There is also a slight chance of injury to myself. Qualified instructors will provide me with a warm-up and cool-down to minimize these risks. The risk of injury will also be minimized by wearing a lightly weighted vest. This will keep me from having to hold weights in my hands.

The benefits of my participation include contributing to the scientific study of the relationships among muscle strength, muscle power, bone mineral density, balance and various psychological variables. I will also gain some understanding of how these variables may change with nine months of exercise training. As a result of my participation, I will learn valuable information about my physical self and perhaps improve some aspects of fitness, if I am assigned to the training group.

I understand that Oregon State University does not provide a research subject with compensation or medical treatment in the event a subject is injured as a result of participation in the research project.

I understand that before I may participate in this study, I must obtain the approval of my personal physician. I will have my physician read this consent form so that he/she is aware of the testing and training procedures. If my physician approves of my participation, I will have him/her sign the attached approval form.

I understand that my confidentiality will be maintained at all times. At no time will my name appear on record form or in computer files in reference to the study. A code number will be used to identify my data and all records shall be kept using the code number.

I have been completely informed and understand the nature and purpose of this research. The researchers have offered to answer any further questions that I may have. I understand that my participation in this study is completely voluntary and I may withdraw from the study at any time without prejudice or loss of the benefits to which my participation entitles me. Questions about the research or any aspect of my participation should be directed to Dr. Christine Snow-Harter at 737-6788. I have read the foregoing and agree to participate.

Subject Signature____

Date_______________

Investigator's Signature_________________________________

Date_______________

BONE MINERAL DENSITY EVALUATION IN APPARENTLY HEALTHY MEN AND WOMEN

It has been explained to me that the purpose of this study is to evaluate the role of physical activity in reducing the incidence of osteoporosis. Osteoporosis is a bone disease characterized by fractures of the vertebrae, wrist and proximal femur (hip). The disease affects men and women, but is more prevalent in women, afflicting one in four women over the age of 60 in this country. The bone loss which leads to fractures begins early in the twenties in the axial skeleton (vertebrae, hip) and in later adulthood in the appendicular skeleton (wrist). Osteoporosis is caused by a number of factors which include genetics, reproductive hormone levels, calcium intake and physical activity. Although current knowledge suggests that athletes have stronger bones, the mode/s of exercise that best promote an increase in bone mass remain/s controversial. The long-term objectives of this study are: 1) to determine whether athletic populations experience normal, age-related bone loss and 2) to identify the types of exercise which can be safely prescribed for improving bone density and reducing bone loss in men and women across the lifespan. These objectives will be met by studying the relationship between exercise training and bone mineral density values in men and women of different ages who have a broad range of physical activity patterns.

I have been invited by Dr. Christine Snow-Harter to participate in this evaluation of bone mineral density of my spine, hip and/or whole body. It has been explained to me that the instrument used to measure my skeleton (a bone densitometer) uses very low levels of radiation to assess mineral content. Additional information on my body composition (percent muscle and fat tissue) will be derived from data collected during the whole body scan. I have been selected because I am healthy, not pregnant and have no history of medical conditions that would affect my skeleton. Prior to the bone density evaluation, I understand that I will be asked to complete a health and activity questionnaire.

I understand that, unless I am on birth control pills, I will have the testing conducted during my menstrual flow or within one week of onset. I have been informed that if I am pregnant or plan to become pregnant, I should not participate in this study. Further, if I become pregnant, I will be asked to inform the researchers immediately and withdraw from the study.

I have been informed that the scan requires that I lie quietly on a table for eight minutes for spine and hip evaluation and 15 minutes for whole body mineral determination and that I will have only one scan at each site.

This technique used to assess bone mineral content gives an accurate measure of bone density with a very low exposure to radiation. It has been explained that this radiation dose is considered safe to administer on several occasions to women/men in my age group provided that the women are not pregnant. The external beam is the only ionizing radiation to which I will be exposed. No injections are given and there are no known hazards from radiation at such a low level. By extrapolation from effects known to occur at high doses, there is less than one chance in a million of causing either malignancy or heritable disease. The only studies that have shown statistically detectable increases in malignancy risk from radiation in children have been at radiation levels more than 1000-fold greater than the doses used here. The calculated radiation exposure with this procedure per scan is approximately 2-5 millirads for a spine and hip scan and 1.5 millirads for a whole body scan. For comparison, a person can be expected to receive about 160 millirads per year from the environment, and about 40 millirads from a standard 2-position chest X-ray. Therefore, risk from participation in this study is negligible. I further understand that I will experience no discomfort from the procedures.

I understand that this measurement of bone mineral density will give me an accurate indication of my bone density and strength in addition to knowledge of my body composition. This information will be valuable to me, to my doctor and to Dr. Snow-Harter and her associates for the determination of bone mineral densities in athletes and healthy individuals across many ages. Further, this evaluation is offered at no charge. The average cost of bone density assessment is $250-300 and a body composition analysis is $20. I have been informed that this evaluation is not diagnostic and that any questions regarding my bone mineral density report should be directed to my physician.

I understand that I am to participate in this study without monetary compensation and that there will be no cost to me for my participation in this study. If I have any questions about the research or my rights, I understand that Dr. Snow-Harter at 737-3222 will be happy to answer them.

I understand that anonymity will be accomplished by a number coding system and that only the researchers will have knowledge of my name. I have been informed that the results of this study may be published in scientific literature and that any data that may be published in such a journal will not reveal my identity.

I understand that my decision whether or not to participate will not cause prejudice toward me. If I decide to participate, I am free to withdraw my consent and to discontinue participation at any time without penalty or loss of benefits to which I an entitled.

_______________________________ ______________
Signature Date

____
Witness

PERSONAL PHYSICIAN CLEARANCE

My patient ______________________________ has notified me about her interest in participating in the study titled Effects of Resistance Training on Bone Mineral Density, Strength, Power and Balance in Post Menopausal Women. I have read the consent form which outlines the test procedures and training program. I understand that only healthy women, with no known cardiovascular, respiratory or metabolic disease will be recruited for this study. To the best of my knowledge, the aforementioned patient is a good candidate for this research study. I understand that if I have any questions about the testing or training procedures, I may contact Dr. Christine Snow-Harter at 737-6788.

____

Physician Signature   Date

____

Address   Phone

APPENDIX B

HEALTH HISTORY FORM

OREGON STATE UNIVERSITY BONE RESEARCH LABORATORY

Health and Physical Activity History

______________________________________ ______________
Last name First name Middle Date of birth

______________________________________ ______________
Address, street work (phone) home

____________________ ______________________________
City, State Occupation and/or sports team

________pounds ____ft_____inches M F (circle one)
Weight Height

Please list your present medications and dosages (include birth control pills/vitamins):

____

****

PAST HISTORY (Check if yes)
Have you ever had?

High cholesterol ___
Rheumatic fever ___
Heart murmur ___
High blood pressure ___
Heart trouble ___
Disease of arteries ___
Varicose veins ___
Lung disease ___
Operations ___
Back injury ___
Other musculoskeletal injury or problems ___
Epilepsy ___

If yes to any of the above, please explain

____

____

FAMILY HISTORY (Check if yes)
Have your grandparents, parents or siblings had?

Diabetes ___
Heart attacks ___
High blood pressure ___
High cholesterol ___
Congenital heart disease ___
Heart operations ___

Other ______________________________

____

Date of last medical exam? ____________

Physician: ______________________

****

PRESENT SYMPTOMS REVIEW (Check if yes)
Have you recently had?

Chest pain ___
Shortness of breath ___
Heart palpitations ___
Cough on exertion ___
Coughing blood ___
Back pain ___
Painful, stiff or swollen joints ___

Other ______________________________

____

HEALTH HABITS

Smoking	YES	NO				
Do you smoke?	___	___				
Cigarettes	___		How many/day?	_______	How many years?	_____
Cigar	___		How many/day?	_______	How many years?	_____
Pipe	___		Times/day?	_______	How many years?	_____

If you have quit smoking, when did you quit? _____ How many yrs did you smoke? ___

Alcohol Consumption

Do you drink alcohol daily? Y N (circle one) If yes, how many drinks/week? ______

Consumption of calcium-rich daily products

How many 8 oz glasses of milk do you drink per day? _____ per week? ____

How many servings of cheese (1 oz) do you eat per day? _____ per week? ____

How many servings of yogurt (1 cup) do you eat per week? _____

Body Weight

What was your weight 1 month ago? _____ What was your weight 2 months ago? _____

Cola Beverages

How many cola beverages do you drink daily? ___________

How many years have you been drinking cola beverages on a regular basis? ______

PHYSICAL ACTIVITY

LIST ALL SPORTS OR ACTIVITIES IN WHICH YOU HAVE PARTICIPATED DURING THE PAST YEAR: (Examples include aerobics, tennis, golf, softball, dance, football, weight training, rowing, hiking, swimming, cycling, etc) Use the back of this paper if necessary

ACTIVITY	AVE # HRS/WK	AVE # MONTHS/YR
Ex. Aerobics	1	2

LIST YOUR INVOLVEMENT IN SPORTS ACTIVITIES FOR 4 YEARS PRIOR TO ABOVE:

(Use back if necessary)

ACTIVITY	# HRS/WK	# MONTHS/YR	# YEARS
Ex. Volleyball	10	4	3

Briefly describe your involvement in physical activity since high school .

OSTEOPOROSIS RISK FACTORS

Please circle true or false for the following. If you think a statement may apply to you but are not sure, place a question mark (?) by that statement.

1. true false I have a history of rheumatoid arthritis.
2. true false I have been treated with cortisone or similar drugs.
3. true false I have a close relative with osteoporosis.
4. true false I have a history of an overactive thyroid gland.
5. true false I have a history of overactive parathyroid gland.
6. true false I have a history of alcoholism.
7. true false I have a history of chronic liver disease.
8. true false I have a history of multiple myeloma.
9. true false I have a history of the blood tumor, leukemia.
10. true false I have a history of stomach ulcers.
11. true false I have lactase deficiency (inability to digest milk).
12. true false Some of my stomach has been surgically removed.
13. true false I take anabolic steroids now or have in the past.
14. true false I avoid milk and other dairy products.
15. true false I usually eat meat at least twice a day.
16. true false I drink more than 2 cups of coffee or tea daily.
17. true false On average, I drink 2 or more soft drinks daily.
18. true false I have about 3 or more alcoholic beverages daily.
19. true false I follow a vegetarian diet and have so for years.
10. true false I am of Caucasian (white race) ancestry.
21. true false I am of Asian (Oriental race) ancestry.
22. true false I am of African-American (black) ancestry.
23. true false I am of Mexican-American or Hispanic ancestry.
24. true false I am not very physically active most of the time.
25. true false I have lost more than 1 inch in height.
26. true false I take or have taken thyroid hormone pills.
27. true false I took phenobarbitol or dilantin for over a year.
28. true false I use Maalox or Mylanta antacids frequently.
29. true false I have taken furosamide (Lasix) for over one year.
30. true false I have been treated with lithium for over one year.
31. true false I have been treated with chemotherapy for cancer.
32. true false I take or have taken cyclosporin A (Sandimmune).
33. true false I have received an organ transplant (kidney, etc.).
34. true false I have had trouble with anorexia nervosa or bulimia.

(Women only)

35. true false I lost my period for a year or more before it came back.
36. true false I have had irregular menstrual periods.
37. true false My menstrual period did not begin until after age 16.
39. true false I have a medical history of endometriosis.
40. true false I lost my periods when I was exercising heavily.
41. true false I have had both ovaries surgically removed.
42. true false I have breast fed a baby for one month or more.
43. true false I take tamoxifin as treatment for breast cancer..
44. true false I went through menopause before age 50.
45. true false I have gone through menopause (change of life).
46. true false I have received estrogen treatment after menopause.

If you take estrogen, for how many years? ________

How many children have you given birth to? ____________

What was the date of your last menstrual period? ____________________

APPENDIX C

PHYSICAL SELF-PERCEPTION PROFILE FOR OLDER ADULTS

THE PHYSICAL SELF PERCEPTION PROFILE (PSPP)

What am I like?

These are statements which allow people to describe themselves. There are no right or wrong answers since people differ a lot.

First, decide which one of the two statements best describes you.

Then, go to that side of the statement and check if it is just "sort of true" or "really true" FOR YOU.

EXAMPLE

Really True for Me	Sort of True for Me				Sort of True for Me	Really True for Me
_____	_____	Some people are very competitive	BUT	Others are not quite so competitive	_____	____

REMEMBER to check only ONE of the four spaces

1._____	_____	Some people feel that they are not very good when it comes to playing sports	BUT	Others feel that they are really good at just about every sport	_____	_____
2._____	_____	Some people feel that they have an attractive body	BUT	Others feel that compared to most, their body is not quite so attractive	_____	_____
3._____	_____	Some people feel extremely proud of who they are and what they can do physically	BUT	Others are sometimes not quite so proud of who they are physically	_____	_____
4._____	_____	Some people feel very alert and alive	BUT	Others feel listless and distracted	_____	_____

Really True for Me	Sort of True for Me				Sort of True for Me	Really True for Me
5._____	_____	Some people do not usually have a lot of medical problems	BUT	Others always have medical problems	_____	_____
6._____	_____	Some adults like the way they are leading their lives	BUT	Other adults don't like the way they are leading their lives	_____	_____
7._____	_____	Some people feel that they are among the best when it comes to athletic ability	BUT	Others feel that they are not among the most able when it comes to athletics	_____	_____
8._____	_____	Some people feel that they have difficulty maintaining an attractive body	BUT	Others feel that they are easily able to keep their bodies looking attractive	_____	_____
9._____	_____	Some people are sometimes not so happy with the way they are or what they can do physically	BUT	Others always feel happy about the kind of person they are physically	_____	_____
10._____	_____	Some people feel that they occasionally need to rely on others to accomplish everyday tasks	BUT	Others feel that they never need assistance to accomplish everyday tasks	_____	_____
11._____	_____	Some people feel compared to most their general physical health is not so good	BUT	Others feel that compared to most they have good physical health, in general	_____	_____

Really True for Me	Sort of True for Me				Sort of True for Me	Really True for Me
12._____	_____	Some adults are very happy being the way they are	BUT	Other adults would like to be different	_____	_____
13._____	_____	Some people are not quite so confident when it comes to taking part in sports activities	BUT	Others are among the the most confident when it comes to taking part in sports activities	_____	_____
14._____	_____	Some people feel embarrassed by their bodies when it comes to wearing few clothes	BUT	Others do not feel embarrassed by their bodies when it comes to wearing few clothes	_____	_____
15._____	_____	When it comes to the physical side of themselves, some people do not feel very confident	BUT	Others seem to have a real sense of confidence in the physical side of themselves	_____	_____
16._____	_____	Some people are confident in their ability to make it through day-to-day activities	BUT	Others feel less secure in their ability to function in day-to-day activities	_____	_____
17._____	_____	Some people feel they must visit the doctor very often in order to care for their physical health	BUT	Others are physically healthy and rarely visit a doctor's office	_____	_____
18._____	_____	Some adults sometimes question whether they are a worthwhile person	BUT	Other adults feel that they are a worthwhile person	_____	_____

Really True for Me	Sort of True for Me				Sort of True for Me	Really True for Me
19._____	_____	Some people feel that they are always one of the best when it comes to joining in sports activities	BUT	Others feel that they are not one of the best when it comes to joining in sports activities	_____	_____
20._____	_____	Some people feel that they are often admired because their physique or figure is considered attractive	BUT	Others rarely feel that they receive admiration for the way their body looks	_____	_____
21._____	_____	Some people always have a really positive feeling about the physical side of themselves	BUT	Others sometimes do not feel positive about the physical side of themselves	_____	_____
22._____	_____	Some people feel confident in their physical ability to care for themselves	BUT	Others feel uneasy about their physical ability to care for themselves	_____	_____
23._____	_____	Some people are not very confident about their level of physical health	BUT	Others feel confident that they always maintain excellent physical health	_____	_____
24._____	_____	Some adults are disappointed with themselves	BUT	Other adults are quite pleased with themselves	_____	_____
25._____	_____	Some people are sometimes a little slower than most when it comes to learning new skills in a sports situation	BUT	Others have always seemed to be the quickest when it comes to learning new sports skills	_____	_____

Really True for Me	Sort of True for Me				Sort of True for Me	Really True for Me
26._____	_____	Some people feel that compared to most, their bodies do not look in the best shape	BUT	Others feel that compared to most their bodies always look in excellent physical shape	_____	_____
27._____	_____	Some people wish that they could have more respect for their physical selves	BUT	Others always have great respect for their physical selves	_____	_____
28._____	_____	Some people are confident in their ability to get around their home and neighborhood	BUT	Others are not confident in their ability to get around their home and neighborhood	_____	_____
29._____	_____	Physically some people are always free of aches and pains	BUT	For others, aches and pains occur quite frequently	_____	_____
30._____	_____	Some adults are dissatisfied with themselves	BUT	Other adults are satisfied with themselves	_____	_____
31._____	_____	Given the chance some people are always one of the first to join in sports activities	BUT	Other people sometimes hold back and are not usually among the first to join in sports	_____	_____
32._____	_____	Some people are extremely confident about the appearance of their body	BUT	Others are a little self-conscious about the appearance of their bodies	_____	_____

Really True for Me	Sort of True for Me				Sort of True for Me	Really True for Me
33.______	______	Some people feel extremely satisfied with the kind of person they are physically	BUT	Others sometimes feel a little dissatisfied with their physical selves	______	______
34.______	______	Some people feel that, compared to most, they are physically able to do for themselves extremely well	BUT	Others feel that compared to most, they are not physically able to do for themselves very well	______	______
35.______	______	Some people feel confident about their ability to be free from illness and medical problems	BUT	Others are not so confident about their ability to remain free from illness and medical problems	______	______
36.______	______	Some adults like the kind of person they are	BUT	Other adults would like to be someone else	______	______

HOW IMPORTANT ARE THINGS TO YOU?

Really True for Me	Sort of True for Me				Sort of True for Me	Really True for Me
1. ______	______	Some people feel that being good at sports is vitally important to them	BUT	Others feel that being good at sports is not so important to them	______	______
2. ______	______	Some people believe that being free from aches & pains and medical problems is vitally important to them	BUT	Others believe that being free from aches & pains and medical problems is not of prime importance	______	______
3. ______	______	Some people feel it is important to physically function effectively and efficiently in daily living	BUT	Others feel that physically functioning effectively and efficiently in daily living is not so important	______	______
4. ______	______	Some people believe that having an attractive physique or figure is vitally important to them	BUT	Others believe that having an attractive physique or figure is not all that important in their lives	______	______
5. ______	______	Some people feel that having very good sports ability and skill is not so important to them	BUT	Others feel that having a high level of sports ability is really important to them	______	______
6. ______	______	Some people believe maintaining good physical health is important to them	BUT	Others feel that being physically healthy is not that important to them	______	______

Really True for Me	Sort of True for Me				Sort of True for Me	Really True for Me
7. ______	______	Some people feel that being physically independent in daily living is not so important to them	BUT	Others feel that it is important to be physically independent in daily living	______	______
8. ______	______	Some people do not feel it is so important for them to spend a lot of time maintaining an attractive body	BUT	Others think that it is vitally important for them to spend time and effort maintaining an attractive body	______	______

APPENDIX D

POSITIVE AND NEGATIVE AFFECT SCHEDULE

The Positive and Negative Affect Schedule

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way during the past week. Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

_____interested

_____distressed

_____excited

_____upset

_____strong

_____guilty

_____scared

_____hostile

_____enthusiastic

_____proud

_____irritable

_____alert

_____ashamed

_____inspired

_____nervous

_____determined

_____attentive

_____jittery

_____active

_____afraid

APPENDIX E

EXERCISE TRAINING LOG

EXERCISE TRAINING LOG

Name:________________________ Dates:________________ ID#:____________

Date	Week #	Body Weight	Sets	Reps	Intensity	Resistance

APPENDIX F

PHYSICAL ACTIVITY LOG

ACTIVITY LOG

Name:______________________ Dates:________________ ID#:__________

Date	Activity	Duration	Date	Activity	Duration

APPENDIX TABLE A

BONE MINERAL DENSITY RESULTS

BONE MINERAL DENSITY RESULTS

Appendix Table A: Lumbar spine and femoral neck bone mineral density results (mean and standard deviation) for Baseline, Month 6 and Month 9

Time	LuBMD(g/cm^2) CONTROL	LuBMD(g/cm^2) EXERCISE	FnBMD(g/cm^2) CONTROL	FnBMD(g/cm^2) EXERCISE
Baseline	.884	.893	.651	.683
(S.D.)	(.118)	(.100)	(.083)	(.062)
Month 6	.880	.893	.654	.679
(S.D.)	(.118)	(.106)	(.082)	(.062)
Month 9	.880	.899	.650	.684
(S.D.)	(.122)	(.108)	(.078)	(.057)

APPENDIX TABLE B

MUSCULAR STRENGTH RESULTS

MUSCULAR STRENGTH RESULTS

Appendix Table B: Muscular strength* results (mean and standard deviation) at baseline, month 3, month 6, and month 9

Time	PFlex (kg) CONTROL	PFlex (kg) EXERCISE	DFlex (kg) CONTROL	DFlex (kg) EXERCISE
Baseline	23.1	26.0	14.7	16.1
(S.D.)	(5.7)	(4.3)	(3.0)	(3.7)
Month 3	19.3	24.9	14.4	14.4
(S.D.)	(5.1)	(5.3)	(3.7)	(4.2)
Month 6	22.9	30.2	15.1	15.8
(S.D.)	(7.4)	(5.8)	(3.4)	(3.9)
Month 9	24.3	34.3	15.7	17.3
(S.D.)	(6.2)	(5.7)	(3.1)	(3.8)

Time	Hip AB (kg) CONTROL	Hip AB (kg) EXERCISE	Hip AD (kg) CONTROL	Hip AD (kg) EXERCISE
Baseline	29.1	26.4	22.5	23.0
(S.D.)	(4.9)	(6.8)	(5.9)	(5.0)
Month 3	29.3	31.0	21.2	23.6
(S.D.)	(5.2)	(5.8)	(4.8)	(4.2)
Month 6	29.6	30.7	20.2	22.0
(S.D.)	(5.0)	(4.8)	(5.3)	(3.8)
Month 9	31.0	32.9	21.9	23.9
(S.D.)	(6.0)	(4.1)	(4.3)	(5.3)

Time	Knee EXT (kg) CONTROL	Knee EXT (kg) EXERCISE
Baseline	41.6	41.9
(S.D.)	(8.0)	(6.7)
Month 3	40.5	41.7
(S.D.)	(6.4)	(7.5)
Month 6	40.9	44.0
(S.D.)	(8.2)	(8.3)
Month 9	43.3	48.5
(S.D.)	(6.7)	(8.2)

*PFlex = Ankle plantar flexor strength
DFlex = Ankle dorsi flexor strength
Hip AB = Hip abductor strength
Hip AD = Hip adductor strength
Knee EXT = Knee extensor strength

APPENDIX TABLE C

STATIC AND DYNAMIC BALANCE RESULTS

STATIC AND DYNAMIC BALANCE RESULTS

Appendix Table C: Results (means and standard deviations) of Static Balance*, Maximal LOS, and Dynamic Balance*** at Baseline, Month 3, Month 6, and Month 9**

Time	Eyes Open F CONTROL	Eyes Open F EXERCISE	Eyes Closed F CONTROL	Eyes Closed F EXERCISE
Baseline	.11	.08	.13	.19
(S.D.)	(.09)	(.06)	(.07)	(.21)
Month 3	.08	.10	.13	.17
(S.D.)	(.04)	(.07)	(.08)	(.13)
Month 6	.08	.08	.12	.23
(S.D.)	(.04)	(.03)	(.11)	(.23)
Month 9	.08	.12	.12	.17
(S.D.)	(.05)	(.08)	(.06)	(.13)

*Eyes Open or Closed F= Fixed surface; body sway represented as a % of LOS

Time	Eyes Open S CONTROL	Eyes Open S EXERCISE	Eyes Closed S CONTROL	Eyes Closed S EXERCISE
Baseline	.35	.38	1.55	1.65
(S.D.)	(.24)	(.29)	(.73)	(.96)
Month 3	.42	.25	1.36	1.72
(S.D.)	(.40)	(.17)	(.85)	(1.52)
Month 6	.24	.21	1.66	1.60
(S.D.)	(.15)	(.10)	(1.96)	(1.48)
Month 9	.30	.26	1.39	1.63
(S.D.)	(.29)	(.20)	(.89)	(1.51)

*Eyes Open or Closed S= Swayed surface; body sway represented as a % of LOS

Time	Max LOS A CONTROL	Max LOS A EXERCISE	Max LOS P CONTROL	Max LOS P EXERCISE
Baseline	87.71	84.71	82.23	80.16
(S.D.)	(5.80)	(8.29)	(7.42)	(9.80)
Month 3	90.24	88.75	79.95	80.67
(S.D.)	(6.22)	(5.60)	(6.54)	(5.98)
Month 6	88.32	87.35	80.48	83.42
(S.D.)	(8.4.)	(7.09)	(1.73)	(6.19)
Month 9	88.48	88.02	77.81	80.74
(S.D.)	(6.06)	(5.26)	(7.40)	(5.41)

**A=Anterior; P=Posterior

Time	Max LOS R CONTROL	Max LOS R EXERCISE	Max LOS L CONTROL	Max LOS L EXERCISE
Baseline	91.63	88.46	88.02	86.29
(S.D.)	(4.45)	(6.99)	(5.87)	(7.02)
Month 3	90.35	90.40	88.92	88.51
(S.D.)	(4.18)	(3.59)	(6.27)	(4.78)
Month 6	91.59	90.26	90.10	89.33
(S.D.)	(2.96)	(5.66)	(6.52)	(6.62)
Month 9	91.77	89.85	87.40	88.71
(S.D.)	(3.16)	(4.40)	(5.88)	(3.93)

**R=Right Lateral; L=Left Lateral

Time	MT AP (sec) CONTROL	MT AP (sec) EXERCISE	MT LAT (sec) CONTROL	MT LAT (sec) EXERCISE
Baseline	6.66	6.43	5.60	5.94
(S.D.)	(2.38)	(2.32)	(1.70)	(1.57)
Month 3	6.72	5.49	5.56	5.20
(S.D.)	(2.57)	(.91)	(1.84)	(1.59)
Month 6	6.71	4.92	5.37	4.86
(S.D.)	(3.31)	(1.32)	(2.08)	(1.05)
Month 9	6.11	5.30	5.65	4.57
(S.D.)	(2.24)	(1.78)	(2.35)	(1.17)

***MT AP=Movement Time Anterior-Posterior; MT LAT=Movement Time Right and Left Lateral

Time	PS AP (% len) CONTROL	PS AP (% len) EXERCISE	PS LAT (% len) CONTROL	PS LAT (% len) EXERCISE
Baseline	335.33	370.46	273.61	314.67
(S.D.)	(55.94)	(115.36)	(31.67)	(56.26)
Month 3	361.37	332.70	283.18	304.94
(S.D.)	(98.41)	(49.59)	(25.46)	(43.32)
Month 6	334.42	332.78	285.81	312.49
(S.D.)	(70.20)	(53.72)	(34.59)	(45.82)
Month 9	329.64	334.16	283.89	290.96
(S.D.)	(82.72)	(70.87)	(24.99)	(35.34)

***PS AP=Path Sway Anterior-Posterior; PS LAT=Path Sway Right and Left Lateral; expressed as a % of path length

APPENDIX TABLE D

MUSCULAR POWER RESULTS

MUSCULAR POWER RESULTS

Appendix Table D: Results of Muscular Power (mean and standard deviation) at Baseline, Month 3, Month 6, and Month 9

Time	Mean Power (Watts) CONTROL	Mean Power (Watts) EXERCISE	Max Power (Watts) CONTROL	Max Power (Watts) EXERCISE
Baseline	258	248	294	295
(S.D.)	(64)	(78)	(65)	(85)
Month 3	263	274	304	322
(S.D.)	(53)	(74)	(61)	(81)
Month 6	264	281	316	338
(S.D.)	(59)	(67)	(69)	(74)
Month 9	263	278	309	339
(S.D.)	(62)	(73)	(68)	(81)

Time	Max Power (W/kg legs lean) CONTROL	Max Power (W/kg legs lean) EXERCISE
Baseline	23.4	22.5
(S.D.)	(4.7)	(4.7)
Month 3*		
(S.D.)		
Month 6	25.0	25.4
(S.D.)	(5.4)	(3.8)
Month 9	24.2	25.1
(S.D.)	(4.7)	(4.1)

*No bone scan to determine legs lean mass

APPENDIX TABLE E

PHYSICAL SELF-PERCEPTION PROFILE RESULTS

PHYSICAL SELF-PERCEPTION PROFILE RESULTS

Appendix Table E: Results of Physical Self-Perception Profile* (mean and standard deviation) at Baseline, Month 3, Month 6, and Month 9

Time	Sports Comp CONTROL	Sports Comp EXERCISE	Attractive Body CONTROL	Attractive Body EXERCISE
Baseline	2.1	1.9	2.4	2.2
(S.D.)	(.8)	(.6)	(.6)	(.7)
Month 3	2.0	2.0	2.6	2.3
(S.D.)	(.8)	(.6)	(.7)	(.7)
Month 6	2.0	1.9	2.4	2.4
(S.D.)	(.7)	(.8)	(.6)	(.8)
Month 9	2.0	2.0	2.6	2.5
(S.D.)	(.9)	(.8)	(.6)	(.8)

*Uncorrected for importance of each subscale

Time	Physical Funct CONTROL	Physical Funct EXERCISE	Medical Probs CONTROL	Medical Probs EXERCISE
Baseline	3.7	3.7	3.6	3.4
(S.D.)	(.3)	(.3)	(.5)	(.4)
Month 3	3.8	3.8	3.6	3.4
(S.D.)	(.3)	(.3)	(.5)	(.5)
Month 6	3.7	3.7	3.5	3.6
(S.D.)	(.3)	(.3)	(.5)	(.3)
Month 9	3.8	3.6	3.7	3.5
(S.D.)	(.2)	(.4)	(.4)	(.5)

Time	Phys SE CONTROL	Phys SE EXERCISE	Global SE CONTROL	Global SE EXERCISE
Baseline	2.8	2.7	3.5	3.4
(S.D.)	(.6)	(.7)	(.4)	(.5)
Month 3	2.8	2.7	3.4	3.5
(S.D.)	(.6)	(.7)	(.4)	(.5)
Month 6	2.8	2.8	3.5	3.5
(S.D.)	(.6)	(.7)	(.5)	(.5)
Month 9	3.0	2.9	3.5	3.5
(S.D.)	(.6)	(.8)	(.5)	(.5)

Time	Sports Comp I CONTROL	Sports Comp I EXERCISE	Attr Body I CONTROL	Attr Body I EXERCISE
Baseline	2.0	1.9	2.7	2.6
(S.D.)	(.9)	(.7)	(.7)	(.7)
Month 3	1.9	1.8	2.6	2.7
(S.D.)	(.8)	(.9)	(.8)	(.7)
Month 6	1.9	1.6	2.6	2.8
(S.D.)	(.8)	(.8)	(.8)	(.7)
Month 9	2.0	1.8	2.7	2.8
(S.D.)	(1.0)	(.9)	(.7)	(.6)

*I=Importance of each subscale

Time	Physical Funct I CONTROL	Physical Funct I EXERCISE	Medical Probs I CONTROL	Medical Probs I EXERCISE
Baseline	3.6	3.8	3.6	3.5
(S.D.)	(.6)	(.4)	(.5)	(.5)
Month 3	3.9	3.8	3.7	3.4
(S.D.)	(.2)	(.4)	(.4)	(.5)
Month 6	3.9	3.9	3.6	3.5
(S.D.)	(.2)	(.3)	(.4)	(.5)
Month 9	3.9	3.9	3.7	3.5
(S.D.)	(.2)	(.3)	(.4)	(.4)

*I=Importance of each subscale

APPENDIX TABLE F

POSITIVE AND NEGATIVE AFFECT SCHEDULE RESULTS

POSITIVE AND NEGATIVE AFFECT SCHEDULE RESULTS

Appendix Table F: Results (mean and standard deviation) Positive and Negative Affect at Baseline, Month 3, Month 6, and Month 9

Time	Positive Affect CONTROL	Positive Affect EXERCISE	Negative Affect CONTROL	Negative Affect EXERCISE
Baseline	3.7	3.6	1.4	1.3
(S.D)	(.6)	(.5)	(.5)	(.4)
Month 3	3.6	3.8	1.4	1.4
(S.D.)	(.5)	(.5)	(.4)	(.4)
Month 6	3.5	3.7	1.2	1.3
(S.D.)	(.6)	(.5)	(.2)	(.4)
Month 9	3.6	3.6	1.6	1.5
(S.D.)	(.6)	(.6)	(.7)	(.5)