

**THE EFFECTS OF HYDRAULIC RESISTANCE CIRCUIT TRAINING ON  
WHOLE BODY BONE MINERAL DENSITY IN POSTMENOPAUSAL WOMEN**

A Thesis by

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I have examined the final copy of this Thesis for form and content and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Education, with a major in Exercise Science.

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## **DEDICATION**

To my loving mother whose relentless care and support never fails to amaze me, and my father, who was taken too early to see all of my accomplishments

## **ACKNOWLEDGMENTS**

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## ABSTRACT

The aim of the present study was to determine whether a 12 week hydraulic resistance circuit training program, could maintain whole body bone mineral density in postmenopausal women. Participants included ten apparently healthy, postmenopausal women ( $56.5 \pm 7.5$  years) who were allocated into two groups: exercise (EX) and control (CON). EX subjects participated in hydraulic resistance circuit training three days a week for 30 minutes per day. Exercise stations consisted of nine hydraulic resistance machines that targeted the main muscle groups and nine aerobic stations that consisted of dancing, jogging and cycling. Bone mineral density of the whole body was assessed at baseline and 12 weeks in both groups. No significant differences ( $P \leq 0.05$ ) in whole body bone mineral density were found between groups determined by repeated measures ANCOVA. However, a trend ( $P = 0.054$ ) for the EX group to increase whole body bone mineral density (baseline BMD=  $1.08 \pm .07$  g/cm<sup>2</sup>, 12-week=  $1.11 \pm .07$ ) over 12 weeks existed. These results suggest that hydraulic resistance strength training is a safe form of exercise and may be beneficial for maintaining bone mineral density in postmenopausal women. However, further research with a larger population and longer study duration is warranted.

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## LIST OF ABBREVIATIONS

BMC	Bone mineral content
BMD	Bone mineral density
BMI	Body mass index
CHF	Chronic Heart Failure
CON	Control group
DEXA	Dual energy x-ray absorptiometry
ECG	Electrocardiogram
EX	Exercise group
GRF	Ground reaction force
$\text{g/cm}^2$	grams per centimeter squared
HCL	Hydrochloric acid
HRCT	Hydraulic resistance circuit training
HRmax	Maximum heart rate
HRT	Hormone replacement therapy
PTH	Parathyroid Hormone
RCT	Randomized controlled trial
RM	Repetition maximum
SERMs	Selective estrogen receptor modulators
$\text{VO}_{2\text{max}}$	Maximal oxygen uptake
WHI	Women's Health Initiative Study

# CHAPTER 1

## INTRODUCTION

When women reach menopause, they undergo many physiological changes. In U.S. and European females, menopause occurs around the age of 50 years at which time there is a dramatic decline in female sex-specific hormones (Asikainen, Kukkonen-Harjula, & Miilunpalo, 2004). Due to increased longevity, the average U.S. female will spend one-third of her life in a postmenopausal state (Greendale & Judd, 1993). One physiological change that has received considerable attention is a marked reduction in bone mass leading to osteoporosis. Osteoporosis is a serious health issue that can reduce quality of life and levies a financial burden on those who experience an osteoporosis-related fracture. One in two women over the age of 50 will experience a debilitating fracture (National Osteoporosis Foundation, 2007). According to the National Osteoporosis Foundation (2007), a fracture of the hip is associated with approximately 20 percent mortality rate one year post-fracture. In 2002, the estimated direct cost for fractures related to osteoporosis was \$18 billion and costs are rising (National Osteoporosis Foundation, 2007). Treatment for bone loss includes pharmacological agents, hormone replacement therapy (HRT), and exercise. The latter has been suggested as an alternative natural treatment in the management of osteoporosis and its efficacy has been extensively researched.

Pharmacological treatments, as well as HRT, are effective in treating menopause-related bone loss (Bushardt, Turner, Ragucci, & Askins, 2006; Komulainen et al., 1998). However, serious adverse effects have been reported with their use (Chlebowski et al., 2003). Due to its osteogenic effects, exercise has been suggested as an alternative

therapy. Studies of spaceflight and bed-rest have demonstrated that bone loss is rapid when mechanical forces acting upon the skeleton are removed (Krolner & Toft, 1983; LeBlanc et al., 2000). Additionally, the bone mineral density (BMD) of young athletes is greater compared to their non-athlete counterparts (Heinonen et al., 1995). From these observations, a considerable amount of research involving exercise and its ability to stimulate bone growth has been performed. However, randomized controlled trials (RCTs) investigating the effects of exercise on changes in BMD in postmenopausal women are conflicting (American College of Sports Medicine, 2004).

### **1.1 Statement of the problem**

Currently, our understanding of how to use exercise in the management of osteoporosis is incomplete. It has been frequently suggested that the type (mode) of exercise should be of weight-bearing nature in order to produce stress on the skeletal system (American College of Sports Medicine, 2004). However, the majority of studies that implemented walking as an intervention failed to produce favorable outcomes in BMD in postmenopausal women and researchers concluded that higher-intensity types of exercise needed to be examined (Cavanaugh & Cann, 1988; Ebrahim, Thompson, Baskaran, & Evans, 1997; Yamazaki, Ichimura, Iwamoto, Takeda, & Toyama, 2004). Other researchers investigated the effects of high intensity weight-bearing exercise such as jogging and stair climbing on BMD in postmenopausal women (Chow, Harrison, & Notarius, 1987; Heinonen, Oja, Sievanen, Pasanen, & Vuori, 1998), which generally produced more favorable outcomes than did the walking interventions. There has been compelling evidence from cross-sectional studies conducted on BMD in professional weight-lifters suggesting that resistance training provides a sufficient stimulus to increase

BMD (Karlsson, Johnell, & Obrant, 1993). Authors who have investigated this mode of exercise in postmenopausal women are not in agreement (Borer, 2005). Authors who have reported the most favorable BMD outcomes have implemented bi-modal interventions consisting of resistance training and endurance type weight-bearing exercise (Chubak et al., 2006; Jessup, Horne, Vishen, & Wheeler, 2003; Kemmler, Engelke, Weineck, Hensen, & Kalendar, 2003). However, performing both modes of exercise into each session requires a substantial amount of time for participants to complete. This may result in low adherence, not be safe for this population, and be difficult to replicate in the community. Circuit-training is a form of exercise that allows several modes of exercise to be utilized concurrently in a time-efficient manner. Hydraulic resistance circuit training (HRCT) and its effects on fitness have been previously studied in older adults and some clinical populations (Cooney & Walker, 1986; Selig et al., 2004; Suomi, Surburg, & Lecius, 1995; Takeshima et al., 2004). These authors found several physiological benefits from the use of HRCT. However, no research has been conducted specifically investigating the effects of HRCT on BMD in postmenopausal women.

## **1.2 Purpose**

The purpose of this study was to assess the effects of 12 weeks of hydraulic resistance circuit training on whole body bone mineral density in postmenopausal women.

## **1.3 Significance of the Study**

Research studies investigating the effects of different modes of exercise on BMD changes in postmenopausal women have produced mixed results (Bassey, Rothwell,

Littlewood, & Pye, 1998; Bemben, Fetters, Bemben, Nabavi, & Koh, 2000; Chow et al., 1987; Kemmler et al., 2003; Nelson, Fisher, Dilmanian, Dallal, & Evans, 1991). Studies using resistance training (Kerr, Ackland, Maslen, Morton, & Prince, 2001; Nelson et al., 1994) and high-impact weight-bearing exercise (Chow et al., 1987; Heinonen et al., 1998) have produced the most favorable outcomes. Valuable insight gained from these studies has led to the design of investigations utilizing both types of exercise in the same session (Chubak et al., 2006; Cussler et al., 2003; Kemmler et al., 2003; Kerr et al., 2001; Milliken et al., 2003). While these studies have reported favorable outcomes, the exercise protocols require substantial daily time to complete and may not be feasible to implement into the community. The findings from this study will provide information regarding whether a time-convenient feasible exercise program consisting of concurrent weight-bearing and resistance exercise in a circuit form can increase or maintain BMD in postmenopausal women.

## **1.4 Variables**

### **1.4.1 Independent Variable**

The independent variable in this study was 12 weeks of hydraulic resistance circuit training in a group of previously sedentary postmenopausal women. A control group of postmenopausal women that remained sedentary for the same duration was also assessed.

### **1.4.2 Dependent Variable**

The dependent variable in this study was whole-body bone mineral density assessed by dual energy x-ray absorptiometry (DEXA) technique.

### **1.4.3 Controlled Variables**

Women taking medications that could influence BMD were excluded. Those medications include hormone replacement therapy (HRT), bisphosphonates, or glucocorticoids.

### **1.5 Research Hypothesis**

It was hypothesized that postmenopausal women participating in 12 weeks of hydraulic resistance circuit training would maintain bone mineral density to a greater extent than the control group.

### **1.6 Assumptions**

It was assumed that women assigned to the control group would refrain from starting an exercise program or participating in any physical activity greater than their normal daily activity levels. It was also assumed that participants did not change their diet over the 12 week study period. Participants were informed at the initial screening visit and baseline testing to not adjust their diet. All women in this study were past menopause. The criterion for being postmenopausal was self-reported lack of menstruation for a year or more. It was assumed that these women were truthful when reporting their menopausal status.

### **1.7 Limitations**

The major limitations in this study are a small sample size and the study duration. Previous studies have chosen to conduct studies of six months or more due to the physiological adaptations of bone. Additionally, this study only included ten participants. Recruitment of postmenopausal women not taking drugs that affect bone metabolism was difficult. Other researchers have found the same problems which resulted in low participant numbers as well.

## 1.8 Delimitations

The results of this study are limited to healthy, sedentary postmenopausal women not taking medications that affect bone metabolism. BMD results pertain to the testing protocol and equipment used in this study. Therefore, studies using other methods for obtaining BMD may not produce the same results.

## 1.9 Definitions

1. Menopause: the permanent physiological, or natural, cessation of menstrual cycles (Borer,2005).
2. Osteoporosis: a disease of the skeleton characterized by low bone mineral density and micro-architectural deterioration. Measured in absolute terms as 2.5 standard deviations below the applicable norm (Frost, 2003).
3. Hormone Replacement Therapy: estrogen or estrogen combined with progesterone administered to compensate for the body's insufficiency to produce them (Borer, 2005)
4. Bone Mineral Density: an estimate of the amount of bone mineral in the path of one or more X-Ray beams (Frost, 2003)
5. Bone Architecture: the size, shape, and orientation of bone, the amount of tissue in it, and the arrangement of that tissue in anatomical space (Frost, 2003).
6. Dual Energy X-ray Absorptiometry: an imaging technique used to assess bone mineral density (Borer, 2005).
7. Bone Remodeling: turnover in bone accomplished by the processes of bone deposition and bone resorption (Frost, 2003).
8. Bone Resorption: the physiological degradation of bone resulting in net loss which is accomplished by the bone cell osteoclasts (Frost, 2003).
9. Mechanical Strain/Stress: the deformation or change in dimension and/or shape of bones caused by a load or any structure. This includes stretching, bending, shortening, and/or twisting (Frost, 2003).
10. Bone Deposition: a physiological process resulting in new bone matrix which is accomplished mainly by the bone cell osteoblasts (Downey & Siegel, 2006).

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Overview of Bone**

An understanding of bone morphology and physiology is necessary in understanding its responses to hormonal influences and mechanical stress. Mature bone is a form of connective tissue that can be categorized into either cortical or trabecular bone. The human skeleton is comprised of approximately 80 percent cortical bone that is metabolically less active than trabecular (Borer, 2005). Cortical bone is located on the surface of flat bones and in the diaphyseal walls of long bones. Trabecular bone can be found closest to the marrow cavity and in the epiphyses of long bones. Additionally, 60-70 percent of the spine is composed of trabecular bone (Snow-Harter & Marcus, 1992). The material and composition of each type of bone is relatively the same. However, the architecture of these bones is inherently different.

Cortical bone derives its strength from its geometric arrangement of osteons, referred to as a Haversian system (Downey & Siegel, 2006). Concentric lamellae, made of mineralized collagen fibers, surround central canals responsible for vessel and nerve passage. The tightly packed fibers of lamellar rings are oriented in an alternating fashion and account for part of bones overall strength (Figure 2.1) allowing the long bones to resist against bending and torsional forces (Downey & Siegel, 2006). Deep within the concentric layers of mineralized fibers lies an interconnected network of mature bone cells called osteocytes (discussed in section 2.1.1). This network allows for diffusion of nutrients in a system surrounded by mineralized matrix.

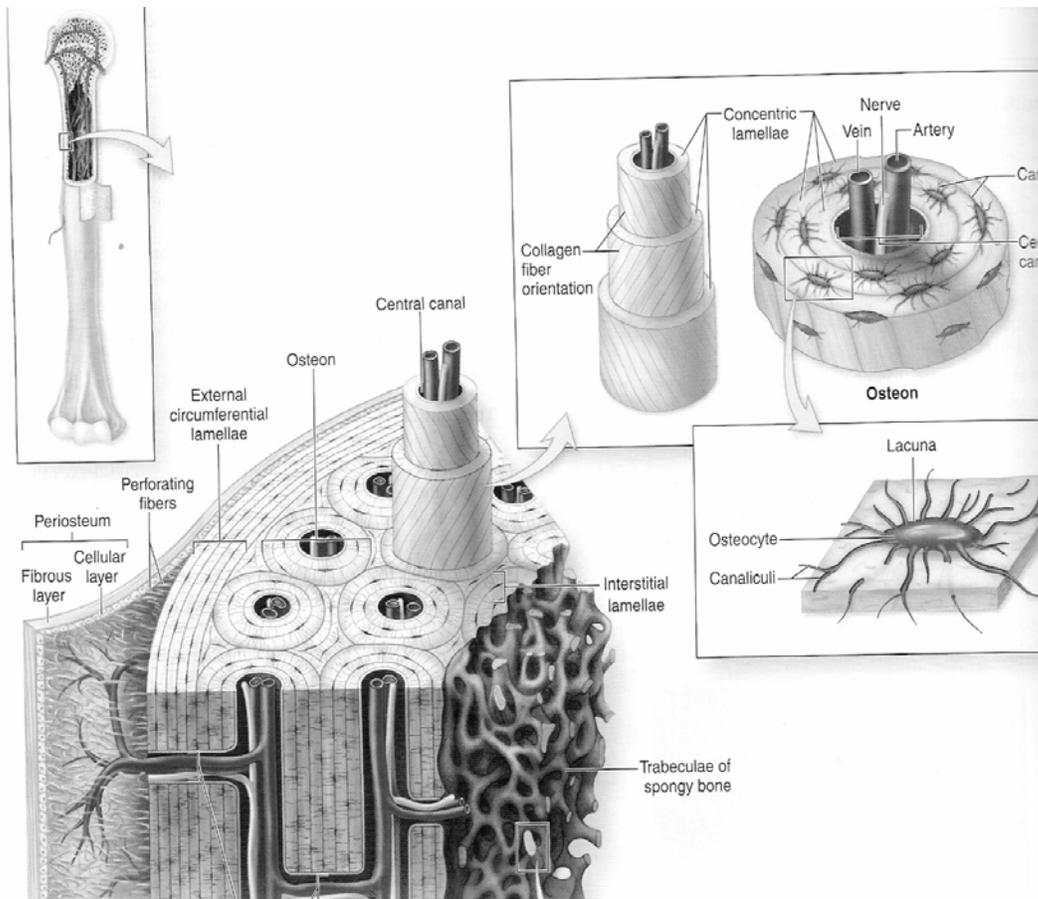


Figure 2.1. Structural make-up of cortical bone (McKinley & O'Loughlin, 2006)

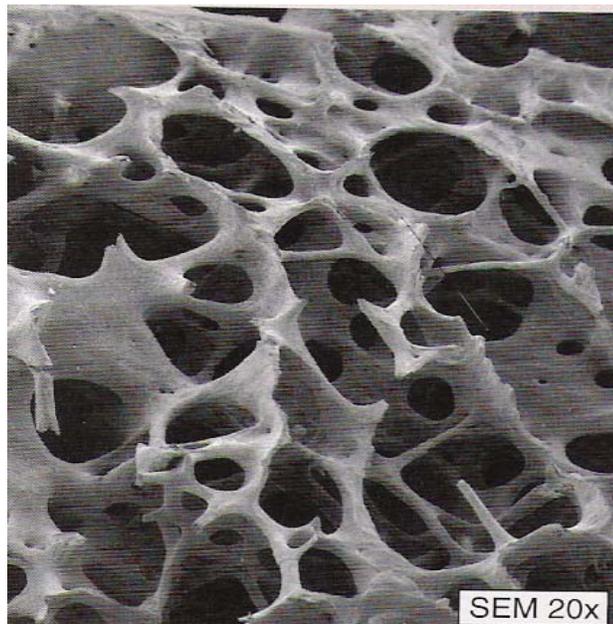


Figure 2.2. Structure of trabecular bone (McKinley & O'Loughlin, 2006)

Trabecular bone's architecture is not made up of haversian systems. It consists of vertical and horizontal lamellae that forms a latticework of struts shaped as plates and rods (Figure 2) (Borer, 2005). Interconnected osteocytes rest in lacunae between the adjacent plates of lamellae allowing nutrient diffusion through the trabeculae. This design allows trabecular bone to resist against compressional forces by distributing the stress throughout the latticework (Downey & Siegel, 2006). Trabecular bone has a large surface area accessible to osteoclastic resorption and is metabolically more active in bone homeostasis than the cortical bone (Marcus, 1987).

### **2.1.1 Bone Cells**

Three main cells found in bone are responsible for bone homeostasis: osteocytes, osteoblasts, and osteoclasts. These bone cells can be classified by their origin, or function as either bone resorbing or formation cells (discussed in section 2.2) critical in the process of bone remodeling.

#### **2.1.1.2 Osteoblasts**

Osteoblasts originate from undifferentiated mesenchymal stem cells found in the marrow (Ducy, Schinke, & Karsenty, 2000). Osteoblasts differentiate during the process of both endochondral and intramembranous bone formation, and will inevitably follow one of three pathways, all critical in bone formation. First, these cells may remain osteoblasts responsible for laying down new bone matrix; second, become embedded in the bone matrix while differentiating into osteocytes; and third, become metabolically inactive elongated bone lining cells found on the surface of most bones in the adult skeleton (Ducy et al., 2000). The primary function of osteoblasts is to produce and synthesize osteoid, which is composed primarily of type I collagen fibers. These

collagen fibers are part of the extracellular bone matrix which accounts for part of bones overall strength. Some osteoblasts will become enveloped in the matrix and rest deep in the bone as osteocytes.

#### **2.1.1.3 Osteocytes**

Osteocytes are spider-shaped mature bone cells derived from osteoblasts that occupy themselves in the lacunae found between the lamellar sheets of matrix. Osteocytes account for more than 90 percent of all cells found in the bone of the human skeleton (Downey & Siegel, 2006). The cellular structure of osteocytes contain tentacle-like cytoplasmic processes that extend through canals called canaliculi allowing a direct pathway to neighboring osteocytes. The pathway permits transfer of fluids, nutrients, and wastes from one osteocyte to the other. Additionally, these cytoplasmic processes contain gap junctions allow the exchange of minerals and fluids between bone and the vascular supply (Downey & Siegel, 2006). In the occurrence of osteocyte death, the surrounding matrix is exposed becoming vulnerable to osteoclast destruction.

#### **2.1.1.4 Osteoclasts**

Osteoclasts are multinucleated cells that differentiate from hematopoietic stem cells, the same stem cells that are pre-cursors for macrophages (Suda et al., 1999). Osteoclasts are responsible for bone resorption. One important feature of osteoclasts is their locomotive ability, which locate to areas susceptible to resorption (Vaananen, Zhao, Mulari, & Halleen, 2000). Additionally, osteoclasts contain two specific membranes, the sealing zone and ruffled border membrane, which are responsible for bone attachment and secretion of components such as hydrochloric acid (HCL) and lysosomal proteases necessary for mineral dissolution and organic matrix degradation (Vaananen et al., 2000).

This process allows minerals stored in the bone matrix to be transported through transport vesicles of osteoclasts into interstitial fluid and eventually the blood. After an osteoclast has completed its matrix degradation, it detaches and migrates to a new site or goes through apoptosis.

## **2.2 Bone Remodeling and Homeostasis**

Bone is a dynamic and active tissue that undergoes continuous turnover and structural micro-cellular change throughout the lifespan. It is estimated that about 20 percent of the human skeleton is replaced every year through bone remodeling (McKinley & O'Loughlin, 2006). Bone remodeling is the compilation of two processes responsible for replacing old bone with new; bone deposition and bone resorption. These processes ensure the mechanical integrity of the skeleton throughout the lifetime and assist in the regulation of calcium homeostasis.

### **2.2.1 Bone Resorption**

Bone resorption is accomplished by osteoclasts. These cells are mobile and are attracted to opportune sites vulnerable to matrix degradation (Vaananen et al., 2000). Once at the site, a specific membrane called the sealing zone forms and attaches to the bone surface. Inside the sealing zone, another specific membrane domain is formed. This membrane, the ruffled border membrane, is responsible for secreting HCL and lysosomal proteases (Vaananen et al., 2000). The HCL converts calcium salts and other minerals into a soluble form which is endocytosed, transported through the cell and exocytosed into the interstitial fluid (Blair, Teitelbaum, Ghiselli, & Gluck, 1989). The lysosomal proteases are responsible for the degradation of the collagen fibers and other organic matrix. The end products of the organic matrix degradation enter the same

transcytotic pathway as the minerals and are exocytosed into the interstitial fluid. Once the bone matrix at the resorptive site has been dissolved and transported, the osteoclast detaches, leaving a resorptive pit or lacuna. Osteoblasts will then migrate to the lacuna and deposit new bone (Downey & Siegel, 2006).

### **2.2.2 Bone Deposition**

Osteoblasts secrete osteoid composed primarily of Type I collagen fibers when differentiating into osteocytes. When new matrix is deposited, an unmineralized band of fibers is laid down known as an osteoid seam (Sandberg, 1991). This band of fibers is constructed in an overlapping fashion accounting for part of bones total strength (Downey & Siegel, 2006). However, in order for the bone matrix to reach its peak strength properties, the new organic matrix must undergo mineralization. Research has shown that after approximately a week of new organic matrix maturity, mineralization occurs (Cowles, DeRome, Pastizzo, Brailey, & Gronowicz, 1998). The minerals are deposited around and within the collagen fibers in a parallel fashion. The enzyme alkaline phosphatase, secreted by osteoblasts, assists in binding the newly formed minerals. The mineralization process occurs abruptly with approximately 60 percent occurring within hours (Downey & Siegel, 2006).

### **2.3 Bone Remodeling Control**

Bone remodeling is regulated primarily by two distinct mechanisms. The first is mediated by the endocrine system in which specific hormones are responsible for regulating the level of calcium and minerals in the blood serum. Blood calcium is vital to normal physiological function. Therefore, the levels available in the blood must remain

homeostatic. Secondly, remodeling is controlled in response to mechanical and gravitational forces placed upon the skeleton.

### **2.3.1 Influence of the Endocrine System**

Several hormones of the endocrine system have an effect on bone remodeling and homeostasis. Of primary concern are parathyroid hormone (PTH), calcitonin, and estrogen. Each plays a significant role in the regulation of remodeling.

PTH is the most important hormone in regulating bone calcium levels (Margolis, Cananlis, & Partridge, 1996). PTH is produced by the parathyroid gland and is released when blood calcium levels decrease below a normal level. The increase in PTH production stimulates osteoclasts to resorb bone, releasing calcium into the blood stream. As blood calcium levels rise, PTH production is extinguished.

When blood calcium levels become too high, calcitonin is released. Calcitonin produced by the thyroid gland targets osteoclast activity by acting as an inhibitor (McKinley & O'Loughlin, 2006). It reduces bone resorption and encourages bone deposition.

The sex hormone estrogen plays an important role in regulating bone growth and remodeling. Following menopause, estrogen levels in women decrease rapidly. This decrease has been correlated with an increase in osteoclastic activity. Several theories exist pertaining to the mechanism by which estrogen effects bone remodeling (Margolis et al., 1996) Currently, the theory that estrogens inhibit the production of Interleuken-6, a cytokine released by osteoblasts, which in turn recruits osteoclasts and stimulates bone resorption (Manolagas & Jilka, 1995). Hormone replacement therapy (HRT) has been previously used as a therapeutic tool to ameliorate bone loss.

### **2.3.2 Influence of Gravitational and Mechanical Stress**

It has been frequently suggested that mechanical loading of bones is vital for normal growth in length and width as well as for maintaining bone strength throughout the life span (Frost, 2003). The relationship between mechanical stress and bone adaptation has been studied for more than a hundred years. Wolff's law states that a bone grows or remodels in response to the demands placed upon it (Wolff, 1892). This has been supported by studies that have assessed bone mass in individuals confined to bed rest (Krolner & Toft, 1983; LeBlanc et al., 2000), who's limb or limbs are immobilized due to injury (Whedon, 1984), and in astronauts exposed to weightless environments (LeBlanc et al., 2000). However, the exact mechanism in which these stresses stimulate new bone formation is not fully understood. More recent studies suggest that stresses or strain placed on the bone create electrical potentials that are detected by the interconnected network of osteocytes deep in the bone as well as on the bone surface that may induce bone formation cells to lay new matrix (Smit, Burger, & Huyghe, 2002).

Bone remodeling is the product of bone resorption and deposition, a tightly coupled process that is regulated by endocrinological factors and mechanical stresses. A balance between resorption and deposition is required to maintain bone strength and quality. However, when bone resorption dominates deposition, a pathological condition leading to increased risk of bone fracture can occur.

## **2.4 Osteoporosis**

Osteoporosis has been referred to as a "silent disease" due to its manifestation and asymptomatic qualities. Many individuals are incognizant of the disease until a fracture occurs in the osteoporotic bone. Osteoporosis is a disease of the skeleton characterized

by low bone mineral density and micro-architectural deterioration (Frost, 2003). Individuals with this disease have weak, fragile bones that are susceptible to fracture. In 2004, the National Osteoporosis foundation estimated that approximately 10 million Americans suffered from osteoporosis and nearly 34 million more had below normal bone density putting them at risk of the disease (National Osteoporosis Foundation, 1999). Of the 10 million already diagnosed with osteoporosis, an alarming 80 percent are women (NIH Consensus Development Panel on Osteoporosis Prevention, Diagnosis, & Therapy, 2001). Fractures associated with osteoporosis have a devastating effect on quality of life and functional ability. Following a hip fracture, the one year mortality rate for older individuals has been estimated as high as 15-20 percent (Schurch et al., 1996) Women are disproportionately affected by osteoporosis mainly due to the hormone estrogen (American College of Sports Medicine, 2004). Once women reach menopause, a dramatic decline in estrogen occurs increasing the risk for osteoporosis.

#### **2.4.1 Risk Factors for Osteoporosis**

Risk factors for the development of osteoporosis can be categorized into four sub-groups: genetic, lifestyle, nutritional, and medical. Genetic risk factors for osteoporosis include Asian or white ancestry, family history, female gender, and petite skeletal frame (Liel et al., 1988). Research exists supporting a relationship between women who exercise excessively (leading to amenorrhea) (Zanker & Swaine, 1998), live a sedentary lifestyle (Nguyen et al., 1994), and who smoke to osteoporosis (Jensen, Christensen, & Rodbro, 1985). Nutritional risk factors include alcoholism, high protein-diet, life-long low dietary calcium intake, lactose-intolerance, and vitamin D deficiency (Hemenway, Colditz, Willett, Stampfer, & Speizer, 1988). Many medical conditions and the

medications used to treat them can cause osteoporosis. These conditions include anorexia nervosa, Cushing's syndrome, Hemolytic anemia, hyperparathyroidism, osteogenesis imperfecta, and long-term use of glucocorticoid medications (Lukert & Raisz, 1990). These risk factors are helpful for doctors when deciding to screen patients for osteoporosis.

### **2.4.2 Diagnosis**

Several methodologies exist for measuring bone mineral density (BMD). These methodologies differ in a number of ways: the extent to which they can isolate densitometric and geometric properties, detect changes in trabecular and cortical bone, the amount of radiation they deliver, and instrument resolution (Genant et al., 1996). Dual energy X-ray absorptiometry (DEXA) is the method of choice in the diagnosis of osteoporosis (Bushardt et al., 2006). DEXA scanning is widely used because it is precise (1-2% variation) (Sievänen et al., 1996), uses low doses of radiation, and can monitor responses to treatment. DEXA scanning requires a skilled, trained operator and is fairly expensive. DEXA technique allows measurement of BMD at specific sites (lumbar spine, femoral neck, and radius) as well as whole body. The World Health Organization defines diagnostic criteria in T-scores to express BMD in standard deviations relative to the normal young adult population mean (National Osteoporosis Foundation, 1999). A T-score of -2.5, or 2.5 standard deviations below the mean, is the specific criteria used for diagnosing osteoporosis. The National Osteoporosis Foundation (1999) recommends BMD testing for all women 65 years of age or older or women who have relevant risk factors associated with the disease.

### **2.4.3 Prevention**

Strategies for preventing osteoporosis should be adopted early in life. Regular weight-bearing physical activity and recommended daily allowances of vitamins and minerals may result in optimal peak bone density (Borer, 2005). Evidence exists that supports women who were physically active in sports or recreation early in life attained higher levels of peak bone mineral density than their less-active counterparts (Borer, 2005; Pocock, Eisman, Yeates, Sambrook, & Eberl, 1986; Teegarden, Proulx, Kern, Sedlock, & Weaver, 1996). Pocock and colleagues (1986) found a significant correlation between femoral neck and forearm bone mineral content (BMC) and the level of aerobic fitness in pre-menopausal women. Other researchers have demonstrated higher peak BMD of the femoral neck and forearm in college-aged women that were involved in sport since childhood compared to their non-sport counterpart (Kontulainen, Kannus, Haapasalo, & Sievanen, 2001). Kontulainen et al. (2001) compared BMC values of the forearm between college tennis players and non-tennis playing sedentary controls finding significantly higher BMC in the tennis group. Furthermore, the same measurements were taken four years later and no significant decreases were found in BMC in the tennis players. Similarly, Teegarden et al. (1996) reported increased BMD of the femoral neck in women (N=204) whom actively participated in high school sports compared to those who did not. These researchers concluded that attaining peak bone mass at an early age through physical activity and sport may be conducive to ameliorating age-induced bone loss later in life. Although increased physical activity and sport in the adolescent years is beneficial in building strong bones, treating individuals with low bone mass through exercise has been inconsistent.

#### **2.4.4 Management of Osteoporosis**

A multitude of treatments exist for low bone mineral density. The primary types of treatment are pharmacological, estrogen or hormone replacement, and exercise training. In depth studies have revealed the efficacy of these treatments. However, some apparent risks are associated with each and currently the role of exercise alone as a treatment is equivocal.

#### **2.4.4.1 Pharmacological Treatment**

Pharmacological treatment has been aimed at either reducing the activity of osteoclasts or increasing the activity of osteoblasts with a net effect of increasing bone formation.

Bisphosphonates are administered to decrease the activity of osteoclasts. Bisphosphonates have two primary mechanisms for decreasing osteoclast activity: bisphosphonates are ingested by osteoclasts and compete with ATP during cellular metabolism causing apoptosis or cell death (Frith, Mönkkönen, Blackburn, Russell, & Rogers, 1997); secondly, bisphosphonates bind and block enzymes specific to cytoskeleton production of the ruffled border responsible for attaching to the bone surface and initiating the resorption process (Vanbeek, Löwik, Van-der-Pluijm, & Papapoulos, 1999). Studies testing the efficacy of bisphosphonates in postmenopausal women are promising (Black et al., 1996; Hosking et al., 1998). The alendronate Fosamax International Trial (FOSIT) observed women for three years in 56 different countries demonstrating a reduction of nonvertebral fracture incidence by 47 percent (Pols et al., 1999). However, bisphosphonate therapy has been associated with some negative side effects. These side effects include abdominal and musculoskeletal pain, nausea, dyspepsia, constipation, diarrhea, and flatulence (Bushardt et al., 2006). Not all

individuals prescribed bisphosphonates will experience a positive outcome and may need an alternative.

Selective estrogen receptor modulators (SERMs) were developed as an alternative to HRT for postmenopausal women. SERMs bind to estrogen receptors acting as either estrogen agonists or antagonists. As an agonist, SERMs stimulate estrogenic responses in bone by decreasing osteoclastic activity resulting in an overall increase in bone formation (Bushardt et al., 2006). Ettinger et al. conducted a three year study with postmenopausal women reporting a reduction in the incidence of spinal fractures with the use of SERMs (1999). An additional advantage of SERMs is the lack of breast and uterine tissue stimulation, which in contrast, has been linked to women on HRT (Ettinger et al., 1999). SERMs have been associated with increased risk of thromboembolic events, and therefore are contraindicated in sedentary individuals and individuals suffering conditions already at risk for thrombosis or embolism (Delmas, Bjarnson, & Mitlak, 1997).

#### **2.4.4.2 Hormone Replacement Therapy**

Bone loss accelerates at the onset of menopause and the first few years thereafter. Due to the sudden decline in estrogen associated with menopause, HRT has been used in the treatment as well as a prophylactic measure in reversing bone resorption and preserving bone mass. Several studies have been published investigating the effects of HRT on bone preservation and fracture risk. One large scale RCT investigated the effect of HRT on fracture risk in 368 postmenopausal women over five years (Komulainen et al., 1998). This study reported a significant reduction ( $P < 0.042$ ) in non-vertebral fractures in the HRT group when compared to the placebo group. These findings were consistent with a similar study conducted using 2016 postmenopausal women on HRT

(N=723) or placebo (N=1293) (Mosekilde et al., 2000). This study found a significant reduction in forearm fracture risk in the HRT group compared to placebo concluding that HRT reduces fractures and should be utilized as the primary prevention for decreased bone mass in postmenopausal women. Although HRT has been shown to be effective in ameliorating bone loss, recent studies have reported alarming implications regarding its use. The Women's Health Initiative (WHI) study was undertaken to investigate the speculation that HRT in postmenopausal was associated with an increased incidence of cardiovascular events and breast cancer (Chlebowski et al., 2003; Pradhan et al., 2002). The WHI found that women on HRT had higher levels of inflammatory markers attributable to cardiac events as well as had an increase in the incidence of irregular mammograms and diagnosed breast cancer (Chlebowski et al., 2003; Pradhan et al., 2002). Due to these adverse effects, HRT may not be viable for all postmenopausal women and other optional therapies such as exercise may be warranted for ameliorating bone loss associated with osteoporosis.

#### **2.4.4.3 Exercise in the Management of Bone loss**

The benefits received from exercise are numerous and well established for most populations. At menopause, women may experience a cohort of health issues such as a decline in aerobic capacity, BMD, muscle mass and strength, as well as weight gain increasing the risk for metabolic diseases (Sowers & LaPietra, 1995). However, the topic that has been given considerable attention in research and in medical practice is menopause-related loss of bone. Due to its osteogenic effects, exercise has been suggested as a therapy for the management of bone loss and research investigating this topic has produced mixed results (American College of Sports Medicine, 2004). RCTs

investigating the efficacy of exercise in ameliorating bone loss have failed to produce definitive conclusions due to inconsistencies in exercise prescription and analysis of outcome measurements (Borer, 2005). Traditionally, exercise regimens aimed at increasing BMD or attenuating its loss have consisted of activity that provides a bone loading stimulus greater than that experienced through everyday activity (American College of Sports Medicine, 2004). Studies utilizing weight-bearing exercise such as walking, jogging, or jumping and resistance training or a combination has had some success; however, the most beneficial mode is still being debated.

#### **2.4.4.3.1 Effects of Walking on BMD**

Walking has been recommended for decades as an easy and inexpensive mode of exercise. Investigations into the effects of walking on BMD preservation are not in agreement. Hatori and colleagues (1993) conducted a study on walking and BMD using 33 postmenopausal women who were assigned to one of three groups: 1) control group (n = 12), 2) above anaerobic threshold (n = 12), and 3) below anaerobic threshold (n = 9). The exercise groups were prescribed 30 minutes of walking three days a week for seven months at their respective intensity levels. Pre and post BMD measurements were obtained through DEXA of the lumbar spine. Results indicated seven months of walking at or above anaerobic threshold (70-80%  $VO_{2max}$ ) produced a significant gain in lumbar spine BMD. There was a decrease of BMD in the exercise group walking below threshold; however, a larger decrease was observed in the control group. The researchers concluded that changes in BMD between groups seemed to be intensity-dependent and that walking at higher intensities may be more beneficial. Nelson and Colleagues (1991) found similar results when implementing higher intensities. Exercise subjects (n = 18) in

their one year study walked at a prescribed intensity of 80 percent of maximum heart rate (HRmax) four days per week. Trabecular BMD of the lumbar spine, measured by computed tomography, increased by a half percent in the exercise group over 52 weeks. In contrast, the control group's BMD decreased by seven percent. These researchers were able to show modest gains in BMD through walking interventions (Hatori et al., 1993; Nelson et al., 1991). Others are not in agreement (Cavanaugh & Cann, 1988; Ebrahim et al., 1997). Cavanaugh and Cann (1988) implemented a similar exercise protocol as Nelson et al. (1991) investigating 52 weeks of progressive brisk walking (65-80% HRmax) and its effects on trabecular lumbar BMD using computed tomography. The exercise group (n = 8) walked three days per week, initially for 15 minutes per day progressing to 40 minutes over the 52 week duration. In contrast to Nelson et al., post BMD measurements revealed a five percent decrease in both the exercise group and the control group. Additionally, Ebrahim and colleagues (1997) conducted a two year investigation which found that brisk walking failed to significantly increase lumbar and femoral neck BMD measured by DEXA in post-menopausal women. Furthermore, an increase in the risk of falls was observed in the exercise group. Walking as a mode of exercise to increase BMD in postmenopausal women may not provide a sufficient mechanical stimulus to bone. Exercise that produces greater stimulus such as jogging or jumping may be more beneficial.

#### **2.4.4.3.2 Effects of High Ground Reaction Force Type Exercise on BMD**

Exercise that produces high ground reaction forces (GRF) such as jogging, jumping, dance, and stair climbing have been postulated to increase BMD in postmenopausal women. However, research investigating this topic has produced

conflicting results. Chow and colleagues (1987) conducted a one year study on the effects of 30 minutes of jogging and aerobic dance (80% HRmax) three days per week on bone mass determined by neutron activation analysis in postmenopausal women. Results indicated an increase in bone mass of the exercise group compared to control. Similar results were found in an 18 month intervention investigating the effects of stair-stepping, jogging, and graded treadmill exercises (75% VO<sub>2max</sub>) on BMD measured by DEXA in early menopausal women (Heinonen et al., 1998). Heinonen and colleagues found that the exercise group was able to significantly maintain BMD of the femoral neck compared to the control. In contrast, some researchers have reported no improvements in BMD with similar exercise interventions (Bravo et al., 1996; Martin & Notelovitz, 1993). Bravo and colleagues conducted a one year exercise study in post menopausal women measuring femoral neck BMD as one of the primary outcomes. Participants were randomly allocated to either an exercise or control group. The exercise group participated in 60 minutes of weight-bearing exercise such as bench-stepping and aerobic dance three times per week. No differences in femoral neck BMD were reported between the exercise and control groups. These findings were supported through the work of Martin and Notelovitz (1993). Their research study implemented treadmill jogging between 70 and 85 percent HRmax three days per week for 12 months. Lumbar spine BMD was assessed using dual-photon absorptiometry in both the exercise and control group at baseline and 12 months. No differences were found in lumbar BMD between groups. One study investigated the effects of vertical jumping on BMD in post-menopausal women (Bassey et al., 1998). Exercise subjects participated in a one year vertical jumping program that produced GRF's approximately four times their weight six times per week for 50 jumps

per day. Pre and post lumbar and femoral neck BMD measurements were obtained through DEXA. After 12 months, no differences in BMD were found between the exercise and control group.

#### **2.4.4.3.3 Effects of Resistance Training on BMD**

Resistance or strength training has been suggested as a therapy for postmenopausal bone loss due to the musculoskeletal strain characteristics associated with it. Investigating this hypothesis, Nelson and colleagues (1994) designed a one year RCT of high-intensity strength training in postmenopausal women. Forty participants were randomly assigned to either a control or exercise group. The exercise group completed 45 minutes of strength training at 80 percent one repetition maximum (1RM) two days per week for 52 weeks. Strength training consisted of large muscle group exercises focusing primarily on bone sites being measured for BMD changes. BMD of the lumbar spine and femoral neck were measured using DEXA. Significant increases of both the lumbar spine and femoral neck were found in the exercise group compared to control. Similar results were reported in a study investigating the effects of resistance training in postmenopausal women over two years (Kerr et al., 2001). The exercise protocol for this study consisted of five upper-body and four lower-body exercises that targeted skeletal sites to be measured. The exercise group was prescribed three sets of eight repetitions 30 minutes per day three days per week at an eight repetition maximum intensity. BMD of the femoral neck and lumbar spine were measured using DEXA. Results indicated maintenance of BMD in the lumbar spine as well as an increase at the femoral neck in the strength group. In contrast to the findings of these studies, others have reported no significant changes in BMD with strength training trials (Bemben et al.,

2000; Maddalozzo & Snow, 2000). Bemben and colleagues (2000) conducted a 24 week trial investigating musculoskeletal responses to different intensities of resistance training in postmenopausal women with BMD as a primary outcome. Subjects were randomly assigned to one of three groups: 1) high-intensity, 2) low-intensity, or 3) control. The high-intensity resistance training group was prescribed 12 exercises (80% 1RM) that produced strain on skeletal sites relevant to BMD measurements three days per week. Subjects completed three sets of each exercise performing eight repetitions each set. The low intensity group followed the same guidelines with exception of intensity (40% 1RM) and repetitions (16). BMD of the lumbar spine, femoral neck, and total body was assessed using DEXA. Neither the high or low intensity resistance training groups increased BMD at any sites. Additionally, a trend for the high intensity group to decrease total body BMD was observed. One RCT implemented a single site specific exercise and measured its effects on lumbar BMD (Revel, Mayoux-Benhamou, Rabourdin, Bagheri, & Roux, 1993). The training group performed 60 repetitions of seated hip flexion in each leg with a five kilogram sand bag placed atop of the knee every day for one year. BMD measured by computed tomography revealed no differences in the lumbar spine between groups. However, the control group had a greater decrease in BMD after one year.

#### **2.4.4.3.4 Effects of Combined Exercise on BMD**

Debate over which mode of exercise is more efficacious for improving BMD has gained considerable attention. Resistance training as well as exercise producing high GRF's has demonstrated increases in BMD (Chow et al., 1987; Nelson et al., 1994). Several researchers have investigated the effects of exercise utilizing both resistance training and different modes of weight-bearing exercise during the same session and its

effects on BMD in postmenopausal women (Cussler et al., 2003; Kemmler et al., 2003; Milliken et al., 2003). Cussler and colleagues (2003) set out to determine if a relationship existed between the amount of weight lifted and the amount of change in BMD over one year of progressive resistance training along with other weight-bearing exercises in postmenopausal women. Exercise subjects trained three days per week on non-consecutive days for 60-75 minutes per session. Resistance training was done using a mix of free weights and machines, targeting muscle groups that attached on or near BMD measuring sites. Women completed two sets of six to eight repetitions at 70-80 percent of 1RM, progressively increasing weight throughout the study in order to maintain the prescribed intensities. Additionally, subjects participated in a circuit of weight-bearing activities such as stair-climbing and box jumping. The total amount of weight lifted was recorded for each individual throughout the whole year. An increase in BMD at the femoral trochanter was observed in the exercise group and was correlated with the amount of weight lifted. Increases in BMD were also reported in the Erlangen Fitness Osteoporosis Prevention Study (Kemmler et al., 2003). Kemmler and colleagues conducted a large controlled trial to investigate the effects of combined resistance and weight-bearing exercise on BMD in postmenopausal women. The exercise subjects participated in two sessions of supervised training and two at home sessions for 14 months. The supervised sessions consisted of resistance exercise and aerobic weight-bearing activity lasting between 60 and 75 minutes. The resistance training aspect of the intervention followed a periodized form with respect to intensity and duration. Weight-bearing exercises followed suit, as they too increased in intensity and difficulty over the duration. Lumbar spine, femoral neck, and radial BMD were measured via DEXA.

Differences were found in the exercise group with respect to lumbar BMD. Additionally, femoral neck BMD was better maintained by the exercise group and decreased in the control. Unlike these authors, Milliken et al. (2003) reported no changes in BMD using a similar protocol. Milliken and colleagues implemented 12 months of resistance training and weight-bearing exercises in a group of postmenopausal women. Pre and post BMD of the total body, lumbar spine, and femoral neck was measured by DEXA. The exercise protocol consisted of 20 minutes of weight-bearing activity (50-70% HRmax) and 35 minutes of resistance exercise (70-80% 1RM) targeting major muscle groups three days per week on non-consecutive days. No differences were found at any site in the exercise group compared to control. However, the exercise group showed a slight trend of better BMD maintenance in whole- body and femoral neck BMD.

Research studies using both weight-bearing and resistance exercise in the same session have produced favorable outcomes (Cussler et al., 2003; Kemmler et al., 2003). These studies individual training sessions were lengthy and each type of training was done at separate times in the session. A protocol that utilizes both types of training concurrently in circuit form to minimize the duration of each session may improve or maintain BMD, which will be discussed in the following chapters.

## CHAPTER THREE

### METHODS

#### 3.1 Participants

Ten healthy, sedentary postmenopausal women ( $56.5 \pm 7.5$  yrs. (mean  $\pm$  SD)) volunteered for the study. Exercise subjects were recruited from a local fitness club who recently joined but had not yet commenced exercising. Control subjects were recruited from a sample of postmenopausal women that had previously volunteered for a non-exercise study at Wichita State University. Menopause was defined as a self-reported lack of menstruation greater than one year. Participants were excluded if taking medications that affect bone metabolism or had any known fractures associated with osteoporosis. Additionally, participants were excluded if they were sedentary for less than a year. Participants read and signed an informed consent form prior to commencement of the study (see Appendix). A Physical Activity Readiness Questionnaire (PAR-Q) (see Appendix) (Canadian Society for Exercise Physiology, 2002) was distributed to and completed by all participants. Each participant underwent baseline and post 12 week measurements. Participants were assigned to either an exercise group (EX) (n=5) or control group (CON) (n=5). Baseline anthropometric data for each group is presented in Table 4.1. The study protocol was approved by the Wichita State University Institutional Review Board.

#### 3.2 Procedures

##### 3.2.1 Exercise Protocol

The EX group participated in 12 weeks of hydraulic resistance circuit training (HRCT) three days per week on non-consecutive days. Warm up was done on a cycle

ergometer for five minutes. The circuit consisted of nine hydraulic resistance machines (Fit Express Inc., Shannon, MS) that targeted the main muscle groups: chest-press/seated row, bicep flexion/tricep extension, shoulder press/lat pull, knee extension/knee flexion, hip abduction/hip adduction, abdominal flexion/back extension, rotary torso, seated leg press, and hydraulic assist dead-lifts. Additionally, nine aerobic stations were interspersed between each hydraulic machine. The aerobic stations consisted of five jogging pads and four cycle ergometers. The jogging pads are composed of soft plastic and hard foam which rest four inches above the ground. Participants were encouraged to jog, dance, or perform step-ups while at the jogging pad stations. Each station was utilized for 40 seconds at which time a queue was sounded alerting the participants to move to the next station. Participants were instructed to complete the circuit twice, which took approximately 30 minutes. Participants were encouraged to reach a prescribed intensity of eight to ten repetition maximum (8-10RM) for resistance exercises and a rate of perceived exertion (RPE) of 12 on the Borg scale (6-20) (Borg, 1970) for aerobic stations. Resistance was controlled by settings on the hydraulic machines (1-6; 1=least resistance 6=highest resistance) which control the diameter of the aperture responsible for allowing hydraulic fluid to pass. Initially, the hydraulic machines were set at the # 2 setting (weeks 1-4) and increased to settings 3 (weeks 5-8) and 4 (weeks 9-12) as time progressed. All exercise sessions were monitored by undergraduate exercise science students who were instructed to give encouragement and aid in prescribed intensity compliance. The control group was instructed to continue their normal physical activity and dietary habits.

### **3.2.2 Assessment of BMD**

Whole body BMD ( $\text{g}/\text{cm}^2$ ) was determined using dual energy x-ray absorptiometry (DEXA) (Hologic QDR 4500, Waltham, Massachusetts) technique at baseline and 12 weeks. All scans were performed and analyzed by the same technician at the Wichita State University Human Performance Laboratory. Standard protocol for whole body BMD scan technique set forth by the manufacturer's guidelines was followed. DEXA calibration was performed using a spine phantom prior to each participant's whole body scans. Variability for whole body BMD technique (1.2%) was previously determined at Wichita State University Human Performance Laboratory.

### **3.2.3 Statistical Analysis**

Data analyses were conducted using the statistical software program SPSS (SPSS Inc., Version 15, Chicago, Illinois). Means and standard deviations were calculated for all group and individual data. Independent t-tests were used to determine group baseline differences of age, height, weight, body mass index (BMI), and BMD. Repeated measures ANCOVA was used to compare the change from baseline to 12 weeks in whole body BMD in EX versus CON with baseline BMD as a covariate. Significance level for t-tests and group by time interactions was set at  $P \leq 0.05$ . All data are presented as the mean  $\pm$  SD.

## CHAPTER 4

### RESULTS

#### 4.1 Subjects

Nineteen participants were originally recruited to participate in the study. Seven participants using HRT and two using glucocorticoids were excluded. Ten sedentary postmenopausal women were assigned to either an EX group (n=5) or CON group (n=5). All ten participants that volunteered and were accepted completed the 12-week study with no complications. The EX participants had good adherence (94%), completing 170 of 180 exercise sessions. Baseline and 12-week anthropometric data for both groups are presented in Table 4.1 and 4.2. No significant differences existed in baseline anthropometric data.

TABLE 4.1

BASELINE ANTHROPOMETRIC DATA FOR EX AND CON

Group	EX (n=5)	CON (n=5)
Height (m)	1.61 ± .06	1.62 ± .08
Weight (kg)	69.44 ± 9.32	77.61 ± 16.01
BMI (weight/[height] <sup>2</sup> )	27.08 ± 4.71	29.25 ± 4.14

Values are shown as mean ± SD

TABLE 4.2

12-WEEK ANTHROPOMETRIC DATA FOR EX AND CON

Group	EX (n=5)	CON (n=5)
Height (m)	1.61 ± .06	1.62 ± .08
Weight (kg)	67.49 ± 10.31	78.33 ± 15.99
BMI (weight/[height] <sup>2</sup> )	26.28 ± 4.79	29.54 ± 4.29

## 4.2 BMD

Independent samples t-test revealed baseline difference in whole body BMD (EX =  $1.08 \pm .07$ , CON =  $1.16 \pm .06$  g/cm<sup>2</sup>) between groups (Table 4.3). Due to this difference, a repeated measure ANCOVA was performed to analyze group by time interactions using baseline BMD as a covariate. Repeated measures ANCOVA revealed no significant difference (P = 0.054) for whole body BMD change over 12 weeks between groups. Table 4.3 presents the changes in BMD over time for both EX and CON groups. Individual BMD data are presented in Table 4.4 and 4.5. Although there were no statistically significant changes in BMD, the trend indicated an increase in BMD for the EX group (3%) and a slight decrease for the CON group (-1%) (Figure 4.1).

TABLE 4.3

BMD VALUES FOR EX AND CON AT BASELINE AND 12 WEEKS

Group	BMD (g/cm <sup>2</sup> ) Baseline	BMD (g/cm <sup>2</sup> ) 12Weeks
EX (n=5)	$1.08 \pm .07^*$	$1.11 \pm .07$
CON (n=5)	$1.17 \pm .05$	$1.16 \pm .06$

\* Significantly different (P $\leq$ 0.05) from CON at baseline. Values are shown as mean  $\pm$  SD

TABLE 4.4

INDIVIDUAL BMD VALUES FOR EX AT BASELINE AND 12 WEEKS

Subjects	BMD (g/cm <sup>2</sup> ) Baseline	BMD (g/cm <sup>2</sup> ) 12Weeks
1	1.17	1.18
2	1.12	1.15
3	1.02	1.05
4	1.11	1.15
5	1.01	1.01

TABLE 4.5

INDIVIDUAL BMD VALUES FOR CON AT BASELINE AND 12 WEEKS

Subjects	BMD (g/cm <sup>2</sup> ) Baseline	BMD (g/cm <sup>2</sup> ) 12Weeks
1	1.23	1.23
2	1.19	1.21
3	1.13	1.10
4	1.17	1.15
5	1.12	1.12

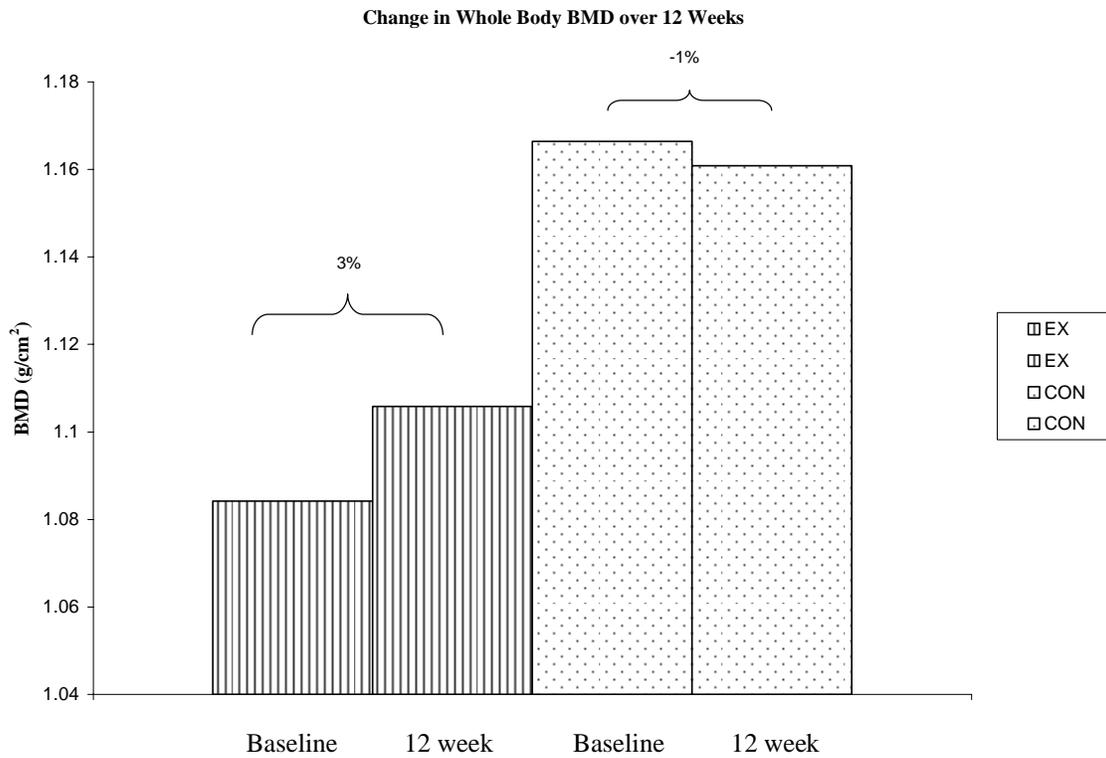


Figure 4.1. Changes in whole body BMD determined by DEXA over 12 weeks. Connecting bars are % change.

## **CHAPTER 5**

### **DISCUSSION**

To the best of the author's knowledge, this is the first intervention utilizing hydraulic resistance circuit training to examine its effects on BMD in postmenopausal women. Research investigating the effects of combined aerobic weight-bearing exercise and resistance training on BMD in postmenopausal women has been conducted by past authors (Chubak et al., 2006; Jessup et al., 2003; Kemmler et al., 2003; Kerr et al., 2001; Milliken et al., 2003). However, this study implemented these types of exercise concurrently in circuit form. The afore mentioned authors' participants performed weight-bearing exercise and resistance training at separate times during the sessions which resulted in a duration of an hour or longer. Additionally, the present study used hydraulic resistance machines whereas the other researchers used more traditional types of resistance such as free weights or pulley machines. The topics of this discussion are four-fold: to address the use of hydraulic resistance in other special populations; to compare the results of the present study with studies using similar modes of exercise, to compare the adherence of the present study with others of similar exercise, and to examine the safety of the present exercise protocol to others that are similar.

#### **5.1 Hydraulic Resistance Circuit Training**

Hydraulic resistance machines use fluid for resistance through a full range of motion (Nerli & Viespi, 1997). These machines feature cylinders with a dial that allows resistance to be adjusted from settings of one through six. The dial controls the aperture inside of the cylinder which either opens or closes to regulate the amount of fluid that passes through with each movement. Additionally, this type of resistance only allows

concentric phase contractions in a push and pull fashion minimizing muscle soreness and possibility of orthopaedic injury associated with eccentric contractions (Suomi et al., 1995). Due to the nature of its resistive properties, hydraulic resistance training has been suggested as a viable option for many clinical populations that may have contraindications to resistance exercise.

Studies have examined the use of hydraulic resistance circuit training in clinical populations (Cooney & Walker, 1986; Selig et al., 2004; Suomi et al., 1995) and found positive outcomes. Selig and colleagues (2004) examined the effects of moderate-intensity hydraulic resistance circuit training in a sample of chronic heart failure (CHF) patients. CHF patients in the EX group performed three months of HRCT three days per week and were continuously monitored by ECG telemetry. Intensity of training was considered moderate as determined by heart rate. At the end of three months, the EX group had significant improvements in forearm blood flow, muscle strength and endurance, and exercise tolerance determined by graded exercise testing. Additionally, no patients dropped out of the study due to adverse effects experienced during the training. Favorable outcomes with no adverse effects were also found in a study that used HRCT in a group of men with mental retardation. Suomi and colleagues (1995) conducted a 12 week study investigating the effects of HRCT on strength in men with mental retardation. The subjects in the EX group participated in 12 weeks of HRCT three days per week. Initially, subjects performed two sets of each exercise with an intensity of 10RM. Resistance and the number of sets increased at two week intervals. Each exercise session lasted approximately 30 minutes. After 12 weeks of HRCT, the EX group significantly increased lower leg strength compared to controls. No subjects were injured

or withdrew from the study. The researchers conclusions were three fold: 1) HRCT was effective at increasing lower leg strength in individuals with mental retardation, 2) adherence to the program may be contributed to ease in the use of the equipment, and 3) HRCT may be a mode of exercise training that requires minimal dependence upon others to complete. Similarly, Cooney and Walker (1986) suggested that hydraulic resistance exercise may be a viable alternative to increase independence in patients with spinal cord injury. Ten otherwise healthy subjects with chronic traumatic spinal cord injury were recruited to participate in 12 weeks of hydraulic resistance exercise three days per week to assess its effects on cardiorespiratory fitness. The protocol was of progressive nature and increased in intensity and volume as time progressed. Intensity was initially set at 60 percent of HRmax measured by ECG and increased to 90 percent by the end of the study. At week one, participants completed one set of each exercise and increased to three sets by the end of week 12. Each session took approximately 30 minutes to complete. Although there was no control group, participants improved cardiorespiratory fitness on average by 28 percent. The researchers concluded that hydraulic resistance exercise is effective at increasing cardiorespiratory fitness and provides an alternative mode of exercise to existing training programs for disabled populations. Additionally, hydraulic resistance exercise may assist in improving independence of individuals with spinal cord injury. To the author's knowledge, no research has been published on the effects of HRCT on BMD in postmenopausal women. Other clinical populations where safety and adherence to exercise programs are critical have found positive outcomes when using HRCT.

## **5.2 HRCT and BMD**

The present study implemented 12 weeks of hydraulic resistance circuit training in a group of postmenopausal women to investigate its effects on BMD. Currently, the American College of Sports Medicine (2004) recommends 30 to 60 minutes of moderate to high intensity weight-bearing endurance activity combined with resistance training three to five days of the week for preserving bone mass in adulthood. The current study's protocol followed these guidelines by combining hydraulic resistance training with weight-bearing activity such as jogging and dancing concurrently in circuit form. The present study found that whole body BMD did not significantly increase over 12 weeks in the EX group, but that the EX showed a trend toward slightly increasing or maintaining BMD compared to the CON who showed a slight but non-significant decrease in BMD (Figure 4.1). It is difficult to compare the results of this study to others due to a lack of research studies utilizing hydraulic resistance circuit training or any type of circuit training that utilized both resistance and weight-bearing exercise concurrently. However, research does exist in which bi-modal interventions were used but at separate times in the session. Wide variations in BMD assessment, prescription of exercise, length of study, and poorly replicable methods of these studies have made comparison between them difficult. The efficacy of HRT to stop bone loss and reduce fractures in postmenopausal women has been previously documented (Mosekilde et al., 2000). However, use of HRT is associated with increased risk for cardiovascular events and breast cancer (Chlebowski et al., 2003; Pradhan et al., 2002). The present study chose to exclude participants taking HRT because of its adverse effects as well as its effects on BMD. Therefore, only studies that did the same will be referred to in this discussion.

The present study demonstrated a trend of the EX to increase BMD after 12 weeks of HRCT compared to the control. This finding is supported by others (Chubak et al., 2006; Jessup et al., 2003; Kemmler et al., 2003) who studied the effects of resistance training combined with aerobic weight bearing exercise on BMD in postmenopausal women. In contrast, Milliken and colleagues (2003) reported no differences in BMD after six months of bi-modal exercise between the EX and CON group. In agreement with Milliken et al., Kerr and Colleagues (2001) reported no changes in BMD as well. Kerr et al. non-significant find may be attributed to the exercise protocol they implemented. These authors failed to progress the resistance aspect of their protocol and used cycling as the aerobic component. This protocol may not have provided a sufficient bone-loading stimulus. It is important to note that although the present study found a trend for the EX to increase, this increase was not significant. The authors were not expecting to find a significant increase in BMD, but hypothesized that an attenuation of bone loss would be apparent in the EX group. The current study was only 12 weeks in duration while others who found significant changes in BMD ranged from 6-14 months (Chubak et al., 2006; Jessup et al., 2003; Kemmler et al., 2003). Bone adaptations to mechanical stress are relatively slow in humans. One remodeling cycle can take three to four months to achieve a new steady state bone mass (Mundy, 1999). The present study may have not been sufficient length to measure the full response of bone to the training program implemented. Additionally, the number of participants in the present study was small (n=10). Small numbers of participants may have limited the statistical power in regards to finding significant differences. Jessup and colleagues (2003) employed the least amount of subjects (n=18) and still found significant differences between EX and CON.

Others that found significant increases had substantially larger participant numbers (Chubak, 2006, n=173; Kemmler, 2003, n=100) than the present study. However, if more participants were involved in this study and followed the current trend, a statistically significant difference may have been found.

### **5.3 Program Adherence, Attrition, and Safety**

Subject adherence in any exercise program is vital to understanding the effects and physiological adaptations it may produce. Therefore, the present study designed an exercise program to meet the following objectives: it should minimize the risk of orthopaedic injury; the time requirements should be feasible; and it should be available to the community. No participants withdrew from the present study and no injuries were sustained in the EX group over the 12 week duration. Additionally, the EX subjects adherence to the exercise program was high, with an overall compliance rate of 94 percent. Others have reported substantial drop-out rates and lower compliance than the present study (Chubak et al., 2006; Kemmler et al., 2003; Kerr et al., 2001; Milliken et al., 2003) and injuries related to training have occurred (Kemmler et al., 2003; Kerr et al., 2001).

A common barrier to participation in exercise training is time constraints. Kemmler and colleagues (2003) reported 21 drop-outs in their study with a compliance rate of 75 percent. The most common reason participants gave for either missing exercise sessions or dropping out was due to either time constraints or reported as study-related problems. Exercise sessions in the study by Kemmler et al. took approximately 60-70 minutes to complete and required the participants to learn many different modes of resistance exercise such as pulley machines, free weights, resistive bands. Additionally,

one participant withdrew due to a fracture sustained during an exercise session. This was a familiar problem found in the study conducted by Kerr and colleagues (2001). Thirteen participants in their study withdrew after six months due to time constraints. Exercise compliance was approximately 90 percent at six months but declined to 74 percent by the end of the study. Each exercise session was an hour long. Three additional participants withdrew due to injury either sustained during exercise or from a pre-existing condition that was made worse. Two studies reported drop-out rates (Chubak et al., 2006; Milliken et al., 2003) but did not report reasons for withdraw. Chubak and colleagues (2006) experienced nine drop-outs in the EX group at three months and Milliken and colleagues (2003) reported 10 drop-outs but neither studies reported compliance rates. Each of these studies had exercise sessions lasting between 60 and 75 minutes. By implementing resistance training and aerobic weight-bearing activity concurrently in circuit form, the present study was able to develop an exercise program that could be completed safely in a time-efficient manner. This may have contributed to the high compliance rates as well as no participant withdraws. However, the present study was 12 weeks in duration whereas the afore mentioned studies were six months or greater. It is possible that a longer study duration would have resulted in less favorable adherence and attrition rates. Additionally, the exercise program still met the criteria proposed by the American College of Sports Medicine (2004) for bone health in adulthood.

#### **5.4 Conclusions**

The following summarizes the main conclusions of this research:

1. 12 weeks of hydraulic resistance circuit training did not significantly increase whole body bone mineral density in postmenopausal women. However, the

trend indicated an increase in BMD for the exercise group. These results were probably confounded by the small population and insufficient study duration employed in this study.

2. Hydraulic resistance circuit training is a safe and time-efficient mode of exercise for postmenopausal women at risk for osteoporosis.

## **5.5 Recommendations for Further Research**

This study has raised further questions into the effects of exercise on bone mineral density in postmenopausal women. The results of this study suggest that a safe and relatively short duration exercise protocol utilizing both hydraulic resistance and weight-bearing exercise concurrently in circuit form may produce positive outcomes in bone health for postmenopausal women. Most exercise programs that have been shown to be effective in increasing bone mass or minimizing its loss has used resistance and weight-bearing exercise in the same session but not concurrently. As a result, exercise sessions are time consuming which may lead to low adherence levels and high drop-out rates in this population. Future research with this mode of exercise needs to focus on employing larger samples of postmenopausal women and longer study durations. The relatively short 12-week duration of this study and small sample size limited the statistical information necessary to provide definitive conclusions on the efficacy of HRCT to increase BMD in postmenopausal women.

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## **APPENDIX**

## **EFFECTS OF HYDRAULIC STRENGTH TRAINING AND BALANCE ON PHYSICAL PERFORMANCE IN OLDER ADULTS**

**PURPOSE:** You are invited to participate in a study designed to improve your balance and strength. We hope to determine how an exercise program affects strength functional ability, mobility, and balance control in older individuals. We want to do this because it will help improve your fitness. Knowledge gained from this project will also assist exercise and medical professionals in prescribing activity and in helping older individuals maintain their independence.

**PARTICIPANT SELECTION:** You were selected as a possible participant in this study because your age is within the range in which we are interested. We will recruit approximately 50 people to participate in this project.

**EXPLANATION OF PROCEDURES:** If you decide to participate, you will be asked to perform a series of tests and then to repeat the tests after approximately 12 weeks, 6 months, and again after 12 months. These tests are designed to measure your strength, balance, physical functional ability, and body composition. The strength, endurance, and flexibility tests will be done at 50 plus Fitness and the balance and body composition test will be conducted at the WSU Human Performance Laboratory (214 Heskett Center). We will ask you to complete a balance questionnaire and stand on a balance platform and on a piece of foam while your balance is assessed. During this test you may experience a fear falling, thus a spotter and sturdy chair will be near by to grab if a temporary loss of balance is encountered. You will also perform a timed test where they will be asked to stand from a chair, walk 8 feet, and return to the chair. Your lower body flexibility will be assessed while sitting in a chair and reaching towards your toes and strength will be assessed while rising from a chair and sitting down for 30 seconds. Your walking ability will be assessed by having you walk around a 50-yard perimeter for six minutes. Your upper body strength will be assessed while lifting a dumbbell (5 pounds for women, 8 pounds for men) for 30 seconds and flexibility by placing your arms behind your back. Your body composition (i.e., muscle, fat, bone) will be assessed with a full body DEXA scan. The DEXA emits a low radiation dose that presents minimal exposure to you - about one-tenth of what you would get in a chest x-ray. If you have had an x-ray exam or nuclear medicine isotope study within the last 7 days, the DEXA assessment will be postponed until 7 days since the exam has passed. Testing procedures will take approximately one hour to complete.

You may also participate in a circuit weight training program to improve your fitness. Exercise sessions will be conducted three times a week at *50 Plus Fitness* on the corner of Central and Woodlawn in Wichita. Each session will be performed at a low to moderate intensity and last approximately 30 to 45 minutes. These sessions will be instructed by the researcher with the help of two WSU graduate students. The program will consist of the following activities: (a) strength training, using hydraulic equipment; and (b) balance training while standing on the floor, foam mats, and other training devices.

**DISCOMFORT/RISKS:** You may experience some mild soreness in your legs or arms one to two days after the strength testing or training sessions. This is a normal response when we use our muscles in a manner different from our usual routine. This soreness usually does not last for more than one or two days. There is a slight risk of a muscle pull that may occur while performing the test. By following proper warm-up and stretching procedures, this risk will be minimized. Finally, there is a very minimal risk of more serious medical complications such as heart attack or sudden death. This project is intended for healthy, asymptomatic men and women over the age of 50 years. Individuals with uncontrolled hypertension (>160/90 mmHg), arrhythmia, coronary artery disease, overt musculo-skeletal pathology, and other pathologies cannot be included in this study. Participation in a well-organized and individualized exercise program greatly reduces these already small risks. This is a very minimal risk for which you have already been screened prior to being accepted into the study, either by our questionnaire or by your physician's approval. Moreover, studies involving exercise have concluded that inactive people are at a much greater health risk at rest than active people are during exercise.

There exists the possibility of certain changes that may occur during the DEXA assessment. The parts of your body that will receive the most radiation exposure are the skin, although your whole body will be exposed to radiation. The radiation exposure is small compared with other commonly accepted medical

procedures such as chest x-rays, lumbar spine x-rays, and dental bite wings. In fact, patient dose is even smaller than exposure to natural background radiation. The amount of radiation that you will receive from this procedure is equivalent to a uniform whole-body exposure of 0.1 mrem, with the exposure being 2.4-4.8 mrem per hip (femur) and spine scan. The typical radiation exposure from a normal chest x-ray is 30 mrem. Although you will a small amount of exposure, the risk from radiation exposure of this magnitude is too small to be measured directly and is considered to be negligible when compared with other everyday risk. We also want to make sure that the amount of radiation that you have received in the past year is within safe limits, so if you have had an x-ray, let us know. If you have recently undergone CT (Computerized Tomography), PET, fluoroscopic, or nuclear medicine studies within the past year, you cannot obtain DEXA assessment. Other changes during DEXA assessment may include but are not limited to motion sickness (lightheadedness, nausea) due to the mechanical movement of the DEXA machine or muscle discomfort due to body position. The Radiation Safety Officer (Dr. Glendon Miller, 978-3347) of Wichita State University can provide you with more information about radiation exposure if you are interested.

**BENEFITS:** Many studies have found that muscular weakness and poor balance is a major limitation in gaining and maintaining physical independence. This program is being implemented in order to see if it will improve your balance and strength, and if this improvement will lead to a more independent lifestyle. In order to determine if this program is performing its purpose, we are asking you to participate in these assessments. By participating in this program you will gain valuable insights into your strength, balance, mobility, and risk for falling. The DEXA assessment will provide information pertaining to your bone mineral content, bone mineral density, and body composition. The information received is not intended to diagnose osteopenia, osteoporosis, and/or obesity. It is suggested that you share the information obtained from you DEXA assessment with your primary care physician. You will be given an additional copy of all assessment information for the purpose of physician consultation.

If you take part, your results will be combined with other participants so it will not be possible to identify your responses in a published report; your name will not be directly associated with any of the results. The information gained in this study will be particularly beneficial to exercise professionals, medical professionals, and the participants to develop appropriate training programs. This is an original study that has the potential to report an outcome that would be very beneficial to the general public and have a significant contribution to the scientific field.

**CONFIDENTIALITY:** Any information obtained in this study in which you can be identified will remain confidential and will be disclosed only with your permission.

**COMPENSATION OR TREATMENT:** Wichita State University does not provide medical treatment or other forms of reimbursement to persons injured as a result of or in connection with participation in research activities conducted by Wichita State University or its faculty, staff, or students. If you believe that you have been injured as a result of participating in the research covered by this consent form, you can contact the Office of Research Administration, Wichita State University, Wichita, KS 67260-0007, telephone (316) 978-3285.

**REFUSAL/WITHDRAWAL:** Participation in this study is entirely voluntary. Your decision whether or not to participate will not affect your future relations with Wichita State University. If you agree to participate in this study, you are free to withdraw from the study at any time without penalty.

**CONTACT:** If you have any questions about this research, you can contact me: Dr. Jeremy A. Patterson, office #112, Heskett Center, telephone (316) 978-5440. If you have questions pertaining to your rights as a research subject, or about research-related injury, you can contact the Office of Research Administration at Wichita State University, Wichita, KS 67260-0007, telephone (316) 978-3285.

You are under no obligation to participate in this study. Your signature indicates that you have read the information provided above and have voluntarily decided to participate. You will be given a copy of this consent form to keep.

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Signature of Subject

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Date

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Witness Signature

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Date

# PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. <b>Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?</b>
<input type="checkbox"/>	<input type="checkbox"/>	2. <b>Do you feel pain in your chest when you do physical activity?</b>
<input type="checkbox"/>	<input type="checkbox"/>	3. <b>In the past month, have you had chest pain when you were not doing physical activity?</b>
<input type="checkbox"/>	<input type="checkbox"/>	4. <b>Do you lose your balance because of dizziness or do you ever lose consciousness?</b>
<input type="checkbox"/>	<input type="checkbox"/>	5. <b>Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?</b>
<input type="checkbox"/>	<input type="checkbox"/>	6. <b>Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?</b>
<input type="checkbox"/>	<input type="checkbox"/>	7. <b>Do you know of <u>any other reason</u> why you should not do physical activity?</b>

If  
you  
answered

## YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

## NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

### DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

**PLEASE NOTE:** If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

**Informed Use of the PAR-Q:** The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

**No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.**

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME \_\_\_\_\_

SIGNATURE \_\_\_\_\_

DATE \_\_\_\_\_

SIGNATURE OF PARENT \_\_\_\_\_

WITNESS \_\_\_\_\_

or GUARDIAN (for participants under the age of majority)

**Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.**



# PAR-Q & YOU

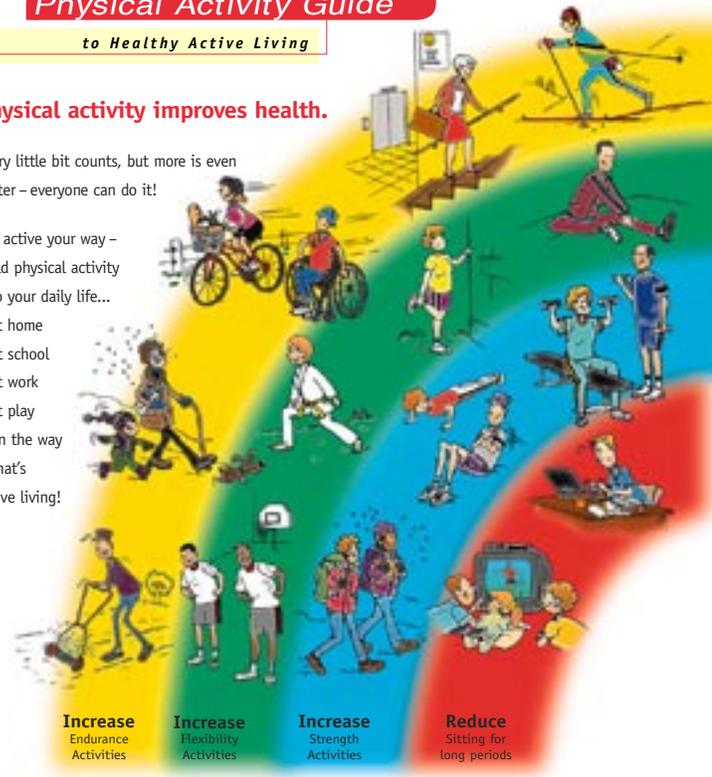
CANADA'S  **Physical Activity Guide**  
to Healthy Active Living

## Physical activity improves health.

Every little bit counts, but more is even better – everyone can do it!

Get active your way – build physical activity into your daily life...

- at home
  - at school
  - at work
  - at play
  - on the way
- ...that's active living!



- Increase** Endurance Activities
- Increase** Flexibility Activities
- Increase** Strength Activities
- Reduce** Sitting for long periods

Choose a variety of activities from these three groups:

**Endurance**  
4-7 days a week  
Continuous activities for your heart, lungs and circulatory system.

**Flexibility**  
4-7 days a week  
Gentle reaching, bending and stretching activities to keep your muscles relaxed and joints mobile.

**Strength**  
2-4 days a week  
Activities against resistance to strengthen muscles and bones and improve posture.

Starting slowly is very safe for most people. Not sure? Consult your health professional.

For a copy of the *Guide Handbook* and more information: **1-888-334-9769**, or [www.paguide.com](http://www.paguide.com)

Eating well is also important. Follow *Canada's Food Guide to Healthy Eating* to make wise food choices.

## Get Active Your Way, Every Day – For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly... and build up.

Time needed depends on effort				
Very Light Effort	Light Effort	Moderate Effort	Vigorous Effort	Maximum Effort
• Strolling	• Light walking	• Brisk walking	• Aerobics	• Sprinting
• Dusting	• Volleyball	• Biking	• Jogging	• Racing
	• Easy gardening	• Raking leaves	• Hockey	
	• Stretching	• Swimming	• Basketball	
		• Dancing	• Fast swimming	
		• Water aerobics	• Fast dancing	
Range needed to stay healthy				

## You Can Do It – Getting started is easier than you think

Physical activity doesn't have to be very hard. Build physical activities into your daily routine.

- Walk whenever you can – get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV.
- Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.
- Choose to walk, wheel or cycle for short trips.
- Start with a 10 minute walk – gradually increase the time.
- Find out about walking and cycling paths nearby and use them.
- Observe a physical activity class to see if you want to try it.
- Try one class to start – you don't have to make a long-term commitment.
- Do the activities you are doing now, more often.

## Benefits of regular activity: Health risks of inactivity:

- |  |  |
|--|--|
| <ul style="list-style-type: none"> <li>• better health</li> <li>• improved fitness</li> <li>• better posture and balance</li> <li>• better self-esteem</li> <li>• weight control</li> <li>• stronger muscles and bones</li> <li>• feeling more energetic</li> <li>• relaxation and reduced stress</li> <li>• continued independent living in later life</li> </ul> | <ul style="list-style-type: none"> <li>• premature death</li> <li>• heart disease</li> <li>• obesity</li> <li>• high blood pressure</li> <li>• adult-onset diabetes</li> <li>• osteoporosis</li> <li>• stroke</li> <li>• depression</li> <li>• colon cancer</li> </ul> |
|--|--|

Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 <http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf>

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### FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below):

The **Physical Activity Readiness Medical Examination (PARmed-X)** – to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy)** – to be used by doctors with pregnant patients who wish to become more active.

#### References:

Arraix, G.A., Wigle, D.T., Mao, Y. (1992). Risk Assessment of Physical Activity and Physical Fitness in the Canada Health Survey Follow-Up Study. *J. Clin. Epidemiol.* 45:4 419-428.

Mottola, M., Wolfe, L.A. (1994). Active Living and Pregnancy. In: A. Quinney, L. Gauvin, T. Wall (eds.), **Toward Active Living: Proceedings of the International Conference on Physical Activity, Fitness and Health**. Champaign, IL: Human Kinetics.

PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

Thomas, S., Reading, J., Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Can. J. Spt. Sci.* 17:4 338-345.

For more information, please contact the:

Canadian Society for Exercise Physiology  
202-185 Somerset Street West  
Ottawa, ON K2P 0J2  
Tel. 1-877-651-3755 • FAX (613) 234-3565  
Online: [www.csep.ca](http://www.csep.ca)

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

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