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EFFECTS OF AN EIGHT WEEK MAXIMAL JUMPING INTERVENTION ON BONE CHARACTERISTICS IN COLLEGE-AGED FEMALES

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BY

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Abstract

Peak bone mass occurs between the second and third decade, around a person's late twenties and is followed by a plateau in bone mineral density (BMD). Osteoporosis can be a result from a failure to achieve peak bone mass (Forwood, 2013a). Although there is a time delay, exercise has shown to have positive effects on bone accrual and to alter bone geometry and density (Reiger & Yingling, 2016). Longitudinal jump interventions have been shown to increase BMD of the femoral neck and lumbar spine in college-aged females. **Purpose**: The purposes of this study were to: (1) compare bone mineral density before and after an eight-week low-repetition, high-impact loading jump intervention in premenopausal women between the ages of 18-24, (2) compare bone geometry before and after the intervention to determine alterations, and (3) compare cross-sectional area of the muscle in the lower limb before and after the intervention. **Methods:** Twenty healthy college-aged females were randomly assigned to a control group or a jump intervention group for the eight-week intervention. Body composition and areal bone mineral density (aBMD) measurements were analyzed using dual energy x-ray absorptiometry (DXA). Peripheral quantitative computed tomography (pQCT) was utilized to measure volumetric bone mineral density (vBMD) of the 4%, 38%, and 66% sites of the nondominant tibia. Jump power and velocity were measured using the Tendo FiTRODYNE power and speed analyzer while jump height and airtime were measured using a Just Jump mat. All tests were measured at the beginning of the study (pre-test) and again eight-weeks later for the post-test. The jump variables were also measured at the four-week time-point (mid-test). The control group was instructed to continue their lives without increasing their physical activity for the eight-week duration of the study. The intervention group engaged in ten maximal countermovement jumps five days per week for the first two weeks of the study, and increased their jumps by five every

two weeks (jumping 15, 20, and 25 times). Independent t-tests were run to compare the control group to the intervention group for all dependent variables at baseline. Two-way repeated measures ANOVA (group x time) were run to compare the group differences in changes in the dependent variables from pre to post intervention. Percent changes in variables were analyzed by independent t-tests (group) or two-way repeated measures ANOVA (group x time) depending on if the dependent variables had one or two time points. **Results:** There were no significant differences in physical characteristics, DXA bone variables or pQCT bone variables, between the two groups at baseline. There were no significant group, time, or group x time effects for any of the bone or body composition variables assessed by DXA. There were significant time effects for the cross-section moment of inertia and section modulus as both groups decreased over time. No significant group, time, group x time effects were found for pQCT variables at the 4% or 38% site of the nondominant tibia. However, significant group x time effects were found for the vBMD of the 66% site of the nondominant tibia and significant time effects were found for total BMC and cortical BMC. **Conclusion:** The jump intervention did not increase DXA variables, 4% and 38% pQCT variables, or jump variables in this cohort of young women. There was a group x time effect on the vBMD of the 66% site of the nondominant tibia. Future studies should focus on a longer intervention to provide time for bone formation to begin. Additionally, recruiting a larger sample size would provide a greater statistical power. Future studies could also increase the intensity of the intervention throughout the duration by using weighted vests or utilizing drop jumps.

Chapter 1: Introduction

Bone without a cortex and trabeculae is like a building without support beams, it will fracture or breakdown when compressed. In the 1830s, Jean Georges Chretien Frederic Martin Lobstein, a French pathologist, discovered that some patients had more porous bones than others and coined the term "osteoporosis" (Patlak, 2001). Extensive pores in the bones weaken the skeleton by deteriorating both cortical and trabecular bone, causing the bone to become fragile enough that simple actions, such as sneezing or stepping off a curb, can cause the bone to break. Fractures from osteoporosis can be fatal due to complications such as thromboembolism, delirium, and pain management (Colón-Emeric & Saag, 2006). It was discovered early on that bone loss is an inevitable consequence of age, and postmenopausal women have a higher risk for the skeletal disease (Patlak, 2001).

One in two women over the age of 50 are affected by osteoporosis and an estimated ten million Americans have osteoporosis, which is why researchers are intent on discovering a cure for the disease (Reiger & Yingling, 2016). Estrogen builds the calcium reserves in bones, but there is a reduction of estrogen at the onset of menopause. The decrease in estrogen causes the breakdown of bone to exceed the buildup, resulting in bone loss and an increased risk of fractures. Estrogen replacement therapy has been shown to prevent a loss in height and reduces fractures risk by half. However, it is not a cure for the disease because it cannot replace the bone matrix that has deteriorated. In order for estrogen to be an effective method of preventing the symptoms of osteoporosis, the replacement therapy needs to be initiated prior to the onset of excessive bone loss. Unfortunately, by the time the symptoms of osteoporosis are apparent, there has already been irreversible damage to the bones, therefore it is imperative to develop effective measures of reducing the effects of osteoporosis (Patlak, 2001). In addition to taking estrogen

replacement therapy prior to the onset of menopause, increasing peak bone mineral density before menopause will also be beneficial.

Mass, geometry, and material properties of bone determine its capacity to resist fractures. Bone mineral density (BMD) can predict the risk of fractures, and although it is determined by genetics, it is also influenced by mechanical factors. The geometry, architecture, and strength of the bone achieved during childhood via mechanical strains are preserved into adulthood and are more important than just BMD for preventing fractures. Peak bone mass occurs between the second and third decade of life, and followed by a plateau in bone mass accrual. Peak bone mass is site specific to each individual bone; the lower extremities reach peak bone mass first, within one year of peak height velocity, while the lumbar spine achieves its peak last at about four years after peak height velocity (Forwood, 2013b). Osteoporosis can result from a failure to achieve peak bone mass early in life. Mechanical loading, in addition to genetics, age, body weight, and calcium intake, influences the variation of peak bone mass (Forwood, 2013b; Tucker, Strong, LeCheminant, & Bailey, 2015). In order for new bone to be acquired, a mechanical strain threshold must be exceeded by the rate and amplitude of the loading; for example, static and isometric exercises do not exceed this threshold and therefore provide minimal adaptation to bone (Forwood, 2013b).

Bone tissue is in a constant state of flux in order to respond to a changing environment and be structurally efficient. Each individual bone undergoes the process of remodeling, which takes three to six months to complete. Through remodeling, the osteoclasts are recruited to a specific site on the bone surface and resorb the bone cells causing the osteoblast to then be recruited to the site in order to deposit matrix to form new bone. During maintenance, remodeling is a balanced process where resorption is matched by formation of the bone matrix.

After stress has been placed on the bone, bone hypertrophy occurs due to the osteoblast activity exceeding the osteoclast activity (Snow-Harter & Marcus, 1991).

Bone adaptation allows the bone to respond to the loading signals placed upon it by altering bone geometry. However, there are three rules that govern bone adaptation: it is driven by dynamic loading not static; only a short duration of loading is required; and bones become less responsive to routine loading (Turner, 1998). Since novel dynamic loading patterns of short duration are sufficient for bone adaptation to occur, static strains do not reach this threshold and therefore do not enhance bone adaptation. Dynamic strains increase bone formation due to the ability to overcome the threshold and apply the necessary strain on the bone in order for adaptation to occur. In addition to dynamic strain on the bone, the frequency and strain rate of the mechanical loads are essential factors in adaptation. The second rule discusses how the formation of bone saturates with longer the duration of dynamic loading, contrary to the belief that the longer the mechanical load, the greater the adaptation of bone. Short duration loading at the same strain rate as a long duration loading will have similar effects on the bone due to the saturation of bone formation. Lastly, bones become accustomed to routine strains such as daily activities like walking. In order to allow for adaptation to continue, the mechanical loading on bone should be atypical of the strains typically placed upon it (Turner, 1998). These rules are imperative to remember when forming a regimen that will result in bone adaptation, especially an alteration in bone mass and geometry.

Exercise has been shown to have a positive effect on bone accrual, however, the results can take several months before changes in the density and geometry can be recognized. There is a time-delay from the onset of exercise strain and stimulation on the bone and the alterations of geometry and density (Reiger & Yingling, 2016). Short bouts of mechanical loads that provide

enough stress on the bone to surpass the threshold in order to allow for adaptations of the bone result in an increase in bone and muscle mass in those with low bone mineral density (Gilsanz et al., 2006). In order to increase strength of bone, the exercise intervention needs to be a protocol to which the bone is not accustomed (Tucker et al., 2015). Impact-loading physical activity involve Ground Reaction Forces (GRFs) and strains on the bone through the muscle contractions. Jump interventions are impact-loading exercises that involve GRFs and imposing stresses on the bone to have an effect on hip BMD in women (Tucker et al., 2015). Maximally jumping produces a dynamic strain on the bone that exceeds the threshold required in order for the bone to adapt. Due to the GRF and strain rate on the bone due to muscle contractions, a maximal jumping intervention in which an individual engages in multiple repetitions of high-impact loading will result in an adaptation of the weight-bearing skeleton that will allow for an increase in BMD and alter the bone geometry. The beneficial effect of jumping protocol was documented by Kato et al. in which premenopausal women participated in a six-month study (Kato et al., 2006a). The women jumped ten times per day, three days per week, which resulted in a significant increase in the BMD of the femoral neck and lumbar spine. A meta-analysis reporting on six studies that examined the effects of a 6-12 month jump intervention in premenopausal women who did not engage in regular exercise documented that high-impact, short duration jump interventions significantly increase the BMD of the femoral neck, lumbar spine, and trochanter compared to a control group. Although previous jump studies reported increases in the BMD, the literature does not discuss the changes in bone geometry and structure that arise from a high-impact exercise intervention (Zhao et al., 2014). This study examined the effects of a high-impact exercise intervention in addition to the potential changes in bone geometry and structure.

Purpose

The purposes of this study were to: (1) compare bone mineral density before and after an eight-week low-repetition, high-impact loading jump intervention in women between the ages of 18-24 years, (2) compare bone geometry before and after the intervention to determine alterations, and (3) compare cross-sectional area of the muscle in the lower, non-dominant leg before and after the intervention. Areal bone mineral density (aBMD) of the dual proximal femur, lumbar spine and total body was measured by dual energy x-ray absorptiometry (DXA), while the volumetric BMD (vBMD), bone geometry, and bone strength of the tibia, and cross-sectional area of the muscle was measured by peripheral Quantitative Computed Tomography (pQCT).

Research Questions

1. Will engaging in maximally jumping five days a week for eight weeks improve bone mineral density and bone mineral content in the lumbar spine, dual proximal femur, and total body density in college-aged females?
2. Will the eight-week jumping intervention alter bone geometry in the 4%, 38%, and 66% tibia sites of the non-dominant leg?
3. Will the jumping intervention increase cross-sectional area of the muscle at the tibia 66% site of the non-dominant leg?
4. Will the eight-week intervention increase vertical jump power output and velocity?

Research Hypotheses

1. It was hypothesized that bone mineral density and bone mineral content will increase in the proximal femur, lumbar spine, and total body after an eight-week intervention in

which a college-age individual engaged in a progressive maximal jump intervention five times per week.

2. It was hypothesized that the jumping intervention will increase bone geometry variables: vBMD, total BMC, cortical vBMD, and cortical BMC at the 4%, 38%, and 66% site of the tibia.
3. It was hypothesized that the jumping protocol will increase the muscle cross-sectional area at the 66% site of the tibia.
4. It was hypothesized that the vertical jump power output and velocity will increase after the eight-week jump intervention.

Significance of Study

By the third decade of life, a person has attained the maximum bone mineral density that they will acquire in their lifetime. Thus, it is important to increase the mass of a person's bone by this time in order to prevent the risk of osteoporosis and fractures later in life. After the third decade has begun, bone mineral density begins to decrease in a consistent manner as the person ages. It is well-documented that high-impact mechanical loading will increase the BMD and alter the geometry. The findings of this study may lead to a feasible, inexpensive way for college-age females to improve their bone health.

Delimitations

Delimitations for this study included the following.

1. This study included healthy women aged 18-24 years.
2. All participants were recruited from the University of Oklahoma, Norman, Oklahoma City area.

3. The findings of this study apply to individuals who have not engaged in regular mechanical loading on their lower limbs in the past six months.
4. All tests were performed at the Bone Density Lab, Sarkeys Fitness Center in Norman, Oklahoma.

Limitations

Limitations for this study included the following.

1. Participants in this study were volunteers and may not be representative of the population.
2. Participation was limited due to the 300-pound weight limit of the DXA and the height limit of 6 feet, 4 inches.
3. This was a longitudinal study and relied on the participant being engaged in the study for eight weeks.

Assumptions

The assumptions of this study included the following.

1. Subjects were honest and accurate when completing all health-related questionnaires.
2. Subjects did take any medication that affects bone metabolism except hormonal contraceptives prior to and during the study.
3. Participants were honest about in their self-reports of engaging in the intervention each day.
4. Subjects performed each jump to their maximal ability.

Operational Definitions

1. Areal BMD (aBMD): mineral mass of bone divided by its projection area in a given direction (g/cm^2) (Schoenau, 2005).

2. Bone Architecture: the cortical and trabecular composition of the bone (Frost, 1997).
3. Bone Mineral Content: the mass of mineral per unit bone length (g/cm) or the mass of mineral contained in the entire bone (g) (Schoenau, 2005).
4. Bone Mineral Density: measured density of a bone dependent on the mineralization of the bone and the amount of bone present (Allen & Burr, 2014).
5. Bone Remodeling: the process of the osteoclasts removing mineralized bone followed by the osteoblast forming new bone matrix, this occurs when a stress has been placed on the bone in order to allow for a balance between bone resorption and formation (Hadjidakis & Androulakis, 2006).
6. Bone Strength Index (BSI): a non-invasive indicator of bone strength by determining the product of the cross-sectional moment of inertia (mm^4) and cortical volumetric density (mg/mm^3) (Cointry et al., 2014).
7. Cortical Bone: also called compact bone, has porosity less than 15% (Schaffler & Burr, 1988).
8. Cortical Thickness: the thickness of the cortical bone pixels identified by the pQCT (mm) (Swinford & Warden, 2010).
9. Dual-Energy X-Ray Absorptiometry (DXA): an x-ray scan that provides a two-dimensional scan of the total body, lumbar spine, and dual femur focusing on site specific bone mass, fat mass, bone-free lean body mass, the scan can allow for a quantitative method of diagnosis osteoporosis and fracture risk. The DXA measures attenuation throughout the body using x-ray beams (40 KeV and 70 KeV) to identify bone mineral and soft tissue composition, the software detects the outline of the bone while the pixels then determine the bone area (Adams, 2013; Bauer, 2013).

10. Endosteal Circumference: the circumference of the inner membrane lining the medullary cavity (mm) (Swinford & Warden, 2010).
11. Ground Reaction Force: non-invasive measure of bone strain during weight-bearing activities, it is the rate of force applied on the bone determined by the peak ground reaction force multiplied by the individual's body weight (Weeks & Beck, 2008).
12. Mechanical Strain: the adaptive reaction of the bone to the mechanical stress placed upon it (Ehrlich & Lanyon, 2002).
13. Mechanical Stress: the physical load that is placed upon the bone that causes bone remodeling to occur resulting in the change of the shape of the bone (Nomura & Takano-Yamamoto, 2000).
14. Muscle Cross-Sectional Area (MCSA): the total area of muscle (mm^2) (Rauch & Schoenau, 2008).
15. Osteoblast: cells utilized for bone formation (Huiskes, Ruimerman, Van Lenthe, & Janssen, 2000).
16. Osteoclast: cells utilized for bone resorption (Huiskes et al., 2000).
17. Osteocyte: a cell that can regulate mineralization located in the bone matrix (Bonewald, 2011).
18. Osteoporosis: a T-Score of 2.5 SD and below the young adult mean value of BMD resulting in reduce bone strength and increase risk of injury or falls (Kanis, Melton, Christiansen, Johnston, & Khaltaev, 1994).
19. Periosteal Circumference: the circumference of the outer membrane lining the cortical shell (mm) (Swinford & Warden, 2010).

20. Peripheral Quantitative Computed Tomography (pQCT): a 3D x-ray scan that allows the analysis of cortical and trabecular microarchitecture of peripheral bones (Scharmga et al., 2016).
21. Strength Strain Index (SSI): an indicator of bone strength by measuring the bone geometry (section modulus) and the properties of cortical bone tissue (mm^3) (Kontulainen et al., 2008).
22. T-Score: determines how many standard deviations above or below the mean BMD with a reference population of young Caucasian females (Carey & Delaney, 2010).
23. Trabecular Bone: porous bone that is found in the spine and articulating joints (Huiskes et al., 2000).
24. Volumetric Cortical Bone Mineral Density (cortical vBMD): reflects the material density of the solid cortex as well as the cortical porosity (mg/cm^3) (Rauch & Schoenau, 2008).
25. Volumetric Bone Mineral Density (vBMD): the ratio of the BMC and the total cross-sectional area of bone (mg/cm^3) (Rauch & Schoenau, 2008).
26. Z-Score: determines how many standard deviations above or below the mean BMD with a reference population of individuals of a matched age, sex, ethnicity, and body-mass (Carey & Delaney, 2010).

Chapter 2: Literature Review

The purposes of this study are to: (1) compare bone mineral density before and after an eight-week low-repetition, high-impact loading jump intervention in premenopausal women between the ages of 18-21, (2) compare bone geometry before and after the intervention to determine alterations, and (3) compare cross-sectional area of the muscle in the lower limb before and after the intervention. This chapter will examine previous literature that discusses the effects of high-intensity activities, especially jumping, on BMD, as well as the effects of hormonal contraceptives on BMD. This literature review is organized into the following sections: (1) Bone Physiology, (2) Fracture Risk and Osteoporosis, (3) Hormonal Contraceptive Effects on BMD, (4) High-Intensity Exercise Effects on BMD, (5) Summary.

Bone Physiology

Bone is a living, dynamic connective tissue that must be able to react to metabolic and structural changes. The composition of bone is dictated by the functional demands being placed upon it. Bone turnover is regulated by the balance between osteoblast and osteoclast functions. When placed under stress, remodeling occurs in bone- the process of resorption and formation (breaking down and being reformed). Remodeling in the endosteal surface of bones takes about 3-6 months to complete (Marcus et al., 2009).

If there is an imbalance in remodeling resulting in an increase in osteoclast activity favoring resorption, then bone loss occurs. Osteoclasts arise at or near the bone surface and erode the underlying bone once activated (Boyle et al., 2003). Osteoblasts are in communication with osteocytes, meaning that there is a structural basis for controlling remodeling when there is strain placed upon the bone (Lanyon, 1987). Once a strain is placed upon a bone, the osteocytes are activated and gravitate towards the area of the bone. Once there, the osteocytes form a vacuole to

the bone surface, creating a sealed compartment. This compartment is then acidified through the use of hydrochloric acid and acidic proteases- causing the osteoclasts to resorb the underlying bone. This method of bone degradation relies on the physical relationship between the bone matrix and osteoclasts. The osteoblast will then be recruited to the site and inhibit the osteoclasts from eroding the bone more and begin forming new bone matrix over the now eroded bone (Boyle et al., 2003; Ross, 2006).

The composition and structure of bone is controlled by the functional demands placed upon the bone. The trabecular bone is in the epiphyses of long bones in the axial skeleton and is highly porous. The porosity of the trabecular bone is a determinant of the stiffness and strength of the bone. If the bone has disuse with age, it will become progressively thinner and perforated by resorption cavities. Cortical bone, also known as compact bone is more dense than trabecular bone and is only 5-20% porous (Marcus et al., 2009). Increasing the osteoclast activity results in a decrease in cortical bone through an increase in porosity. This decline in cortical bone leads to a loss in strength of the bone (Reid, 2013). Additionally, the reduction of cortical bone is more predictive of femoral neck fractures then the loss of trabecular bone. There is a larger age-related loss of cortical bone as well compared to trabecular bone.

Fracture Risk and Osteoporosis

With an increase in age, comes an increase in the risk of fractures associated with osteoporosis. Osteoporosis is caused by a failure to attain an optimal peak bone mineral density early in life. Endosteal bone apposition is ceasing as well as epiphyses are closing by the age of 16, meaning that it is imperative for people to increase their BMD before their third decade of life when BMD begins to decline. Although different skeletal locations achieve peak BMD at different ages, so there is no defined age that a person will know that they have reached their

peak. However, peak BMD is attained around late adolescence but could continue to increase into the early twenty's (Matkovic et al., 1994; Recker et al., 1992; Teegarden et al., 1995).

Low bone mineral density and increased defective osteocytes are the main causes of osteoporosis and other skeletal diseases. Osteoporosis occurs when bone resorption exceeds the demand of the osteoblasts and the BMD T-score falls below -2.5 (Cohen & Shane, 2009; Rubin et al., 2009). Fractures of the hip are the most common osteoporotic fractures. Although the femoral neck and the trochanter are at an equal chance for becoming fractured, there is evidence that suggests that trochanter density is the predominant indicator of the vulnerability of the femur. It is imperative to increase the BMD of the femur early in life in hopes of reducing the risk of osteoporosis with age. Once peak BMD is attained, BMD begins its general decline with age- meaning it is important to prevent the decline of BMD into the third decade (Bassey & Ramsdale, 1994). By the age of 48-50 years, women reach a cessation of their menstrual cycle known as menopause. This marks the beginning of bone loss which continues until death. Trabecular bone has a larger surface area than cortical bone, causing the matrix of the distal arm and vertebrae to have primary fractures at the onset of menopause (Favus, 2006).

In premenopausal women, a Z-score is used to categorize BMD: below -2.0 is below expected range for age, and above -2.0 has a BMD above expected range per age. Due to the use of Z-scores, osteoporosis cannot be diagnosed in premenopausal women because T-scores are the criteria for diagnosis. Although premenopausal women with low BMD are at a higher risk for fractures, the evidence is still unclear as to the extent which BMD predicts the prevalence for fractures. Young women with low BMD generally have an underlying exposure that altered the bone mass accumulation during adolescent years, such as medications (glucocorticoids, cancer

chemotherapy, heparin), anorexia nervosa, or vitamin D and calcium deficiencies (Cohen & Shane, 2009).

Hormonal Contraceptive Effects on Bone Mineral Density

The female reproductive system affects skeletal growth and development through modeling and remodeling into adulthood and menopause. Menarche begins in most females at the age of 11-13 years old and stimulates mineral acquisition and skeletal growth for the next decade. Within the first four years after menarche, BMD reaches a third of the BMD peak then the increase slows but continues into the third decade of life. The menstrual cycle typically last 28 days in females but could vary from 21-40 days. The hypothalamus secretes gonadotropin-releasing hormones (GnRH) allowing the gonadotrophs in the anterior pituitary gland to secrete Follicle Stimulating Hormone (FSH) and Luteinizing Hormone (LH) in a cyclical pattern (Clarke & Khosla, 2010; Hartard et al., 2007).

The menstrual cycle can be divided in to the earlier follicular (proliferative) phase and the later luteal (secretory) phase. At the end of the follicular phase, before the transition into the luteal phase, ovulation occurs. Gonadotrophs secrete FSH and LH in a pulsatile pattern dependent on the pulsatile secretion of GnRH by the hypothalamus. FHS secretion increases during the late luteal phase and continues its increase into the early follicular phase, allowing the ovarian follicles to develop and grow before the decrease in FSH secretion for the rest of the cycle until the late luteal phase. However, FSH does surge during ovulation before continuing its decrease in secretion. LH secretion has a slower onset increase in the late follicular phase until it surges for 1-3 days in the middle of the cycle then begins to decrease until its lowest levels in the late luteal phase. In addition, the ovaries secrete serum estradiol and progesterone. Estradiol secretion increases 7-8 days prior to the LH surge, decreases quickly while LH peaks, then

increases again a week after the LH surge. Progesterone also increases secretion prior to the LH surge and peaks about a week after the LH surge before decreasing secretion towards baseline levels. Estrogen and progesterone have receptors on bone cells that allow the hormones to directly benefit the skeleton. Both estrogen and progesterone stimulate an increase in BMD beginning at menarche. At the onset of menarche, estrogen suppresses the resorption and increases formation of bone cells (Clarke & Khosla, 2010; Hartard et al., 2007).

According to Chiu et al. (Chiu et al., 1999) the increase in bone resorption in the middle and late follicular phase is due to the low levels of estrogen and progesterone during the earlier follicular phase. Additionally, the low levels of bone resorption during the late luteal phase is due to the increased levels of estrogen and progesterone in the mid-luteal phase. The researchers wanted to investigate the changes in female sex hormones during the menstrual cycle and determine if these changes were related to changes in bone formation and resorption. This study measured bone-specific alkaline phosphatase (BAP), osteocalcin (OC), and bone resorption markers, serum and urine deoxypyridinoline (Dpyr) in 20 premenopausal women, age 23-40 years old, who were not taking oral contraceptives. During one menstrual cycle, measurements were taken three times a week. Estrogen and progesterone levels are known to fluctuate throughout the cycle, however, BAP, OC, and Dpyr levels did not show a significant change throughout the cycle. It was concluded that due to the relationship between these hormones, women experience increased bone resorption each month during a normal menstrual cycle from the onset of menarche to menopause.

Burr et al. (Burr et al., 2000) documented that when young women take oral contraceptives, there is the potential that it could alter the normal accretion of bone mass that would occur due to exercise. Women between the ages of 18-31 (n=123) were classified by oral

contraceptive use (OC, NOC) and divided into an exercise group and non-exercise group randomly. This was designed as a longitudinal study, lasting two years with measurements taken every six months. Measurements included using a Lunar DXA to measure the bone mineral content, density and geometric information of the femoral neck in order to calculate the bending rigidity of the hip. The study concluded that either exercise or OC use alone depresses the normal increase of bone mass and the femoral neck mechanical strength; however, the combination of the exercise and OC use was less detrimental than each one individually. This could be due to the fact that long-term exercise and OC use suppress the increase of bone density and strength at the femoral neck. The researchers believed that impact exercises are more osteogenic than aerobic exercises.

Oral contraceptive pills contain lower estrogen doses in order to reduce the risks of thromboembolic events (Cromer et al., 2008). This increases the chance that OCs no longer provide enough estrogen to allow for optimal bone accrual in young women. In addition, it had become apparent that the depot medroxyprogesterone acetate (DMPA) contraceptive injection reduces the peak bone mass a woman taking the injection will achieve as well as increases the risks of osteoporotic fractures later in life. This was a longitudinal study, lasting for two years that focused on 433 postmenarcheal girls who were between the ages of 12-18 who were on the injection, taking OC, or were untreated. A DXA was performed every six months in order to observe the BMD of the spine and femoral neck. It was concluded that those receiving the injection had significant loss of BMD in the lumbar spine and femoral neck while those taking OC or untreated had an increase in BMD. The researchers believed it is important to determine if there is a sufficient level of estrogen in OCs that allow an optimal skeletal development in young women.

High-Intensity Exercise Effects on Bone

During the onset of puberty and into adolescent years, young women attain about 45-60% of their adult peak bone mass. Although there have been conflicting results, it is possible that bone mass and density of several important skeletal regions may increase into the early adult years (Blimkie et al., 1996). Past research has found contrasting results; exercise interventions in adolescent girls resulted in no significant change in bone mass, whereas exercise interventions resulted in a significant change in bone mass. Even with contrasting results from numerous studies, there is evidence that high-intensity loading is an effective bone-building activity. According to Witzke & Snow (Witzke & Snow, 2000) a high intensity loading activity must have a ground reaction force (GRF) greater than four times the body weight. Additionally, static loading is known to be less effective for increasing BMD than dynamic loading while strain rate is more effective than the number of trials performed (Kato et al., 2006b).

A meta-analysis that combined seven studies was added to the literature in 2013; this was the first meta-analysis on exercise and the effects on bone mineral density that included randomized control trials (Kelley et al.,, 2013). The seven studies included in the meta-analysis had interventions that lasted at least 24 weeks in order to allow sufficient time for bone remodeling to occur. Exercise protocols for the seven studies included a frequency ranging from 2-7 days per week throughout the study, and exercises that included circuit training, strength training, and aerobic activities. Overall, the seven studies documented that there was a statistically significant increase in the both the femoral neck and the lumbar spine BMD (Kelley et al., 2013).

Poor muscle strength and coordination can result in an increase in falls and fall-induced fractures later in life. While an increase in physical activity and performance can improve bone

mass and strength in hopes of reducing the chance for falls and osteoporosis with age. An 18-month study, in which healthy, sedentary females between the ages of 35-45 engaged in an exercise intervention, had two groups: a training group and a control group (Heinonen et al., 1996). The training group exercised at a frequency of 3 times a week and performed high-impact exercises for twenty minutes in addition to a warm-up and cool-down period of 15 minutes. For the high-impact exercises, the subjects alternated between an aerobic jump protocol and a step program. The BMD of the femoral neck, lumbar spine, and distal femur where measured for baseline values and after the 18-month study. The training group had a significant increase in the BMD of the femoral neck, lumbar spine, and distal femur compared to the control group. The high-impact exercise protocol promoted the integrity of the skeleton; however, the researchers were unsure as to how long the effects on the BMD last or if the effects will disappear once training has stopped. If continued, high-impact exercises will result in an increase in bone mass and potentially a decrease in osteoporosis and osteoporotic falls later in life (Heinonen et al., 1996).

High-impact as well as low-impact exercises improve the bone mass of the lumbar spine, however, only high-impact exercises have a positive effect on the femoral neck (Wallace & Cumming, 2000). High-impact exercises have a positive benefit on L1 compared to L2-L4. This may be due to the fact that L1 is smaller than L2-L4 and therefore has a lower BMD and generates higher loading stresses. This discovery was documented in a 12-month exercise intervention in which a training group exercised three times a week and the control group continued with their everyday activities. For the training exercises, the 35-40-year-old women recruited for the study engaged in 60 minutes of high-impact exercises including stamping, running, walking, and step patterns. At the end of the 12 months, the BMD of the training group

increased significantly compared to the control group in the femoral neck and L1, however, there were no significant changed in L2-L4 in the training group. This study shows that a high-impact exercise intervention can increase the BMD of the lumbar spine as well as the upper femur in a safe and efficient manner (Vainionpää et al., 2005).

Resistance training has been shown to have a positive effect on BMD and muscular strength due to high joint compressive forces (Blimkie et al., 1996). In a 26-week study in which adolescent females were assigned to either a resistance training group (3 days/week) or to a control group, bone mineral content was measured for the total body and lumbar spine. Although the lumbar spine BMD of the treatment group increased in the first 13 weeks of the study, there were no statistically significant changes between the control group and the resistance training group's bone mineral content at the end of the 26 weeks. Additionally, there was significant increases in strength for the resistance group at the end of the study (Blimkie et al., 1996). This study showed that resistance training protocols increase the bone mineral content as well as muscular strength.

One major barrier to engaging in the minimum amount of activity (150 minutes of moderate-intensity aerobic activity and two days of muscular strength training a week) necessary to maintain and improve body composition and bone health is a lack of time to complete these activities (Brown et al., 2018). Sixteen women participated in a 12-week intervention study looking at how different high-intensity interval training protocols affect body composition and physical fitness. The college-aged females were randomly assigned into the multimodal HIIT group or the rowing HIIT training group. The multimodal group utilized resistance training exercises including barbells for squats, dumbbells for lunges, and sprints-like movements such as hurdle hops. The rowing HIIT group utilized a rowing ergometer for each training session. At the

end of the 12 weeks, there was an overall decrease in the total body fat percentage for both groups and a significant increase in total body BMC. This study demonstrated that high-intensity exercises are feasible options in improving skeletal health in college-aged females.

Jump Protocol Effects on Bone

Jumping is a high-impact exercise that has been discovered to place a strain on the bone that overcomes the threshold necessary to increase the BMD. An animal study in which rats were divided into 5 jump groups based on how many jumps they would engage in per day (5,10,20,40, 100), five days per week and one control group took place for 8 weeks. At the end of the study, the lengths of the tibia and femur of the rats were measured as well as the mass and morphometry of the bones. The training groups had a significant increase in bone mass compared to the control group. Additionally, the cortical areas of the tibia and femur were significantly greater in the training groups compared to the control group. This study showed that a large number of jumps per day were not necessary in order for bone hypertrophy to occur and for the bone geometry to alter (Umemura et al., 1997).

Rodent studies have shown that if there is a time delay between jumps to allow for a restore of bone sensitivity, then the overall BMD increase will be greater than if the jumps are consecutive. Although human research on this concept is minimal, Tucker et al. performed a sixteen-week exercise intervention in 60 women between the ages of 25 to 50 (2015). The women were placed into three groups: a control group, a treatment group that jumped ten times in each set, and a treatment group that jumped twenty times per set. Each treatment group engaged in two sets per day with an eight-hour rest period between, and allowed 30 seconds of recovery in-between each jump. After the 16 weeks, hip BMD was measured for all participants. Both treatment groups significantly increased their hip BMD compared to the control group by

the end of the 16 weeks. There was not a significant difference between the two treatment groups, possibly due to the concept that once the threshold for the increase in BMD has been attained during an exercise, the continued stimulus on the bone will not result in greater gains (Tucker et al., 2015).

The most common sites for osteoporotic fractures are the hip and the spine, which is why it is imperative to determine an exercise protocol that results in an increase in BMD of the lumbar spine and femoral neck. A meta-analysis combined six studies in which healthy, premenopausal women engaged in a jump protocol exercise intervention (Zhao et al., 2014). The interventions lasted from 6-12 months and involved 10-50 jumps per day, 3-7 times per week. The overall results of the studies were that the BMD of the femoral neck increased significantly; however, there was no significant change in the lumbar spine. This could be due to the fact that the femoral neck is more sensitive in its response to the high-impact exercise and the response of bone to the jump protocol may be site specific. The findings of the women jumping both 10 times per day and 50 times per day had a similar increase in the femoral neck BMD, indicating that once the threshold for the mechanical strain has been reached, there is no further increase in BMD. This means that continuous bouts of exercise will not result in an increase in the BMD accrual. However, this meta-analysis documents that a high-impact jump intervention is beneficial in increasing the BMD of the femoral neck which could decrease the chance for hip fractures later in life (Zhao et al., 2014).

According to Kato et al. (2006) the BMD of the femoral neck could be increased by performing 10 maximum vertical jumps three days a week. This was a six-month study in which 42 college age women were randomly divided into two groups (jump training vs. control). Measurements were taken prior to the study and after the six months had ended; BMD was

measured in the lumbar spine and femoral neck using DXA. After the six months, there was a significant increase in the lumbar spine BMD and femoral neck BMD compared to the control group. The researchers chose a low-repetition protocol because after a certain number of repetitions, there is a decrease of sensitivity in the mechanoreceptors of bone. Young women who had not yet reached the age of peak bone mass were the participants of this study, however, it can be assumed that low-repetitions of maximum vertical jumps are ideal for enhancing and maintaining peak bone mass in young adult women.

The BMD of the femur could be increased by exercises, such as jumping, that engage the weight-bearing skeleton with repeated extra loads according to Bassey and Ramsdale (Bassey & Ramsdale, 1994). This was a six-month study in which 27 premenopausal women were randomly assigned to a control group and a treatment group. Both groups exercised in a group setting as well as at home (test group performed high-impact exercises while the control group performed low-impact exercises). Prior to the study, BMD of the lumbar spine and femoral neck were measured on the participants using DXA; measurements were taken again at the end of the six months. The treatment group attained a significant increase in BMD after the six months compared to the control group. The researchers purported that the BMD of the femur increased because the landing ground reaction force would produce tensile forces at the trochanter and increase the functional strain at the trochanter. However, the BMD of the lumbar spine did not significantly increase because there was no overload of the spine during their high-impact exercises.

Exercise protocols consisting of jumping for three weeks stimulates bone metabolism in women who take oral contraceptives and those who do not (Reiger & Yingling, 2016). This was a 15-day study in which 23 college-age females between the age of 18-25 engaged in 10 42cm

drop jumps 5 days a week for 3 weeks. Serum markers for bone formation were taken during three time periods (day 0, between day 8-13, and day 21). After the three weeks, the bone formation and resorption markers had increased for both groups- the OC group had lower levels than the non-oral contraceptive group but not significantly. This study also proved that OC use is not detrimental to bone metabolism and will respond in the same way that non-OC users respond in regard to exercising.

It has been documented that an increase in repetitions of exercises do not elicit a linear increase in BMD due to the desensitizing of the mechanoreceptors. It is unclear, if the sensitivity of the mechanoreceptors are restored after a recovery period has occurred (Erickson & Vukovich, 2010). Twenty-one males participated in a study in which they were divided into three groups, a control group, a group that jumped once a day, (J1) and a group that jumped twice a day (J2). All participants in intervention groups jumped 3 days a week for eight weeks, there was a six-hour recovery period for the group that jumped twice a day. All participants jumped the same number of jumps each (i.e.- J1 group jumped 10 times for two sets, while J2 jumped 5 times the first set and 5 times six hours later), with a progressive protocol in which they increased number of jumps each week. By the end of the eight weeks, there was a significant time effect for the serum bone formation marker. This increase in the serum bone formation marker demonstrated that the jump protocol was able to elicit a response from bone turnover that favored formation. There was no difference in the serum marker between the two groups meaning that the difference in the protocols did not stimulate greater results in one protocol versus another and that both jump interventions could result in an increase in bone formation (Erickson & Vukovich, 2010).

Summary

Peak bone mineral density is attained by the beginning of the third decade of life. In order to prevent the onset of osteoporosis and reduce the risks of fractures, it is imperative to increase BMD as well as prevent the decrease of BMD with age. Oral Contraceptives do not impede the increase of BMD that can be achieved through high-impact exercise, such as maximum vertical jumping. Maximum vertical jumping is a feasible way for college-aged females (no matter if they take oral contraceptives) to increase BMD and prevent the decrease of BMD.

Chapter 3: Methods

The purposes of this study were to: (1) compare bone mineral density before and after an eight-week low-repetition, high-impact loading jump intervention in premenopausal women between the ages of 18-21, (2) compare bone geometry before and after the intervention to determine alterations, and (3) compare cross-sectional area of the muscle in the lower limb before and after the intervention. This chapter describes the methods to be used for this research study, focusing on the sample, instrumentation and measurement protocols, research design, data collection procedures, and data management and analysis.

Participants

Participants for this research study were recruited from the University of Oklahoma Norman campus, Norman, and Oklahoma City. Methods of recruiting included the distribution of flyers as well as through classroom recruitment, word of mouth, and advertisement. All of the participants in the study were healthy women between the ages of 18-24 years. Additionally, none of the participants had engaged in regular mechanical loading of their lower limbs in the past six months in order to ensure that potential changes in bone characteristics are due to the jump protocol. The University of Oklahoma Institutional Review Board (#9716) approved all of the protocols prior to beginning the study. The subjects were then randomly divided into two groups: a jump group and a control group. All testing was conducted at the Bone Density Lab in the Sarkeys Fitness Center, University of Oklahoma- Norman campus.

Power analysis was determined using G Power (software 3.1). The meta-analysis analyzed by Kelley et al. (2013) was utilized to determine the effect size and power size based to enter into the G Power software. An effect size of 0.342 for the femoral neck was analyzed as

well as an effect size of 0.201 for the lumbar spine with a power size of 0.8 for both. Based on these effect sizes, 20-52 participants were required for adequate statistical power.

Inclusion Criteria

The following subjects were included in this research study.

1. All subjects were healthy, premenopausal women ranging in age from 18-24 years.
2. Women did not have chronic back or joint problems.
3. The subject's weight was less than 300 pounds due to the weight limit of the DXA.
4. The subject's height was less than 6 feet due to the height limit of the DXA and pQCT to ensure for accurate measurements.

Exclusion Criteria

The following subjects were excluded from this research study.

1. Women taking medications that could alter bone density or metabolism such as glucocorticoids, GnRH agonist, immunosuppressants, and anti-depressants.
2. Women who engaged in regular exercise that included mechanical loading of the lower limbs in the past six months (i.e.- gymnastics, cycling, running, weight lifting, etc.).
3. Women who had surgery, fractures, or open wounds in the past year.
4. Women who have metal implants in their spine, hip or leg regions.

Research Design

This research study was a mixed factorial research design with one repeated measures variable (time) and one between subjects variable (group). The intervention for this study included an eight-week protocol in which the subjects in the jump group engaged in 10 maximal jumps five times for two weeks, then increase five jumps every two weeks to a total of 25 jumps in order to examine the difference in BMD, BMC, bone geometry, bone strength, calf muscle

cross-sectional area and jump power before and after the intervention. The time-frame of eight weeks was chosen due to the fact that it takes three to six months for bones to remodel, however, changes can be detected in eight weeks using the pQCT. Additionally, the maximal jumping protocol was chosen based on previous literature showing that the BMD of the femur can be increased through exercises that engage the weight-bearing skeleton, such as jumping.

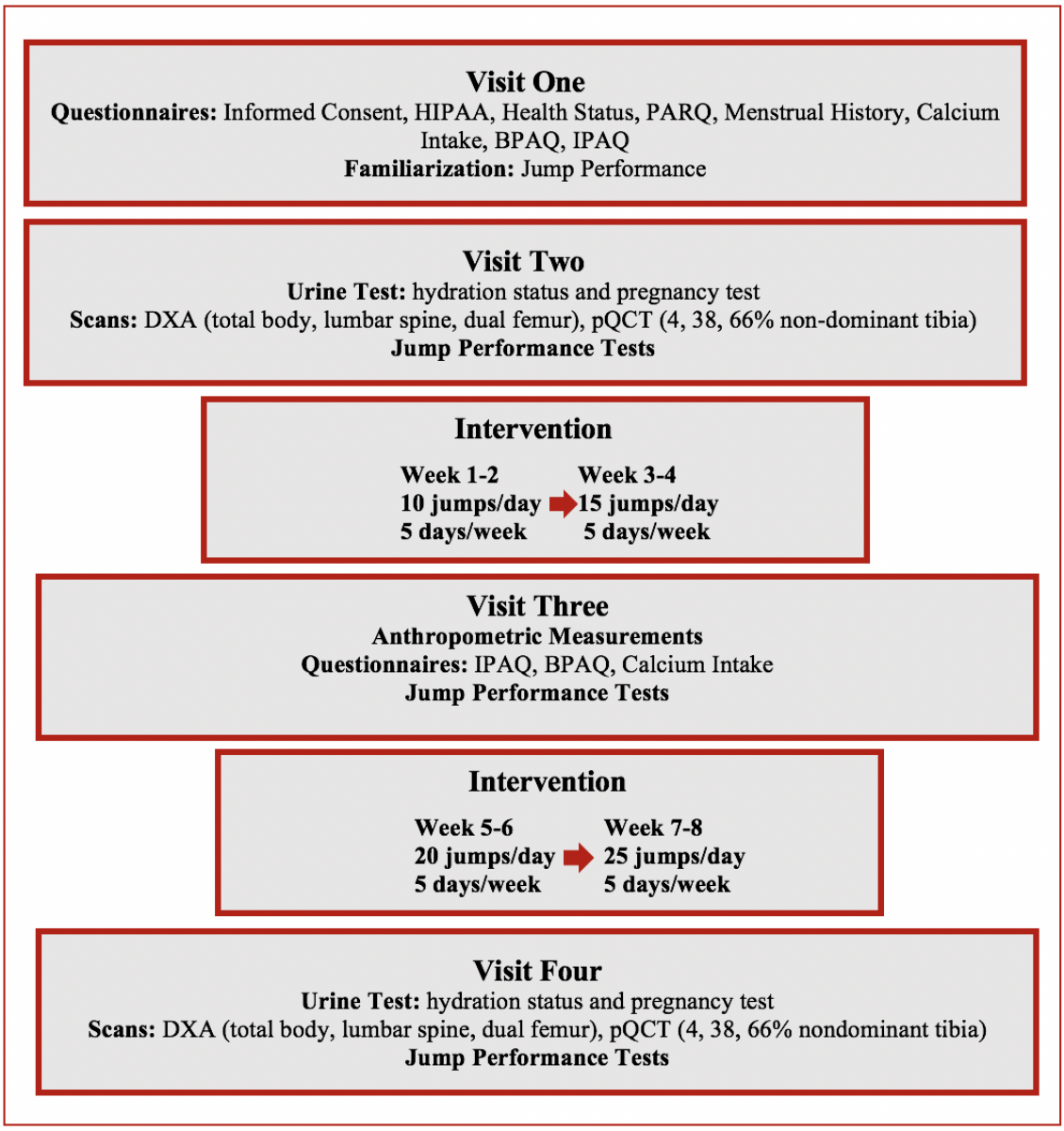

Figure 1. Overview of the Research Design

The study required the participants to visit the Bone Density Research Laboratory at the University of Oklahoma-Norman campus on four different occasions. The first visit consisted of the participants filling out an informed consent form and the appropriate HIPAA forms, health-related questionnaires that include: a Health Status Questionnaire, Bone-Specific Physical Activity Questionnaire (BPAQ), International Physical Readiness Questionnaire (IPAQ), calcium intake food frequency questionnaire, menstrual history questionnaire, and Physical Activity Readiness Questionnaire (PAR-Q). The Health Status Questionnaire included questions regarding age, gender, normal physical activity, and medications taken over the past six-months. The questionnaires also provided information about medical history and exclusion criteria for each woman. The first visit included informing the subject of how the DXA and pQCT test will be performed and what to expect from each test. In addition, the first visit included familiarization with the Tendo and the Just Jump mat so the subject understood what was expected of them when the research study began.

The second visit involved DXA scans of the proximal femur, the lumbar spine, and the total body. These scans took approximately twenty minutes to complete and required the subject to lay on the DXA as still as possible. Next, the subject was instructed to sit in a chair and have a pQCT scan performed at different sites of their tibia in order to determine the geometry of the subject's bone. The pQCT scan took approximately eight minutes. After the scans were completed, the subject performed a maximal jump test using the Tendo and the Just Jump mat in order to measure the maximal power output, maximal velocity, jump height, and air time of the jump.

Once the pre-test was completed, the subject was informed that the eight-week testing period had begun. If they were in the jump group, the researchers reminded the subjects how to

maximally jump and had them practice so the researchers can improve or critique their form. They were reminded to jump 10 times a day, five days a week for the first two weeks and then increase the number of jumps by five jumps every two weeks until the intervention period was completed. The repetition count, 10 jumps per day for the first two weeks then increasing by five jumps every two weeks was decided because magnitude of the exercise is more important than the number of trials performed. Additionally, the number of jumps increased every two weeks to ensure that there was progression in the intervention. The subjects were allowed to perform their daily maximal jumps on a hard, flat surface, such as tile or wood floors in their home or any building of their choosing. Additionally, the subjects could chose whether to jump in the morning or in the evening, but were be asked to keep the time-frame consistent throughout the study to increase compliance to the study. The subjects were sent a daily text message reminder every night at 8:00 pm to ensure that they jumped five times a week. The communication between the researchers and the participants allowed the participant to discuss any issues that arose, such as injuries, lack of compliance to the study, or complications with the protocol. If the subject was in the control group, they were told to continue their normal daily activities for the next eight-weeks until time for the mid-test and post-test.

The third visit, the mid-test, took place after four weeks and required the participants in both groups to return to the Bone Density Laboratory. The participants were asked to fill out the calcium intake questionnaire, BPAQ, and the IPAQ. After the questionnaires were completed, the participant's weight was measured and they were asked to perform three jump tests in order to determine the jump height, jump power, jump velocity, and time in air. The mid-test was used to check for compliance over the course of the eight weeks as well as to ask the participants if

there were any problems or issues they had when performing the jumps. The control group were reminded to continue their normal daily living for the remaining four weeks.

The fourth visit took place 8 weeks following the pre-test and was a repeat of the second visit. After the fourth visit, the subjects received a ten dollar Starbucks gift card as well as their DXA results and they were finished with the research study.

Bone-Specific Physical Activity Questionnaire (BPAQ)

This questionnaire instructed the subject to record any sport or physical activity they participated in regularly as well as the age they were when engaging in the activity from the age of one to their current age. Additionally, the questionnaire asked the subject to list any sport or physical activity they participated in regularly in the past twelve months and the average frequency (sessions per week). The goal of the questionnaire was to evaluate the past and current status of the bone-loading sports and physical activities of the subject and give a total, past, and current BPAQ score. The BPAQ is a good predictor of BMD and has been validated with other methods. The questionnaire is able to establish the effect of mechanical loading on site specific elements of the skeleton (Weeks & Beck, 2008).

International Physical Activity Questionnaire (IPAQ)

This questionnaire was used to determine the physical activities that participants engaged in as part of their everyday life. The questionnaire asked the subject in the past seven days how long they spent being physically active including activities they do around the house and yard, getting from place to place, and activities they do recreationally as well as sports or exercise they engage in. The goal of the questionnaire was to determine if the subject is designated into a low, moderate, or high intensity physical activity level. Other assessments of physical activity scores have been used to validate the IPAQ (Craig et al., 2003).

Calcium Intake Questionnaire

This questionnaire presented a list of food options and instructed the subject to record the number of servings of the particular food they consume in a week as well as daily in order to get an estimate of their calcium intake for the past year. In addition, the subjects were asked to list any dietary supplements they take daily/weekly, listing the brand name, amount (mg per dose), and total number of doses per day/week. The purpose of the questionnaire was to evaluate the daily amount of calcium (mg/day) that the subject consumed based on specific foods. The calcium intake questionnaire is based on a validated quantitative food frequency questionnaire (Musgrave, Giambalvo, Leclerc, Cook, & Rosen, 1989).

Menstrual History Questionnaire

This questionnaire instructed the subject to provide the researchers with a complete menstrual status and menstrual history. Questions regarding their menstrual status included frequency and length of their cycle, symptoms they have, and information about oral contraceptive use. Additional questions regarding their menstrual history included when their first menstrual cycle began, any irregularities or abnormalities in their cycle, and if any problems arose in which consultation with a doctor was necessary.

Anthropometric Measurements

The subject's height was measured using a wall stadiometer (Novel products Inc., Rockton, IL) and rounded to the nearest half centimeter. The subject was instructed to remove their shoes, stand against the stadiometer with their heels against the wall, head facing forward, and arms at their side while holding their breath. Weight was measured using a digital weight scale (Tanita Corporation of America, Arlington Heights, IL) and recorded in kilograms. The

subjects were instructed to remove their shoes, empty their pockets, and wear minimal clothing while recording their weight.

Hydration and Pregnancy Testing

The subject's hydration status was measured by measuring a urine sample with an optical refractometer (VEE GEE CLX-1, Rose Scientific Ltd., Alberta, Canada) prior to testing with the DXA and pQCT. The refractometer was calibrated each day prior to testing to ensure for accurate results. Hydration status were evaluated by measuring the urine specific gravity of each subject. The researcher transferred 1-2 drops of urine onto the daylight prism of the refractometer, then closed the plate to allow for a thin layer of urine, free of gaps or air bubbles, to cover the daylight prism plate. The urine specific gravity was then read by holding the refractometer upwards into the light. This allowed the researchers to ensure that the subject's hydration was within the accepted ranges (1.004-1.029 USG). If the subject's hydration did not fall within the accepted ranges, it would affect the level of accuracy of the BMD measurements and the subject had to be rescheduled until returned to normal hydration levels.

A pregnancy test was also be conducted using test strips (SAS Pregnancy Strip, SAS Scientific, San Antonio, TX) prior to testing. To perform this test, the test strip was positioned vertically above the urine sample with the arrows pointing downward. The strip was then placed into the urine, making sure not to touch the stop line into the urine sample, for 15 seconds. Once removed, the strip was placed on a flat, non-absorbent surface for four minutes. After four minutes, the test strip was read to check if the results were negative or positive. None of the women had a positive pregnancy test.

Dual Energy X-Ray Absorptiometry (DXA)

DXA (GE Lunar Prodigy, Version 16, Madison, WI) was used to measure BMC (g) and BMD (g/cm^2) of the total body, lumbar spine (L1-L4), and dual proximal femur. The DXA filter converts an x-ray beam into low (40 KeV) and high (70 KeV) energy peaks. During the total body scan, body composition variables including fat mass, fat free mass, bone free lean body mass, and percent body fat were measured. The x-ray attenuation after passing through tissue produces a scan image on the computer. The total radiation emitted by the DXA onto the subject was a minimal 0.05-1.5 mrem, which is comparable to spending an extra day in the sunlight each year. The DXA produces 2D images, meaning that it is unable to measure the thickness of the bone. Prior to testing each day, calibration and quality assurance (QA) procedures were completed according to the proper procedures per the given software. A calibration block of a known density was scanned during the QA in order to conduct a series of test to analysis the functional performance of the software.

The subject was instructed to lie on the DXA after removing shoes and any metal or jewelry they may have on during the scan. For positioning of the subjects, they had to lie supine in the middle of the DXA table with their hips and shoulders aligned. Three different scans were performed and took about twenty minutes to complete. The thickness of the participant at the navel determined the speed scan for the total body and lumbar spine scan. The precision, or reproducibility of the DXA scan, can be affected by the positioning of the participant on the table. Poor positioning can incorrectly increase or decrease the BMC measured by the software (Baim et al., 2005). To correct for the precision of the scan, each researcher underwent competency tests to ensure they understood the proper positioning of each test. For the total body, the subject positioned themselves supine in the middle of the table with their hips and

shoulders aligned. Additionally, a Velcro strap was placed around their ankles and just below the knees to prevent their legs from moving. For the second scan, the lumbar spine (L1-L4), the researcher placed a foam block under the legs to ensure the spine is flat against the table and the hip joint is at a 45-90-degree angle. The subject then crossed their arms and moved their arms so they were perpendicular to the table and would not be seen in the scan. The scan measured from T12 to L5 vertebrae, meaning that when the scan began, the laser crosshairs were placed 2 cm below the umbilicus so the iliac crest and T12 vertebra was visible in the scan. The final scan on the DXA was the dual femur scan. The foam block from the previous test was removed and the participant's feet were placed in the foot brace to allow internal rotation of the leg. This internal rotation allowed the femoral neck and femur to be properly exposed in the scan. The laser crosshairs were then placed 7-8 cm below the trochanter so the ischium was visible. In the Bone Density Research Laboratory, the coefficient of variation (%CV) for the precision and accuracy of the DXA for the total body BMD is 0.7%, the spine is 1.4%, the total left and right hip is 0.6%, the right trochanter is 0.6%, the left trochanter is 0.7%, the right femoral neck is 0.9%, and the left femoral neck is 1.01%. The %CV for the precision of the DXA for body composition variables is the percent body fat and fat mass is 2.0%, the bone free lean body mass is 1.9%, and the fat free mass is 1.7%.

Peripheral Quantitative Computed Tomography (pQCT)

A peripheral quantitative computed tomography XCT scanner with software version 6.0 (Stratec Medizintechnik GmbH, Pforzheim, Germany) was used to measure cortical BMC (mg/mm), cortical area (mm^2), trabecular BMC (mg/mm), and trabecular area (mm^2) of the tibia at the 4%, 38%, and 66% sites of the nondominant leg. The pQCT measurements allowed the technician to assess the thickness of cortical and trabecular bone and bone strength (SSI) at

multiple bone sites. Additionally, calf muscle cross-sectional area at the 66% site was measured in order to determine if the training program had any effect on the CSA of the muscle in the leg. The pQCT can accurately measure small changes in the muscle CSA that can occur due to training programs (DeFreitas et al., 2010). Calibration and quality assurance of the pQCT took place prior to testing each day. The researcher measured the tibia length of the nondominant leg from the tibia plateau to the medial malleolus. Afterwards, the subject sat in the chair and placed their nondominant leg into the gantry of the pQCT machine. The subject's information was entered into the pQCT and a scout view was run to identify the reference point at the medial malleolus. Once the reference point was set, the scans of the 4%, 38%, and 66% of the tibia were performed. The technicians were instructed and understood the proper placement and positioning of each leg before beginning the experiment in order to ensure for proper precision and reproducibility of the scans. Sharmga et al. determined that the pQCT was reliable and valid compared to a microCT in terms of being highly sensitive to cortical bone alterations (Scharmga et al., 2016). For the Bone Density Research Laboratory, the %CV for the 4% of the tibia total vBMD is 1.01%, the total vBMC is 1.19%, Peri C is 1.39%, the 38% for the tibia total vBMD is 0.21%, the vBMC is 0.33%, Peri C is 0.19%, the Endo C is 0.35%, Cort vBMD is 0.20%, the Cort vBMC is 0.36%, the Cort Area is 0.47%, the 66% of the tibia total vBMD is 0.67%, the total vBMC is 0.24%, the Peri C is 0.33%, the Endo C is 0.74%, the Cort vBMD is 0.25%, the Cort vBMC is 0.34%, and the Cort Area is 0.38%.

Jump Test Measurements

Jump velocity and power were measured using the Tendo FiTRODYNE power and speed analyzer (Tendo Sports Machines, Trencin, Slovak Republic), and jump height and air time were measured using a jump mat (Just Jump, Probotic, AL). During the first visit to the laboratory, the

subject had a familiarization session prior to the actual testing to allow the subject to understand the motion of the countermovement jump and to become comfortable with the action.

The jump tests were performed during the first and fourth visits after the DXA and pQCT scans as well as during the mid-test visit. Their height and weight were measured while wearing shoes and a transfer belt. Three practice countermovement jumps were performed by having the participant crouch down and jump maximally with non-restrictive arm movements, making sure they cushion their landing. The technician checked that the subject did not tuck the feet under nor did she squat too far when landing. To set up the test, the jump mat was placed on a level surface, the transfer belt was placed snugly around the subject's waist, and the tether from the Fitrodyne was securely attached to the belt near the iliac crest. The barbell from the Fitrodyne was placed parallel to the jump mat on a level surface, but at a distance to ensure that the subject did not land on it. To perform the test, the subject stood in the middle of the jump mat with their feet shoulder-width apart, crouched down, then jumped maximally with non-restrictive arm movements, and landed on the mat. The FiTRODYNE recorded the power (watts) and velocity (meters/seconds) of the jump while the Just Jump device recorded the jump height (inches) and air time of the jump (seconds). The subject was then instructed to perform three maximal jumps with one-minute rest between each jump. The variables from the jumps were recorded in on the subject's data sheet and the average of each variable will be used for the data analysis. Intraclass Correlations (ICCs) values for the jump power, velocity, air time, and jump height range from 0.80-0.98 for the Bone Density Research Laboratory.

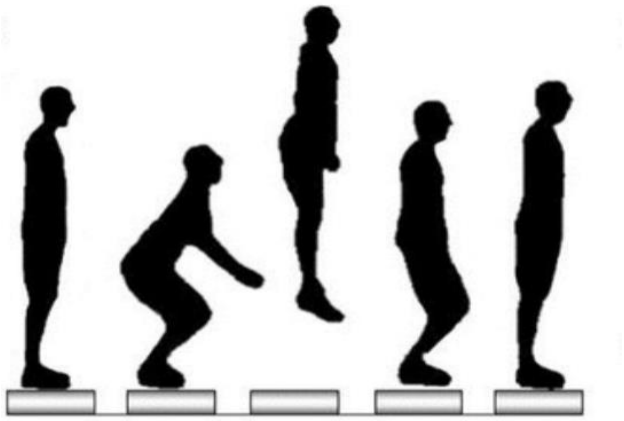

Figure 2. Overview of the Maximal Countermovement Jump.

Statistical Analysis

All statistical procedures were performed using IBM SPSS 24 (SPSS Inc., Chicago, IL) software. All descriptive data were reported as mean ± SD. Dependent variables were checked for normality using the Shapiro-Wilks test. Independent t-tests were performed to determine the differences between the jump intervention group and the control group for physical characteristics, BMD, BMC, bone geometry, jump power, and jump height at baseline. If significant group differences were detected, those baseline variables will be used as covariates in subsequent analyses. Two-way repeated measures ANOVA (group × time) with a Bonferroni post hoc test were performed to determine group differences in changes in the dependent variables from pre to post intervention. If a significant group × time interaction was found, the model was decomposed by performing paired t-tests comparing time points within each group. Independent T-tests were used to analyze the percent changes of the variables when there were two timepoints, if there were three timepoints, a two-way repeated measure ANOVA was utilized in order to determine the level of significances. The level of significance was be set at $p \leq 0.05$.

Chapter 4: Results and Discussion

The purposes of this study were to: (1) compare bone mineral density before and after an eight-week low-repetition, high-impact loading jump intervention in premenopausal women between the ages of 18-21, (2) compare bone geometry before and after the intervention to determine alterations, and (3) compare cross-sectional area of the muscle in the lower limb before and after the intervention.

Participant Characteristics

A total of 20 participants (Intervention n=10, Controls n=10) between the ages of 18-24 years completed the study and were included in the final analysis. Nine females had signed consent forms but were excluded from the study due to an age that exceeded the inclusion criterion (n=1), exercised more than the inclusion criterion (n=4), medications that altered bone geometry (n=1), had surgery in the past year (n=1), and voluntarily withdrew from the study (n=2). Of the females enrolled, two reported having an IUD while seven reported taking hormonal contraceptives. Of the participants not taking hormonal contraceptives, 9 participants reported having regular menstrual cycles while two participants reported having an irregular menstrual cycle. There were no significant height or weight differences between the two groups. Leg dominance was determined by asking the participants which foot they kicked a ball with. Nineteen participants reported being right footed while only one participant reported being left footed. The majority of participants self-identified as Caucasian (n= 17); other ethnicities represented were Black (n=2) and Asian (n=1). No participants reported any signs or symptoms of any bone injuries throughout the eight-week intervention period. Participants did not report compliance on their jumps, it was not stated if a subject did not jump on days they were required to.

Baseline participant characteristics are found in Table 1. No significant differences existed between the two groups for age, height, weight, calcium intake, or past, current, or total BPAQ scores (all $p \geq 0.121$). Additionally, no significant group differences were found for total MET minutes/week and total walking/week, as assessed by the International Physical Activity Questionnaire. Calcium intake group means were below the recommended 1000 mg/day for 18 participants (n=9 from both groups) (Quann, Fulgoni, & Auestad, 2015).

Table 1. Baseline Participant Characteristics (means ± SD)

	Time	Intervention (n=10)	Controls (n=10)
Age (years)		20.50 ± 2.12	20.50 ± 2.22
Height (cm)		165.00 ± 7.96	166.85 ± 5.81
Weight (kg)		65.86 ± 7.34	71.39 ± 14.83
Calcium Intake (mg/day)	Pre	665.92 ± 263.99	746. 92 ± 685. 06
	Post	607.50 ± 232.68	641.71 ± 369.41
BPAQ-Past		48.99 ± 45. 90	80.88 ± 73.51
BPAQ-Current	Pre	14.83 ± 15.84	9.10 ± 10.83
	Mid	12.88 ± 16.40	7.55 ± 10.51
	Post	9.31 ± 11.37	2.24 ± 5.28
BPAQ-Total	Pre	31.92 ± 26.81	44.99 ± 37.77
	Mid	30.11 ± 26.22	44.22 ± 35.76
	Post	26.71 ± 19.75	39.56 ± 35.65
Total MET (min/week)	Pre	2414.55 ± 2151.89	4088.50 ± 3077.26
	Mid	2031.05 ± 2327.22	3284.25 ± 3640.52
	Post	3695.85 ± 4628.72	3405.90 ± 3705.09
Total Walking/week	Pre	1232.55 ± 1529.24	2805.00 ± 2147.55
	Mid	1315.05 ± 1495.80	1955.25 ± 2260.82
	Post	1631.85 ± 1723.11	1824.90 ± 1910.82

BPAQ: Bone Physical Activity Questionnaire

Dual Energy X-Ray Absorptiometry Measures

DXA was used to assess changes in aBMD and body composition for the total body, and site-specific areas. There were no significant group differences in baseline DXA variables. Table 2 shows information pertaining to the two total body scans that were completed pre and post the eight-week intervention period. No significant group x time interactions or main effects for time or group were found for total body aBMD, BMC, percent fat mass, fat mass, total body bone free lean body mass, or fat free mass (all $p \geq 0.105$). No significant time effects were found for total body aBMD, BMC, percent body fat, fat mass, bone free lean body mass, or fat free mass (all $p \geq 0.068$). Based on the International Society for Clinical Densitometry guidelines, all participants had normal aBMD values according to their Z-Scores (Lewiecki, Baim, Langman, & Bilezikian, 2009).

Table 2. Total Body aBMD and Body Composition Over Time (mean ± SD)

	Time	Intervention (n=10)	Controls (n=10)
Total Body aBMD (g/cm^2)	Pre	1.206 ± 0.077	1.226 ± 0.058
	Post	1.186 ± 0.088	1.227 ± 0.057
Total Body BMC (g)	Pre	2598.97 ± 403.78	2673.69 ± 278.41
	Post	2607.38 ± 403.40	2684.83 ± 270.11
Total Body % Fat	Pre	33.91 ± 6.88	35.62 ± 8.59
	Post	34.47 ± 7.12	36.16 ± 8.70
Total Body Fat Mass (kg)	Pre	22.33 ± 5.93	26.21 ± 11.32
	Post	22.57 ± 6.37	26.44 ± 11.09
Total Body BFLBM (kg)	Pre	40.30 ± 4.68	41.79 ± 3.52
	Post	39.72 ± 4.66	41.70 ± 3.98
Fat Free Mass (kg)	Pre	42.89 ± 4.98	43.68 ± 4.37
	Post	42.38 ± 4.94	43.38 ± 4.34

aBMD: Areal Bone Mineral Density
BMC: Bone Mineral Content
BFLBM: Bone Free Lean Body Mass

Regional aBMD and body composition information is shown in Table 3. There were no significant group differences at baseline for DXA variables. No significant main effects for time or group or group x time interactions were found for dominant leg fat mass, dominant leg lean mass, nondominant leg fat mass, or nondominant leg lean mass. Additionally, there were no significant main effects for time or group, or group x time interactions for right arm fat mass, right arm lean mass, left arm fat mass, or left arm lean mass (all $p \geq 0.180$). There were no significant time effects for dominant leg fat mass, dominant leg lean mass, nondominant leg fat mass, nondominant leg lean mass, for right arm fat mass, right arm lean mass, left arm fat mass, or left arm lean mass (all $p \geq 0.076$).

Table 3. Regional aBMD and Body Composition Over Time (means ± SD)

	Time	Intervention (n=10)	Controls (n=10)
Dominant Leg Fat Mass (g)	Pre	4414.10 ± 1280.12	5000.50 ± 2001.03
	Post	4257.00 ± 1199.80	5024.10 ± 1876.41
Dominant Leg Lean Mass (g)	Pre	6081.30 ± 964.75	6924.55 ± 873.81
	Post	6611.50 ± 866.39	6804.90 ± 861.29
Nondominant Leg Fat Mass (g)	Pre	4329.90 ± 1215.20	4929.80 ± 2001.99
	Post	4245.80 ± 1244.45	4930.60 ± 1869.19
Nondominant Leg Lean Mass (g)	Pre	6687.40 ± 884. 27	6811.55 ± 839.92
	Post	6574.70 ± 826.70	6716.35 ± 829.03
Right Arm Fat Mass (g)	Pre	1109.40 ± 375.95	1206.75 ± 514.36
	Post	1127.10 ± 392.14	1229.80 ± 508.17
Right Arm Lean Mass (g)	Pre	2281.30 ± 256.69	2372.05 ± 345.64
	Post	2279.90 ± 260.84	2341.15 ± 294.58
Left Arm Fat Mass (g)	Pre	1071.90 ± 356.71	1177.90 ± 515.26
	Post	1093.60 ± 373.55	1209.35 ± 528.11
Left Arm Lean Mass (g)	Pre	2202.10 ± 206.83	2264.00 ± 265.34
	Post	2215.40 ± 235.34	2288.25 ± 292.59

Lumbar Spine (L1-L4) and dual hip aBMD variables are shown in Table 4. There were no significant group differences at baseline for lumbar spine and dual hip aBMD DXA variables. No significant group x time interactions, or main effects for time or group were found for lumbar spine (L1-L4) aBMD or BMC (all $p \geq 0.105$). Additionally, no group x time interactions or main effects for time or group were found for any dominant and nondominant hip aBMD variables (all $p \geq 0.105$). There were no significant time effects for any lumbar spine variables or dominant and nondominant hip variables (all $p \geq 0.274$). Calcium intake was significantly positively correlated with dominant femoral neck aBMD at the pre ($r=0.455$, $p=0.042$) and post ($r=0.472$, $p=0.036$) time points.

Table 4. Lumbar Spine and Dual Hip aBMD Over Time (means ± SD)

	Time	**Intervention (n=10)**	**Controls (n=10)**
Lumbar Spine (L1-L4) aBMD (g/cm^2)	Pre	1.253 ± 0.109	1.132 ± 0.148
	Post	1.258 ± 0.110	1.317 ± 0.147
Dominant			
Femoral Neck (g/cm^2)	Pre	1.116 ± 0.074	1.199 ± 0.138
	Post	1.106 ± 0.071	1.207 ± 0.132
Trochanter (g/cm^2)	Pre	0.872 ± 0.043	0.890 ± 0.105
	Post	0.871 ± 0.035	0.882 ± 0.103
Total Hip (g/cm^2)	Pre	1.109 ± 0.066	1.152 ± 0.093
	Post	1.095 ± 0.064	1.149 ± 0.94
Non-Dominant			
Femoral Neck (g/cm^2)	Pre	1.116 ± 0.089	1.177 ± 0.119
	Post	1.108 ± 0.101	1.179 ± 0.115
Trochanter (g/cm^2)	Pre	0.872 ± 0.055	0.897 ± 0.088
	Post	0.877 ± 0.051	0.891 ± 0.089
Total Hip (g/cm^2)	Pre	1.100 ± 0.073	1.143 ± 0.089
	Post	1.095 ± 0.069	1.139 ± 0.091

There were no significant group differences in percent changes in Lumbar Spine (L1-L4) aBMD from pre to post-time points (p=0.476).

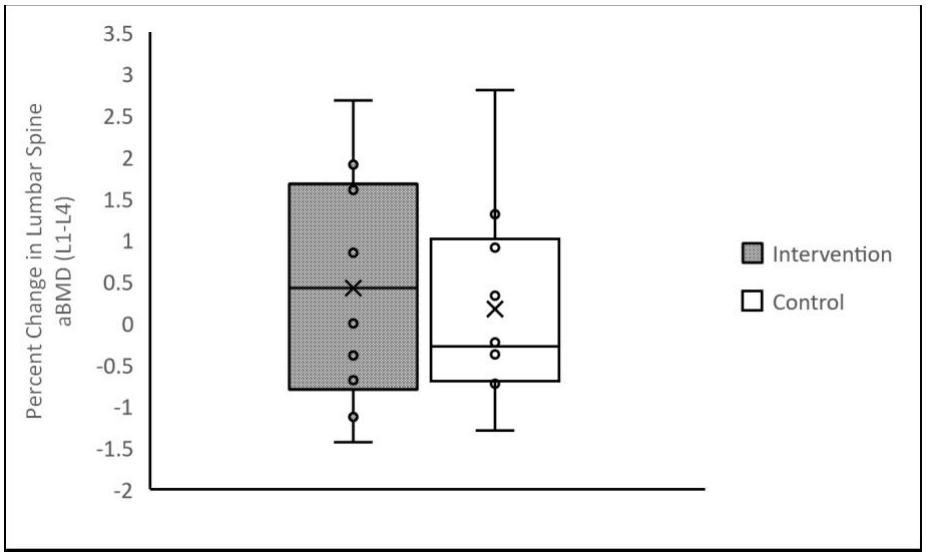

Figure 3. Percent Change for Lumbar Spine (L1-L4) aBMD
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in dominant neck aBMD from pre to post-time points (p=0.748).

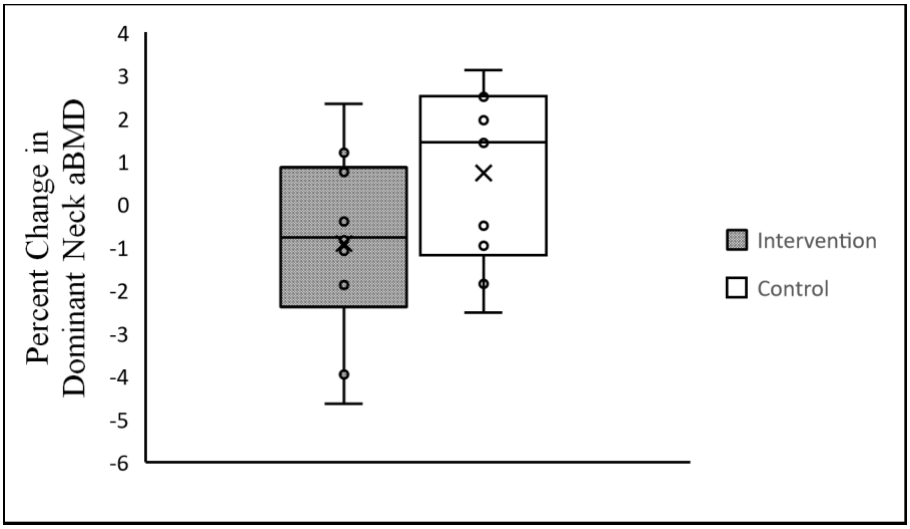

Figure 4. Percent Change in Dominant Neck aBMD
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in nondominant neck aBMD from pre to post-time points (p=0.300).

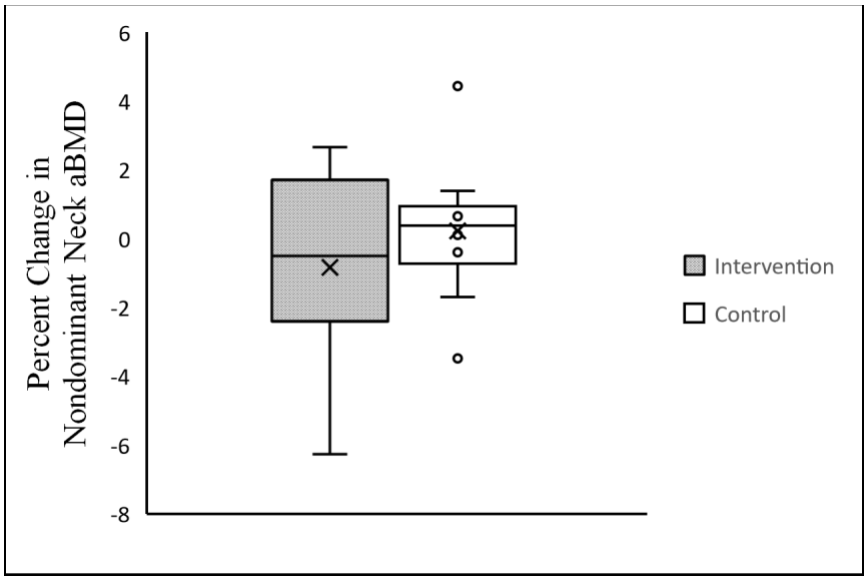

Figure 5. Percent Change in Non-dominant Neck aBMD
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in dominant trochanter aBMD from pre to post-time points (p=0.359).

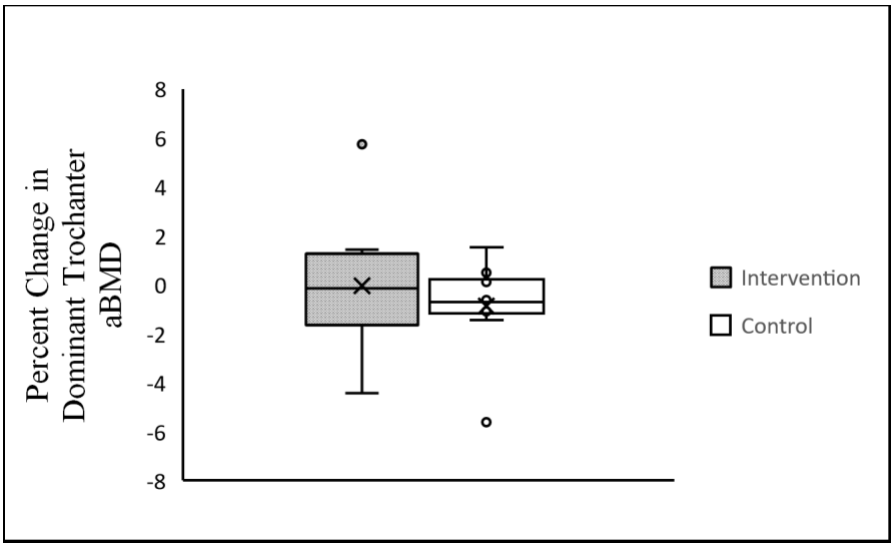

Figure 6. Percent Change in Dominant Trochanter aBMD
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were significant group differences for percent changes in nondominant trochanter aBMD from pre to post-time points in which the intervention group increased over time and the control group decreased over time. (p=0.035).

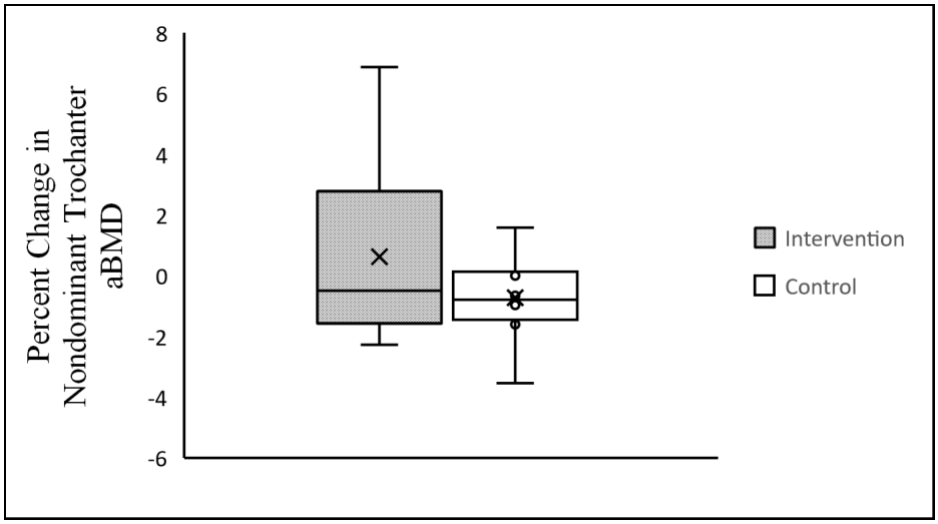

Figure 7. Percent Change in Nondominant Trochanter aBMD
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in mean dominant total hip aBMD from pre to post-time points (p=0.268).

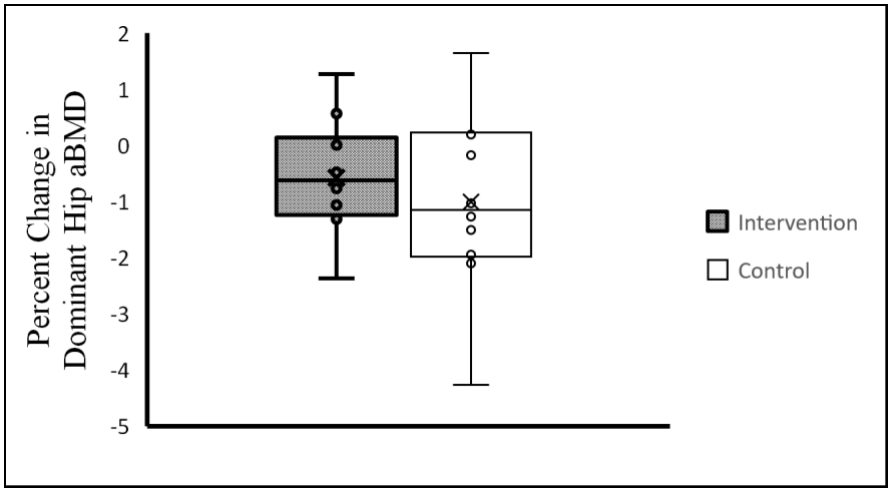

Figure 8. Percent Changes for Dominant Hip Total aBMD
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in nondominant total hip aBMD from pre to post-time points (p=0.425).

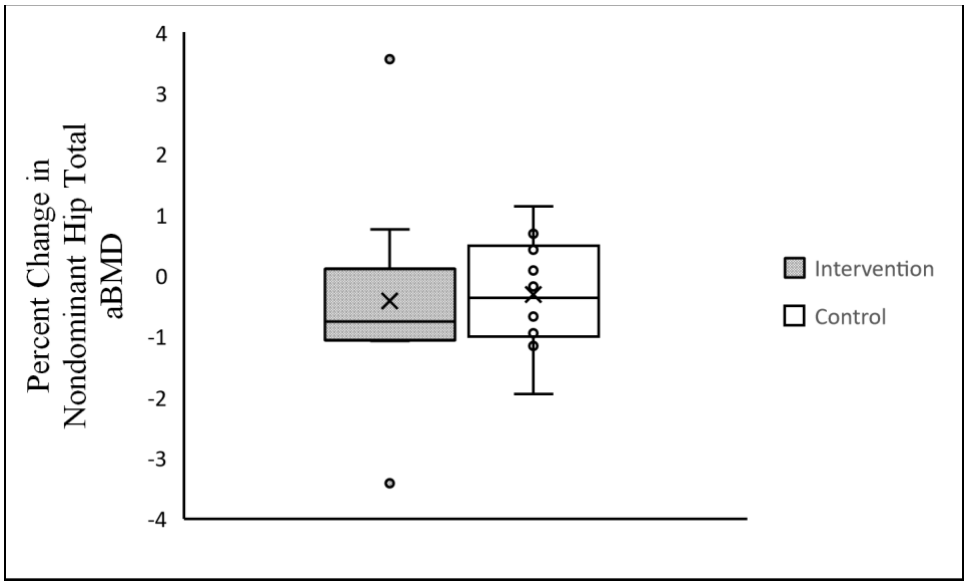

Figure 9. Percent Change in Nondominant Hip Total aBMD
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

Hip Structural Analysis variables over time are shown in Table 5. There were no significant group differences for hip structural variables at baseline. There were no significant group x time interactions, or main effects for time or group were found in dominant and nondominant hip variables for strength index, buckling ratio, section modulus, or cross-section moment of inertia (all $p \geq 0.095$). There were significant time effects for the dominant hip section modulus ($p=0.022$) and cross-section moment of inertia ($p=0.030$) with both groups significantly decreasing over time.

Table 5. Hip Structural Analysis Variables Over Time (means ± SD)

	Time	Intervention (n=10)	Controls (n=10)
Dominant Hip			
Strength Index	Pre	1.670 ± 0.562	1.520 ± 0.301
	Post	1.690 ± 0.360	1.530 ± 0.283
Buckling Ratio	Pre	2.700 ± 0.986	2.200 ± 1.013
	Post	2.500 ± 0.897	2.630 ± 1.124
Section Modulus (mm^3)	Pre	714.320 ± 186.179	728.590 ± 80.949
	Post	698.880 ± 149.949*	687.460 ± 65.146*
CSMI (mm^4)	Pre	10767.100 ± 4187.241	10184.700 ± 1472.188
	Post	10487.300 ± 3376.704*	9500.400 ± 1027. 685*
Non-Dominant Hip			
Strength Index	Pre	1.570 ± 0.340	1.540 ± 0.320
	Post	1.600 ± 0.170	1.550 ± 0.217
Buckling Ratio	Pre	2.210 ± 0.968	2.420 ± 1.203
	Post	2.660 ± 0.938	2.310 ± 0.893
Section Modulus (mm^3)	Pre	688.030 ± 138.910	690.410 ± 59.062
	Post	673.920 ± 143.447	702.100 ± 56.903
CSMI (mm^4)	Pre	10045.000 ± 2918.481	9832.400 ± 1366.255
	Post	10154.500 ± 2792.040	9730.500 ± 1442.144

CSMI: Cross-Section Moment of Inertia
*$p \leq 0.05$ significant vs pre

There were no significant differences for percent changes in mean dominant hip section modulus from pre to post-time points (p=0.221).

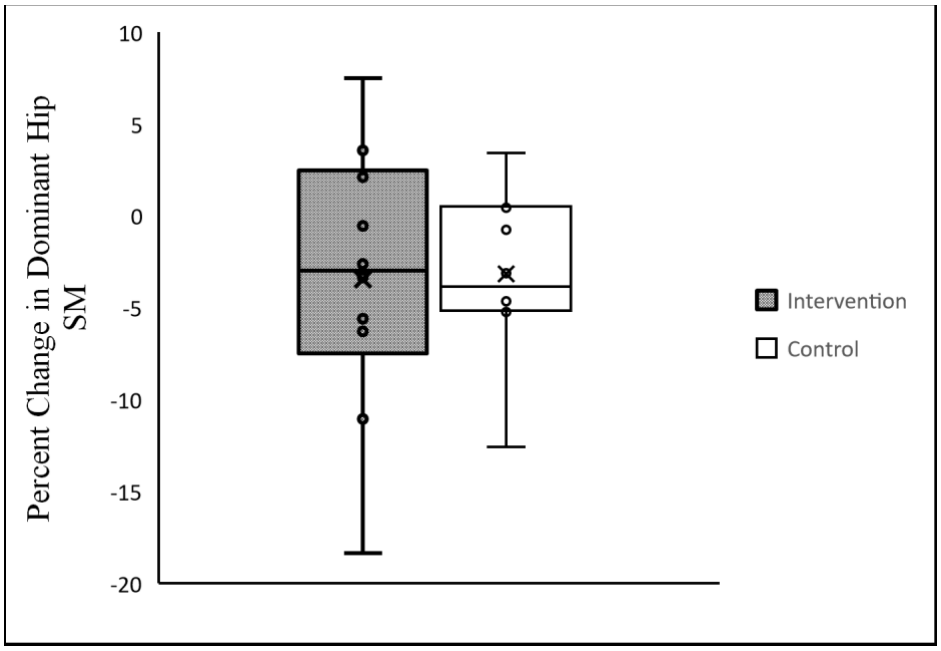

Figure 10. Percent Changes for Dominant Hip Section Modulus
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in mean dominant hip CSMI from pre to post-time points (p=0.763).

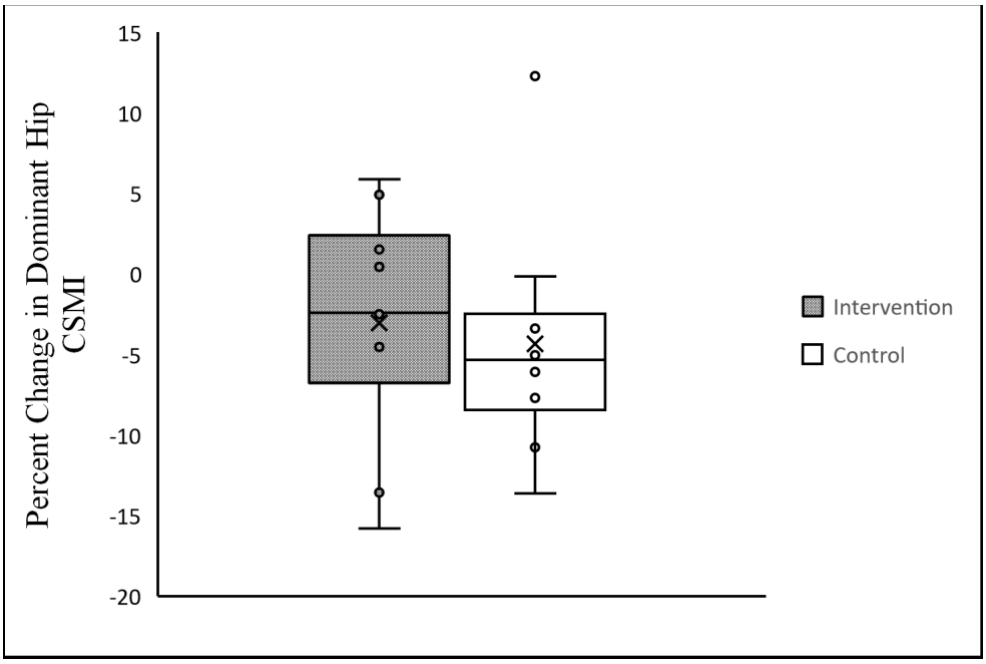

Figure 11. Percent Changes for Dominant Hip CSMI
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

Peripheral Quantitative Computed Tomography Measures

Tables 6-8 show the changes over time in pQCT variables from the 4%, 38%, and 66% non-dominant tibia sites. There were no significant group differences for pQCT variables at baseline. No significant main effects for group or time, or group x time interactions were found for any of the 4% site of the nondominant tibia (all $p \geq 0.134$), including total and trabecular BMC, vBMD, area, bone strength index, and the periosteal circumference. Additionally, there were no significant time effects for the variables of the 4% site of the nondominant tibia (all $p \geq 0.1919$).

Table 6. 4% Non-Dominant Tibia pQCT Variables Over Time (means± SD)

	Time	Intervention (n=10)	Controls (n=10)
Total			
BMC (mg/mm)	Pre	318.135 ± 53.202	322.757 ± 40.588
	Post	318.483 ± 53.546	320.948 ± 40.915
vBMD (mg/cm^3)	Pre	325.920 ± 46.198	318.940 ± 46.178
	Post	325.000 ± 47.027	318.480 ± 46.359
Area (mm^2)	Pre	978.608 ± 110.415	1016.608 ± 77.699
	Post	983.696 ± 118.145	1012.352 ± 78.382
BSI (mg^2/mm^4)	Pre	105.387 ± 30.241	104.340 ± 27.030
	Post	105.180 ± 30.366	103.628 ± 26.978
Trabecular			
BMC (mg/mm)	Pre	210.961 ± 38.707	223.780 ± 32.977
	Post	212.025 ± 38.616	222.490 ± 33.151
vBMD (mg/cm^3)	Pre	268.650 ± 40.886	270.890 ± 44.167
	Post	268.730 ± 40268	270.420 ± 44.692
Area (mm^2)	Pre	787.648 ± 99.367	830.544 ± 74.921
	Post	792.416 ± 106.622	827.312 ± 74.877
BSI (mg^2/mm^4)	Pre	57.746 ± 17.853	61.685 ± 18.503
	Post	57.976 ± 17.709	61.262 ± 18.624
Periosteal Circ. (mm)	Pre	110.73 ± 6.29	111.84 ± 5.40
	Post	111.00 ± 6.69	111.86 ± 5.60

BMC: Bone Mineral Content
vBMD: Volumetric Bone Mineral Density
BSI: Bone Strength Index
Circ.: Circumference

Table 7 shows the nondominant tibia pQCT variables for the 38% site. There were no significant group variables for the 38% site of the tibia at baseline. There were no significant main effects for group or time, or group x time interactions for any of the variables of the 38% site of the nondominant tibia (all $p \geq 0.223$) including total and cortical BMC, vBMD, area, cortical thickness, periosteal circumference, endosteal circumference, iPolar, and stress strain index. Additionally, there were no significant time effects for the variables at the 38% site (all $p \geq 0.211$).

Table 7. 38% Non-Dominant Tibia pQCT Variables Over Time (means± SD)

	Time	Intervention (n=10)	Controls (n=10)
Total			
BMC (mg/mm)	Pre	326.461 ± 53.645	342.948 ± 42.229
	Post	326.719 ± 52.976	343.147 ± 41.547
vBMD (mg/cm^3)	Pre	957.940 ± 43.643	958.090 ± 58.253
	Post	958.510 ± 45.159	957.310 ± 59.315
Area (mm^2)	Pre	340.896 ± 55.339	359.968 ± 56.164
	Post	340.944 ± 54.209	360.560 ± 56.117
Cortical			
BMC (mg/mm)	Pre	313.655 ± 51.617	331.561 ± 41.580
	Post	314.145 ± 50.947	331.765 ± 40.857
vBMD (mg/cm^3)	Pre	1185.750 ± 15.740	1189.850 ± 21.518
	Post	1185.230 ± 12.003	1188.180 ± 24.153
Area (mm^2)	Pre	264. 688 ± 44. 826	279.104 ± 38.515
	Post	265.088 ± 43.358	279.712 ± 38.281
Thickness (mm)	Pre	5.498 ± 0.662	5.647 ± 0.445
	Post	5.512 ± 0.639	5.656 ± 0.429
Periosteal Circ. (mm)	Pre	65.255 ± 5.334	67.076 ± 5.196
	Post	65.268 ± 5.226	67.132 ± 5.191
Endosteal Circ. (mm)	Pre	30.712 ± 4.014	31.593 ± 4.478
	Post	30.633 ± 4.068	31.593 ± 4.478
iPolar (mm^4)	Pre	20375.982 ± 6705.018	22003.777 ± 6422.248
	Post	20354.056 ± 6667.516	22060.205 ± 6364.701
SSI (mm^3)	Pre	1412.328 ± 351.283	1542.741 ± 312.412
	Post	1403.053 ± 340.621	1542.567 ± 307.460

BMC: Bone Mineral Content
vBMD: Volumetric Bone Mineral Density
Circ.: Circumference
SSI: Stress Strain Index

Table 8 shows the nondominant tibia pQCT variables of the 66% site. There were no significant group differences for the 66% site of the tibia at baseline. There were no significant group x time interactions or main effects for group or time for total and cortical BMC, area, cortical thickness, periosteal circumference, endosteal circumference, iPolar, stress strain index, or muscle cross sectional area (all $p \geq 0.085$). There was a significant group x time interaction for total vBMD ($p=0.043$) as the control group decreased in total vBMD over time while the intervention group increased in total vBMD over time. There was a significant time effect for total BMC ($p= 0.028$) and cortical BMC ($p=0.037$) as both groups had an increase in the variables over time.

Table 8. 66% Non-Dominant Tibia pQCT Variables Over Time (means± SD)

	Time	Intervention (n=10)	Controls (n=10)
Total			
BMC (mg/mm)	Pre	358.332 ± 61.315	376.294 ± 38.720
	Post	359.336 ± 61.349*	376.429 ± 38.570*
vBMD (mg/cm^3)†	Pre	741.130 ± 54.733	734.850 ± 56.096
	Post	743.010 ± 53.793*	733.480 ± 56.331*
Area (mm^2)	Pre	484.816 ± 84.236	514.576 ± 64. 012
	Post	485.008 ± 84.786	515.680 ± 63.396
Cortical			
BMC (mg/mm)	Pre	325.420 ± 54.988	343.514 ± 35.287
	Post	326.460 ± 55.021*	343.919 ± 35.251*
vBMD (mg/cm^3)	Pre	1150.520 ± 14.650	1153.240 ± 23.440
	Post	1150.290 ± 11.508	1152.540 ± 21.478
Area (mm^2)	Pre	282.960 ± 48.779	298.368 ± 35.424
	Post	283.872 ± 48.410	298.864 ± 35.002
Thickness (mm)	Pre	4.415 ± 0.545	4.515 ± 0.415
	Post	4.343 ± 0.545	4.519 ± 0.422
Periosteal Circ. (mm)	Pre	77.789 ± 6.767	80.274 ± 4.982
	Post	77.802 ± 6.797	80.364 ± 4.934
Endosteal Circ.(mm)	Pre	50.048 ± 5.942	51.903 ± 5.061
	Post	49.942 ± 6.087	51.969 ± 5.140
iPolar (mm^4)	Pre	35701.333 ± 11973.456	39148.889 ± 9516.589
	Post	35739.463 ± 11990.101	39136.185 ± 9448.099
SSI (mm^3)	Pre	2106.059 ± 507.615	2300.964 ± 366.140
	Post	2111.279 ±514.030	2308.397± 370.585
Muscle CSA (mm^2)	Pre	6997.248 ±1199.7	6976.612 ±1222.981
	Post	6962.624± 1200.210	7028.688 ±1128.129

BMC: Bone Mineral Content
vBMD: Volumetric Bone Mineral Density
Circ.: Circumference
SSI: Stress Strain Index
*$p \leq 0.05$ Significant vs pre
† $p \leq 0.05$ Significant Group x Time Effect

There were no significant group differences for percent changes in mean 66% tibia total BMC from pre to post-time points (p=0.254).

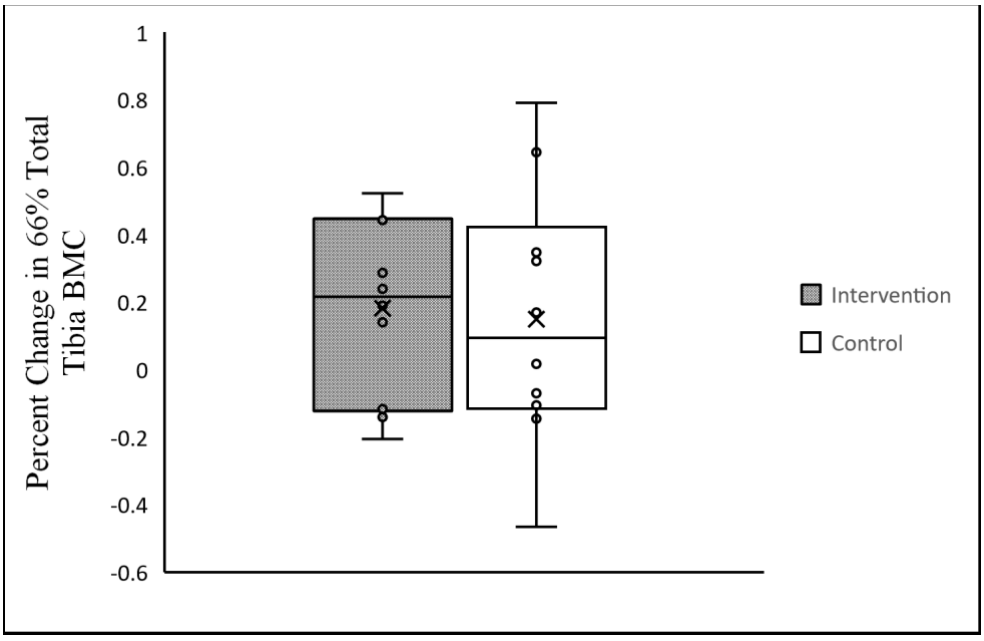

Figure 12. Percent Changes for 66% Tibia Total BMC
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in mean 66% tibia total vBMD from pre to post-time points (p=0.171).

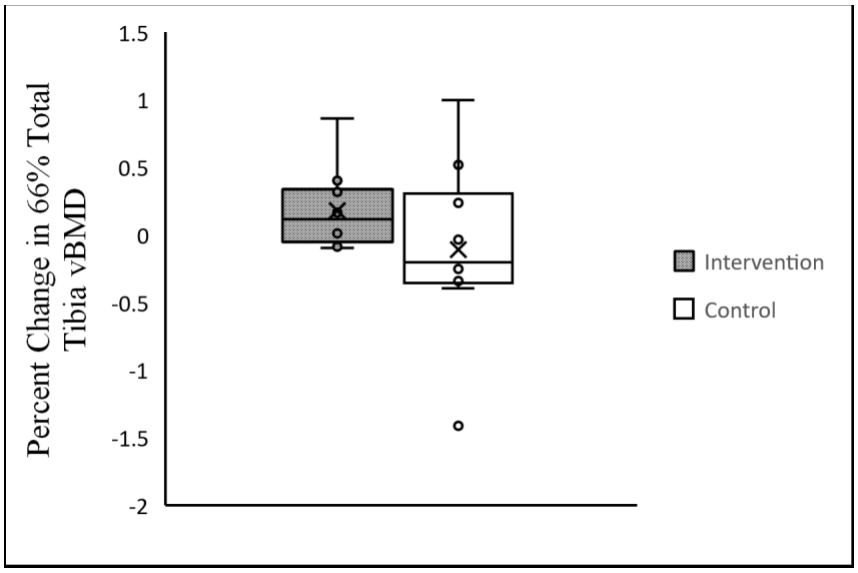

Figure 13. Percent Changes for 66% Tibia Total vBMD
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in mean 66% tibia cortical BMC from pre to post-time points (p=0.054), however, there was a trend.

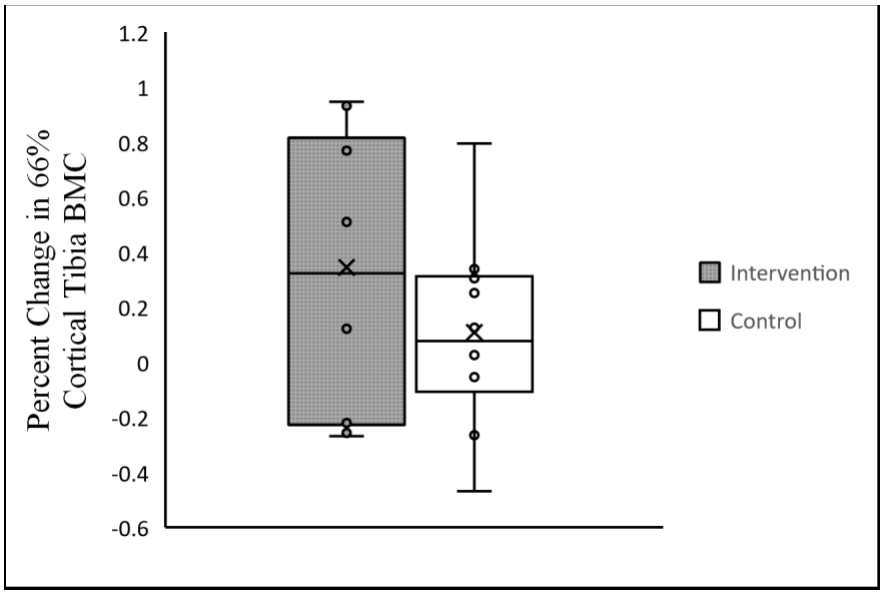

Figure 14. Percent Changes for 66% Tibia Cortical BMC
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

Jump Test Measurements

Maximal jump variables were the highest value the subject achieved in the three jumps, while the average variable was the average of the three trials. There were no significant group differences for jump variables at baseline. There were no significant group x time interactions or main effects for group or time for average and maximal jump height, time in air, jump power, and jump velocity (all $p \geq 0.147$). There was a significant time effect for maximal jump height ($p=0.031$), which decreased from mid to post in both the control group and the intervention group. Additionally, there was a significant time effect for average jump height ($p=0.041$) and average jump time ($p=0.028$) with both groups increasing from pre to mid time points.

Table 9. Jump Variables Over Time (means± SD)

	Time	Intervention (n=10)	Controls (n=10)
Average Jump Height (cm)	Pre	32.08 ± 3.51	32.92 ± 3.33
	Mid	33.38 ± 4.93*	34.16 ± 2.84*
	Post	33.12 ± 4.22	33.40 ± 3.38
Average Time in Air (s)	Pre	0.51 ± 0.03	0.51 ± 0.02
	Mid	0.52 ± 0.04*	0.52 ± 0.02*
	Post	0.51 ± 0.03	0.52 ± 0.03
Average Jump Power (W)	Pre	755.16 ± 159.23	801.46 ± 245.94
	Mid	760.67 ± 163.28	868.03 ± 206.61
	Post	769.73 ± 174.45	822.47 ± 194.75
Average Jump Velocity (m/s)	Pre	1.17 ± 0.20	1.13 ± 0.13
	Mid	1.18 ± 0.22	1.23 ± 0.10
	Post	1.21 ± 0.19	1.17 ± 0.08
Max Jump Height (cm)	Pre	32.31 ± 3.10	33.25 ± 3.67
	Mid	33.91 ± 5.00	35.05 ± 3.51
	Post	33.25 ± 4.04#	33.22 ± 3.58#
Max Time in Air (s)	Pre	0.51 ± 0.02	0.52 ± 0.03
	Mid	0.52 ± 0.04	0.53 ± 0.03
	Post	0.52 ± 0.03	0.52 ± 0.03
Max Power (W)	Pre	791.50 ± 183.48	842.50 ± 260.93
	Mid	792.00 ± 184.38	897.90 ± 219.73
	Post	794.20 ± 180.62	861.50 ± 201.07
Max Jump Velocity (m/s)	Pre	1.23 ± 0.23	1.18 ± 0.14
	Mid	1.22 ± 0.24	1.27 ± 0.11
	Post	1.25 ± 0.20	1.23 ± 0.09

*$p \leq 0.05$ significant vs pre
#$p \leq 0.05$ significant vs mid

.

There were no significant group differences for percent changes in mean jump height from the pre to mid-test or the pre to post-test (all $p \geq 0.172$).

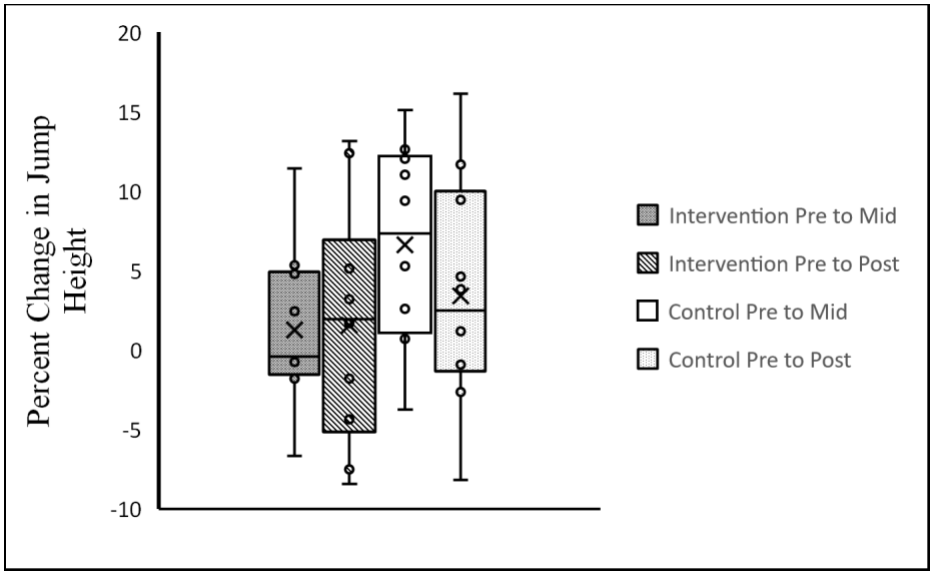

Figure 15. Percent Changes for Jump Height Pre to Mid-Test and Pre to Post-Test
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

There were no significant group differences for percent changes in mean jump time from the pre to mid-test or the pre to post-test (all p=0.127).

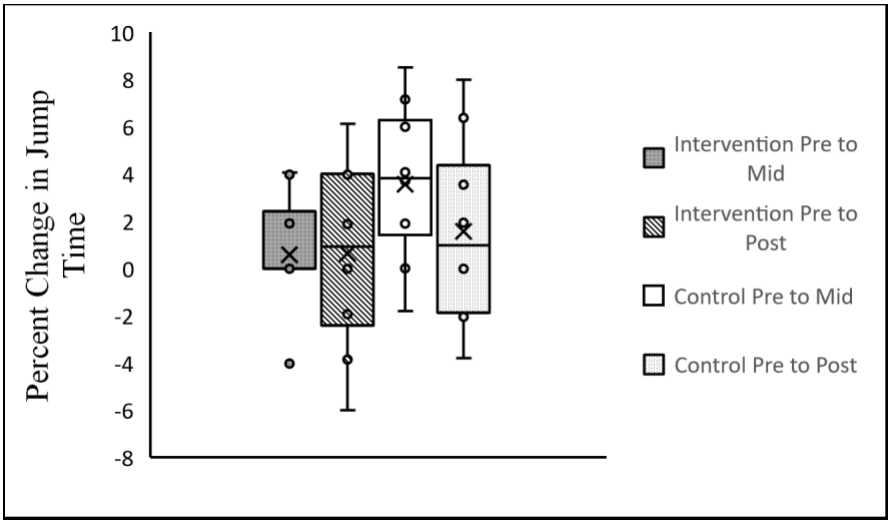

Figure 16. Percent Changes for Jump Time Pre to Mid-Test and Pre to Post-Test
X denotes mean, line denotes median, boxes denote the 25th and 75th quartiles.

Discussion

The purposes of this study were to: (1) compare bone mineral density before and after an eight-week low-repetition, high-impact loading jump intervention in premenopausal women between the ages of 18-21, (2) compare bone geometry before and after the intervention to determine alterations, and (3) compare cross-sectional area of the muscle in the lower limb before and after the intervention.

Areal Bone Mineral Density and Body Composition

In this study, the jump intervention was not effective for improving total body and site specific aBMD or BMC at any site. In a six-month study performed by Kato et al. college-aged women were asked to engage in 10 maximal countermovement jumps a day, 3-7 days per week (Kato et al., 2006a). By the end of the six months, the researchers found a significant increase in the aBMD of the femoral neck of the intervention group and no change in the aBMD of the femoral neck in the control group. These results contradicted those in the current study, where the intervention group had a decrease in femoral neck aBMD, and the control group observed an increase in aBMD of the femoral neck. This difference could be due to the short duration of the current study, whereas Kato et al. performed a jump intervention over a six-month period. They also observed a significant increase in the lumbar spine of the intervention group, whereas the current study found no significant differences in the lumbar spine. This could be due to the subjects not performing a true maximal countermovement jump and therefore not having an overload of strain on their spine. Since the current study was unsupervised, the subjects informed the researchers that they engaged in maximal countermovement jumps. However, they could have been jumping but not to their maximal ability (Kato et al., 2006a). The current study had subjects engaging in over 10 jumps as well as a progressive intervention in which they increased

by 5 jumps every two weeks, whereas Kato and colleagues continued to have their subjects jump 10 times throughout the six months. The reason behind the current study increasing the participant's jumps throughout the duration was to ensure that the body was not adapting to the unusual stress placed upon the bone and allow the sensitivity of the markers to continuously be overloaded. Unfortunately, even with the increase in the number of jumps completed, the current study did not find the same results as Kato et al. Due to the lack of supervision, it is possible that as the intervention continued, the participants may have decreased their efforts and did not adhere to the proper protocols.

Tucker et al. divided women between the ages of 25-50 into three groups (Tucker et al., 2015). The two jumping groups completed 10 CMJ and 20 CMJ twice per day for 16 weeks respectively and a sedentary control group was also included. Tucker et al. found that there was a significant increase in hip BMD and hip structural analysis (HSA) variables in the intervention groups compared to the control group, but there was no significant difference among the two intervention groups. The data suggest that both CMJ groups performed a sufficient volume of exercise to elicit a positive bone remodeling response (Tucker et al., 2015). In the current study, no significant group x time interactions were found from the HSA variables. The changes in the hip BMC were likely too small to translate into significant differences in hip structural analysis measure. There was a significant time effect found for the Section Modulus and CSMI for the dominant hip with a decrease in both groups over time. The lack of significance found in the BMC of the femur could be due to the participants not engaging in their true maximal countermovement jump, and therefore not placing enough strain on the bone to elicit a response. The subjects were not required to demonstrate their maximal jumps to the researchers on a daily basis, nor were they asked if they engaged in their complete training set for each day. If the

subjects were not placing a maximum strain on the bone, then an insufficient stimulus was sustained to result in consistent osteogenesis.

Bassey and Ramsdale performed a study in which premenopausal women were randomly separated into a control group in which they engaged in low-impact exercise and a treatment group that engage in high-impact exercises for six months (Bassey & Ramsdale, 1994). At the end of the six months, there was a significant group difference in the femoral neck BMD in which the treatment group increased. There were no significant differences in the lumbar spine BMD. This contradicted the current study which discovered no significant differences in the lumbar spine BMD, nor the femoral neck BMD. Studies have shown that maximal countermovement jump protocols provide enough of a landing ground reaction force to allow for a functional strain on the femur to cause an increase in BMD (Bassey & Ramsdale, 1994). The subjects of the current study were not compliant enough with the protocol to elicit an increase in BMD of the femoral neck and lumbar spine.

A meta-analysis combined studies in which premenopausal women jumped between 10-50 times a day, 3-7 days a week for 6-12 months. The consensus of the studies was that maximal countermovement jump studies in premenopausal women results in a significant increase in the BMD of the femoral neck, but no significant differences in the lumbar spine. It takes 3-6 months in order for bone turnover to take place and an increase in BMD to be noticeable on the DXA. There is a chance that the short duration of the current study was causing an increase in the BMD of the lumbar spine and dual femoral neck, however, the DXA would have been unable to detect the slight changes. Future studies are encouraged to lengthen the duration of the intervention period to maximize the effect of the femoral neck or lumbar spine. There is a threshold for bone turnover, and once it has been achieved, no more formation can occur, it is probable that the

number of jumps in the current study were not enough to surpass the threshold. It could be possible that an increase in the number of jumps performed could have elicited a greater increase in the BMD variables of the lumbar spine and femoral neck (Zhao et al., 2014).

In this study, the jump intervention was not effective for improving total body BMC. The lack of significance could be due to the short duration of the intervention. Witzke & Snow (2000) saw similar results in which after their nine-month plyometric jump training in adolescent girls, there was an overall increase in total body BMC. The difference in nine-months versus eight-weeks may have been the reason that the current study did not see a significant difference in the increase in total body BMC between the two groups whereas Witzke saw a significant difference. Witzke saw significant changes with a small sample size (n=25), similar to the current study, but contradicted the results of the current study which did not find any significant changes in total body BMC (Witzke & Snow, 2000).

Body composition and total BMC improved in a 12-week intervention in which college-aged females were randomly divided into a multimodal intervention group or a rowing intervention group. The multimodal group performed exercises such as lunges and hurdle hops while the rowing group used a rowing ergometer throughout the 12 weeks. By the end of the intervention, both groups had a significant decrease in body fat percent, an increase in total body BMC, and an increase in lean mass (Brown et al., 2018). The current study analyzed no significant differences in either group for total body percent fat, total body BMC, or lean mass. The lack of findings for BMC could be due to the short duration of the intervention, or the jump protocol did not allow for a stress to be placed on bone throughout different areas of the body. Additionally, the participants of the study were sedentary and jumping 10-25 times a day would not cause them to be in a calorie deficit state and therefore would not change body composition.

The jump intervention focused on straining the bones of the spine and the femur while neglecting to stress the arms. In order to see an increase in the total body BMC, exercises in which the total body is engaged are necessary. Additionally, there was no significant increase in lean mass, potentially due to the jump exercises not placing enough strain on the muscle of the legs to elicit an improvement. The jump exercise was not enough work placed upon the body to allow for more muscle cells to develop and increase the lean mass of the subjects.

Volumetric Bone Mineral Density

In this study, the jump intervention was not effective in improving the bone geometry of the 4% and 38% site of the nondominant tibia, the total and cortical BMC of the 66% site improved throughout the study as well as the vBMD in the intervention group. The lack of significant findings in the 4% and 38% site could be due to the short duration of the study or the small sample size observed. In a 13-week long study, Evans and colleagues found a group x time interaction for the trabecular vBMD at the 4% site of the tibia as well as a group x time effect at the 38% site for total area (Evans et al., 2012). The study divided 57 college-aged females into a sedentary control group and three groups which trained three days a week: resistance training, aerobic training, and a combined resistance and aerobic trained. At the 38% site, there was an increase in total area in the aerobic training group and the combined training group compared to the resistance training group and the control group. The 4% site of the tibia had a significant increase in the trabecular density in the aerobic and combined exercise groups compared to the resistance exercise and control group (Evans et al., 2012). The current study observed that the 4% trabecular vBMD remained the same in both the intervention group and control group over time. Additionally, the 38% total area of the tibia remained the same in both the intervention and control group. Evans et al. found no significant differences at the 66% site of the tibia (Evans et

al., 2012). This could be due to the current study placing a higher load on the cortical bone at the 66% site that bone turnover was activated. The differences in the exercises shown in the study performed by Evans et al. and the jumps from the current study place strains on different parts of the tibia, allowing for different bone alterations to occur. However, the 4% site of the tibia contains more trabecular bone and is more metabolically active than trabecular bone, therefore the 4% site of the tibia should have experienced more bone turnover and formation. The lack of significant change in the 4% site could be potentially the sample size was too small to observe a noticeable change or the jump intervention did not place a great enough load on the site. Additionally, it takes about eight weeks in bone remodeling to see a change in bone geometry on the pQCT, although this study was eight-weeks, it might not have been enough time for the changes to be noticeable on the pQCT.

Lester et al. observed differences in bone geometry pre and post an eight-week intervention (Lester et al., 2009). Fifty-six college-aged women were divided into four groups: control group, aerobic exercise group, resistance training group, and combined aerobic and resistance training group. All treatment groups exercised three times a week for the eight-week duration of the study. The researchers found a significant difference in the vBMD of the 4% site of the tibia. They also found no significant differences in the 38% and 66% site of the tibia. The current study found no significant group differences in the 4% site of the tibia after the eight-week intervention. The 4% site of the tibia had a significant difference in the study performed by Lester and colleagues due to the fact that the site is more metabolically active and bone remodeling takes about 8 weeks to occur, which was the timeframe of the study. In the current study, no change was found potentially due to the small sample size of 20 participants compared to 56 participants. Lester and colleagues also had all training protocols done in a supervised

location, meaning that their participants were compliant with the intervention. The participants were also sedentary individuals, who were more responsive to the training protocol than sedentary individuals. Additionally, although both studies were eight weeks long, maybe more time was necessary in order to allow for bone turnover to complete and be detected by the pQCT. Lester et al. saw no significant change in the 38% and 66% site of the tibia while the current study found a significant group difference in the vBMD of the tibia as well as significant time effects of the total and cortical BMC of the 66% site (Lester et al., 2009). The findings in the current study could be due to the maximal countermovement jump intervention placing a higher load on the 66% site of the tibia compared to the aerobic and resistance training exercises performed by Lester et al. This higher load could activate the bone formation at the 66% site which was detected by the pQCT.

Physical Performance

In this study, the jump intervention was effective in improving the average jump height and jump time in both groups while the maximal jump height decreased over time. Vlacholpoulos et al. reported that after nine months of a high-impact jump intervention, there was an increase, though not significant, for countermovement jump height, which was observed in the current study (Vlachopoulos et al., 2018). They had 93 adolescent male athletes perform 20 maximal countermovement jumps four times a day, four times a week for nine months. The lack of significant group x time effect in the current study could be due to the fact that all participants were sedentary, and therefore at the same physical level at baseline. However, by the end of the eight weeks, the intervention group had been engaging in multiple jumps a week for eight weeks and therefore would be more likely to improve their overall jump output variables. It is also possible that the controls increased their level of physical activity despite being

encouraged to keep their activity levels the same throughout the eight weeks. Since the subjects were not asked to record their level of activity throughout the duration of the study, their activity levels could have increased, and the subjects did not feel inclined to inform the researchers. This could result in the lack of significant findings between the two groups at the end of the study.

Physically active men with osteopenia of the hip or spine participated in a study in which they were randomly placed in a resistance training group or a jump intervention group (Hinton et al., 2015). The resistance training group exercised twice a week that included exercises that load the hip and spine such as lunges, modified deadlifts, and squats. The jump protocol included exercises that involved single leg and double leg jumps and that varied by direction and intensity and performed them at a supervised location three times a week. At the end of the 12-month study, the participants in the jump intervention group increased their vertical jump height (Hinton et al., 2015). The current study had the same findings in that both the control group and intervention group significantly increase their vertical jump height on average throughout the duration of the study. The intervention group increased their height because they were consistently jumping five days a week and therefore better able to perform the exercise by the end of the eight weeks. The control group may have seen an increase in their jump height because it was their third time jumping for the study and they better understood what was expected and how to perform the jump. There also could have been a learning curve with the control group in which they got better each time they jumped because they were realizing their past mistakes and how to correct them.

In determining if a time effective HIIT protocol could have an osteogenic effect on bone metabolism, Brown et al. analyzed college-aged females participating in a multimodal HIIT protocol versus a rowing HIIT protocol (Brown et al., 2018). The multimodal HIIT protocol

included exercises such as hurdle hops, lunges, and squats while the rowing HIIT protocol used the rowing ergometer. All participants went to the supervised location three times a week for the 12-week study duration. By the end of the study, both groups had an increase in overall muscular power of their jump (Brown et al., 2018). The current study found no significant differences between the average jump power at the end of the eight weeks versus baseline measurements. The lack of findings could be due to the participants giving their maximal effort at the beginning of the study, then not trying their best since the study was unsupervised, and they performed the exercises on their own throughout the study. Since the study was not supervised, the participants were able to perform the jumps how they wished and whether or not they were maximally performed was not documented.

Limitations

There are several weaknesses to consider for this study. The sample size was small which could have prevented finding any significance in the study and underestimated the significant changes between the two groups. The study duration should also be considered when interpreting the findings due to the fact that it generally takes four to six months to see changes in bone mineral density by DXA. It takes eight-weeks to see a change in bone geometry on the pQCT and the study should have been long enough to observe the changes, but no changes were detected, meaning the protocol was not effective in improving bone geometry of the tibia. The intervention group had to hold themselves accountable to jump every day on their own terms. They were sent a daily reminder in order to ensure that they engaged in the intervention and continuously jumped, however, it was up to the individual to perform the jump correctly as well as jump on a hard surface and complete the appropriate number of jumps each day. Unfortunately, compliance was not monitored throughout the study. They were asked at the mid-

test if they were compliant with the protocol of the intervention and if they had any issues, but they did not record their jumps or issues with each individual jump day. The novelty of the intervention was that the subjects were unsupervised while performing each maximal countermovement jump, this was a limitation to the study because researchers are unsure if the subjects performed the jumps everyday as well as if they performed them to their maximal ability.

Chapter 5: Conclusions

The purposes of this study were to: (1) compare bone mineral density before and after an eight-week low-repetition, high-impact loading jump intervention in premenopausal women between the ages of 18-24, (2) compare bone geometry before and after the intervention to determine alterations, and (3) compare cross-sectional area of the muscle in the lower limb before and after the intervention.

Research Questions

1. Will engaging in maximally jumping five days a week for eight weeks improve bone mineral density and bone mineral content in the lumbar spine, dual proximal femur, and total body density in college-aged females?

   No, this unsupervised jump intervention did not improve BMD or BMC in the lumbar spine, dual proximal femur, and total body density in this cohort of females.

2. Will the eight-week jumping intervention alter bone geometry in the 4%, 38%, and 66% tibia sites of the non-dominant leg?

   No, this unsupervised jump intervention did not improve bone geometry in the 4% or 38% site of the non-dominant tibia in this cohort of females.

   There was an increase in the vBMD of the 66% site of the non-dominant tibia of the intervention group compared to a decreased in the vBMD of the 66% site in the control group.

   There was also an increase in total BMC and cortical BMC of the 66% site of the nondominant tibia for both groups.

3. Will the jumping intervention increase cross-sectional area of the muscle at the tibia 66% site of the non-dominant leg?

No, this unsupervised jump intervention did not improve the cross-sectional area of the muscle at the 66% site of the tibia of the non-dominant leg in this cohort of females.

4. Will the eight-week intervention increase vertical jump power output and velocity?

   No, this unsupervised jump intervention did not improve the vertical jump power output and velocity in this cohort of females.

Clinical Significance

The current study found a significant group x time interaction for the 66% total vBMD of the non-dominant tibia in which the control group decreased while the intervention group increased. Thus, a maximal jump intervention increases bone mineral density and geometry in the 66% of the tibia of college-aged females. Although the protocol assigned for the current study may not be the ideal way to improve peak bone mass before the second decade of life, since total body, lumbar spine, and dual femur BMD was not improved. An increase in bone variables and peak bone mineral density could prevent or reduce the risk of fractures and osteoporosis later in life. Which is why an intervention program in which lumbar spine and dual femur BMD increase are important to research. The current study was an unsupervised program, in which the subjects engaged in the maximal jump protocol on their own without logging their jumps. The purpose of the study being unsupervised was to allow for college-aged females to be given a protocol in which they can improve their BMD while not having to go to the gym or spend hours a day engaging in osteogenic exercises. The lack of improvements in BMD and BMC found in this study could be due to compliance issues from the participants that would not have been an issue if the study was supervised. The subjects were asked to engage in the maximal countermovement jumps on their own time to their best ability. Since they were not supervised nor reported their jumps to the researchers, they were able to perform the jumps

however they wished. The subjects may not have been performing maximal jumps when engaging in the intervention nor are the researchers aware if the subjects jumped five times a day. There were significant findings of the bone geometry in the tibia, which shows that the jump intervention has a potential to increase BMC of college-aged females. Additionally, the short duration prevented the DXA from analyzing improvements in BMD and BMC, but bone turnover could have started favoring bone formation and rebuilding bone that was absorbed. This study gives an intervention that is a feasible, inexpensive way for college-age females improve their bone health before reaching their peak, if they perform maximal countermovement jumps five days a week correctly.

Suggestions for Further Research

A larger sample size should determine the effects of a maximal jumping intervention on bone characteristics, a larger sample size should be utilized. The larger the sample size, the more accurate and observable the results from the DXA and pQCT will be and more significant differences between the groups may arise. A larger sample size in an intervention study, the more statistical power and the more likely a change will be detected in BMD and BMC from the intervention protocol. Additionally, a longer duration for the intervention should be considered when determining the effects on bone mineral density and bone geometry because it takes 4-6 months in order for bone formation to be observed due to high mechanical loads being placed upon the bone. The current study took place over eight weeks, which did not give enough time for bone formation to begin and be observed through the DXA. With a longer study, the differences in total body, lumbar spine, and dual femur BMD could be detected and analyzed to determine if the protocol provided significant differences between groups as well as from baseline. A weighted vest could be used to increase the overall weight of the subject in order to

increase the load placed upon the ground reaction forces. With the use of a weighted vest, there can be a progression of the weight in order to continue to overload the ground reaction force and hopefully increase the change in BMD. The eight-week intervention may not have allowed the bone formation to be fully completed or activated. Supervision to the jump program would allow for more compliance and assurance that the participants engage in the protocol throughout the duration of the study. Without supervision to the protocol, a log or daily monitoring of the subject's compliance would be beneficial. A record of how the subject performs each jump is necessary throughout the study to determine if they are constantly jumping to their maximal ability, or if they are altering how they perform the jump. Without supervision of the participants, there needs to be more assurance that they are completing the maximal jump intervention and complying to the exercise description. It would be beneficial in future research to supplement calcium intake to meet the recommended daily allowance of 1000 mg/day to ensure that there is sufficient calcium to support osteogenic processes.

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Appendix A

Flyer

Verbal Script

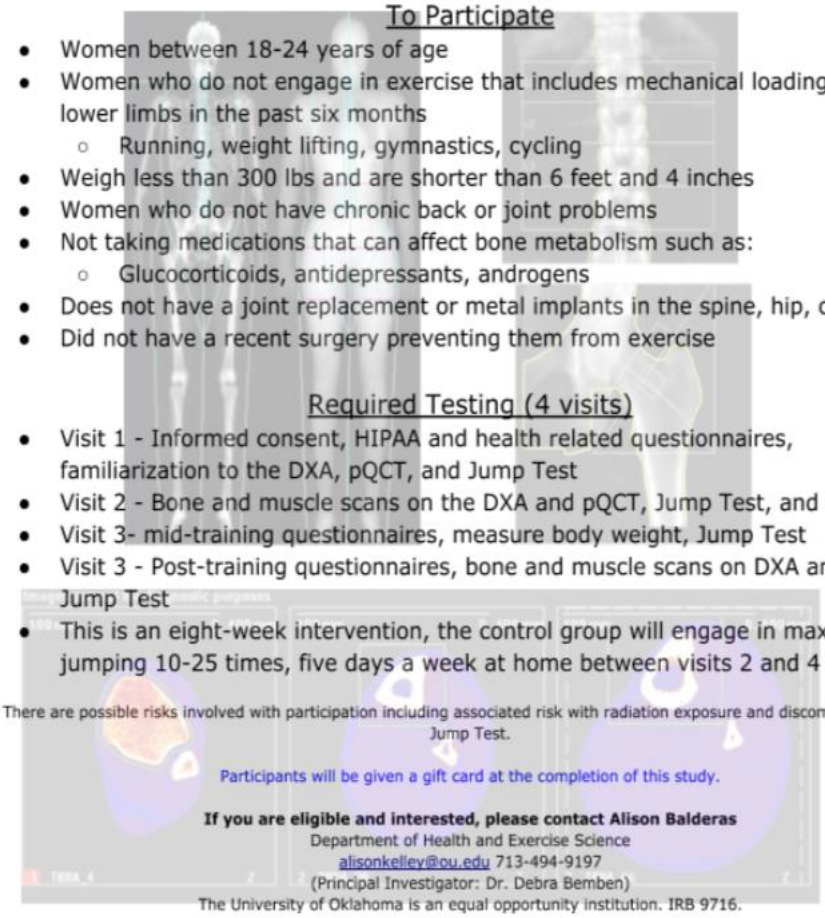
Mass Email Script

Facebook.com Script

Screening Checklist

FEMALE PARTICIPANTS NEEDED

Effects of an Eight Week Maximal Jumping Intervention on Bone Characteristics in College-Aged Females



To Participate

- Women between 18-24 years of age
- Women who do not engage in exercise that includes mechanical loading of the lower limbs in the past six months
  - Running, weight lifting, gymnastics, cycling
- Weigh less than 300 lbs and are shorter than 6 feet and 4 inches
- Women who do not have chronic back or joint problems
- Not taking medications that can affect bone metabolism such as:
  - Glucocorticoids, antidepressants, androgens
- Does not have a joint replacement or metal implants in the spine, hip, or legs
- Did not have a recent surgery preventing them from exercise

Required Testing (4 visits)

- Visit 1 - Informed consent, HIPAA and health related questionnaires, familiarization to the DXA, pQCT, and Jump Test
- Visit 2 - Bone and muscle scans on the DXA and pQCT, Jump Test, and
- Visit 3- mid-training questionnaires, measure body weight, Jump Test
- Visit 3 - Post-training questionnaires, bone and muscle scans on DXA and pQCT, Jump Test
- This is an eight-week intervention, the control group will engage in maximally jumping 10-25 times, five days a week at home between visits 2 and 4

There are possible risks involved with participation including associated risk with radiation exposure and discomfort during the Jump Test.

Participants will be given a gift card at the completion of this study.

If you are eligible and interested, please contact Alison Balderas

Department of Health and Exercise Science
alisonkelley@ou.edu 713-494-9197
(Principal Investigator: Dr. Debra Bemben)

Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu	Alison Balderas alisonkelley@ou.edu

Verbal Recruitment Script

Hello, my name is Alison Balderas, I am a graduate student in the Department of Health and Exercise Science at the University of Oklahoma. I invite you to participate in a research study entitled "Effects of an Eight Week Maximal Jumping Intervention on Bone Characteristics in College-Aged Females".

We are looking for healthy women between the ages of 18-24 years old. Potential participants must not be engaging in regular exercise that includes mechanical loading of the lower limbs in the past six months (running, weight lifting, gymnastics, cycling), weigh more than 300 lbs or be more than 6 feet and 4 inches tall. Additionally, potential participants should not be pregnant, and not taking medications that can affect bone density. Participants will also be excluded if they have artificial knee/hip joints or other metal implants in the spine or hips. Women with recent surgeries, fractures, or open wounds and those physical disabilities that prevent them from performing weight lifting exercises will also be excluded from this study.

This study is an eight week long study in which we will compare bone characteristics before and after a jump intervention protocol. Testing includes four visits to the Bone Density Laboratory at the University of Oklahoma. During the first visit, the participants will sign and date the informed consent and HIPAA forms and complete the Health Status Questionnaire (HSQ), menstrual history questionnaire, Bone-specific Physical Activity Questionnaire (BPAQ), International Physical Activity Questionnaire (IPAQ), Calcium intake questionnaire, and Physical Activity Readiness Questionnaire (PAR-Q). Participants will also be familiarized with the DXA, pQCT, and how to correctly perform the jump test. After the first visit, participants will be randomly divided into a control group or a training group. During the second visit, participants will have their urine pregnancy test, hydration measurement, and anthropometric measurement. Following this, you will have a total of 7 bone scans measured by 2 different machines to assess your bone health. The bone density of your total body, lumbar spine, and both hips will be measured by dual energy x-ray absorptiometry (DXA). The bone density of one of your lower legs will be measured at 3 places using peripheral Quantitative Computed Tomography (pQCT), another type of bone scanner. Finally, the participant will perform the jump test to measure their jump power and output. Participants will then be informed if they are in the control group or the training group. The control group will be instructed to continue their normal every day activities, while the training group will be instructed to engage in the jump intervention. The jump intervention consists of engaging in 10 maximal countermovement jumps five days a week (Monday-Friday) for the first two weeks, then increasing by 5 jumps every two weeks (10, 15, 20, 25) for the whole eight week intervention. The third visit will be a mid-training visit (during the fourth week) were the participant will come into the laboratory and complete mid-training questionnaires, have their weights measured, and perform the jump test. The fourth visit will be at the end of the eight weeks, and the participant will come back into the laboratory to complete post-training questionnaires, have their weight measured, DXA and pQCT scans, and perform a jump test. The visits in the laboratory will take approximately 5.5

hours to complete. The training group will spend approximately 65 minutes per week engaging in the jump intervention.

There are possible risks involved with participation, including risks associated with the radiation exposure as well as discomfort during the jump test. Information regarding your results will be provided at the end of the study upon your request. You will be receive a gift card upon completing the study.

The Principal Investigator for this study will be Dr. Debra Bemben.

I would be happy to answer any additional questions that you may have about the study. Thank you!

IRB NUMBER: 9716
IRB APPROVAL DATE: 02/23/2019

Mass Email Script

We are looking for healthy women between the ages of 18-22 years old to participate in a study entitled "Effects of an Eight Week Maximal Jumping Intervention on Bone Characteristics in College-Aged Females". Potential participants must not be engaging in regular exercise that includes mechanical loading of the lower limbs in the past six months (running, weight lifting, gymnastics, cycling), weigh more than 300 lbs or be more than 6 feet and 4 inches tall. Additionally, potential participants should not be pregnant, and not taking medications that can affect bone density. Participants will be excluded if they have artificial knee/hip joints or other metal implants in the spine or hips. Women with recent surgeries, fractures, or open wounds and those physical disabilities that prevent them from performing weight lifting exercises will also be excluded from this study.

This study requires 4 visits for a total time commitment of 5.5 hours inside the Bone Density Research Laboratory at the University of Oklahoma-Norman Campus. This is an eight week study in which we will compare bone characteristics before and after a jump intervention in a training group and a control group. The training group will be required to spend an addition 65 minutes per week engaging in their maximal jump intervention at home. This study requires exposure to a small amount of radiation by 2 different machines DXA and pQCT and you will have a total of 14 bone scans to assess your bone health. Participants will perform the jump test in order to measure their jump power and output.

There are possible risks involved with participation, including risks associated with the radiation exposure as well as discomfort during the jump test. Information regarding your results will be provided at the end of the study upon your request. You will receive a gift card upon completion of the study.

If you are interested and for more information, please contact Alison Balderas at alisonkelley@ou.edu.

The Principal Investigator for this study is Dr. Debra Bemben.

The University of Oklahoma is an equal opportunity institution. IRB 9716.

IRB NUMBER: 9716
IRB APPROVAL DATE: 12/03/2018

Facebook.com

We are looking for healthy women between the ages of 18-24 years old for a study entitled "Effects of an Eight Week Maximal Jumping Intervention on Bone Characteristics in College-Aged Females". Potential participants must not be engaging in regular exercise that includes mechanical loading of the lower limbs in the past six months (running, weight lifting, gymnastics, cycling), weigh more than 300 lbs or be more than 6 feet and 4 inches tall. Additionally, potential participants should not be pregnant, and not taking medications that can affect bone density. Participants will be excluded if they have artificial knee/hip joints or other metal implants in the spine or hips. Women with recent surgeries, fractures, or open wounds and those physical disabilities that prevent them from performing weight lifting exercises will also be excluded from this study.

This study requires 4 visits for a total time commitment of 5.5 hours inside the Bone Density Research Laboratory at the University of Oklahoma-Norman Campus. This is an eight week study in which we will compare bone characteristics before and after a jump intervention in a training group and a control group. The training group will be required to spend an addition 65 minutes per week engaging in their maximal jump intervention at home. This study requires exposure to a small amount of radiation by 2 different machines DXA and pQCT and you will have a total of 14 bone scans to assess your bone health. Participants will perform the jump test in order to measure their jump power and output.

There are possible risks involved with participation, including risks associated with the radiation exposure as well as discomfort during the jump test. Information regarding your results will be provided at the end of the study upon your request. You will receive a gift card upon completion of the study.

If you are interested and for more information, please contact Alison Balderas at alisonkelley@ou.edu.

The Principal Investigator for this study is Dr. Debra Bemben. The University of Oklahoma is an equal opportunity institution. IRB 9716.

IRB NUMBER: 9716
IRB APPROVAL DATE: 02/23/2019

Screening Checklist

Effects of an Eight Week Maximal Jumping Intervention on Bone Characteristics in College-Aged Females

Name:_____ Date:_____

Does the subject meet the inclusion criteria for the study?

	YES	NO
Female		
Age between 18 and 24 years		
Does not have chronic back or joint problems		
Weight is less than 300 pounds		
Height is less than 6 feet and 4 inches		

Does the subject have any exclusion criteria?

	YES	NO
Engage in regular exercise that includes mechanical loading of the lower limbs in the past six months -Running -Weight lifting -Gymnastics -Cycling		
Medications known to affect bone mineral density -Corticosteroids (asthma) -Anabolic steroids -Anti-depressants -glucocorticoids		
Has had surgery, fractures, or open wounds in the past year		
Has metal implants in spine, hip, or leg region		

Is the subject qualified for the study (circle one)? YES NO

Primary Investigator approval
Dr. Debra Bemben

Signature: _____ Date: _____

IRB NUMBER: 9716
IRB APPROVAL DATE: 02/23/2019

Appendix B

Informed Consent

HIPPA Form

Consent Form
University of Oklahoma Health Sciences Center (OUHSC)
University of Oklahoma- Norman Campus
Effects of an Eight Week Maximal Jumping Intervention on Bone Characteristics in College-Aged Females
Principal Investigator: Debra Bemben, PhD

This is a research study. Research studies involve only individuals who choose to participate. Please take your time to make your decision. Discuss this with your family and friends.

Why Have I Been Asked To Participate In This Study?
You are being asked to take part in this trial/study because you are a healthy college-aged female who does not engage in mechanical loading of the lower limbs.

Why Is This Study Being Done?
The purpose of this study is to examine how an eight-week maximal jumping intervention affects bone characteristics compared to a control group.

How Many People Will Take Part In The Study?
Approximately 60 females will participate in this study, all at this location.

What Is Involved In The Study?
You will be required to undergo four visits to the laboratory for assessment of bone and jump performance characteristics. All testing visits will take place in the Bone Density Research Laboratory and will take about 5.5 hours to complete. Outside of the laboratory, if you are assigned to the jump intervention group, you will spend approximately 65 minutes per week engaging in the jumps. You will be screened by email or in person to determine whether you meet the inclusion criteria. If you qualify for the study based on pre-screening, you will be scheduled for the first visit.

You will be randomized to either the jump intervention group or to the control group. Randomization means that you are put in a group by chance, using a table of random numbers.

The **first visit** will take approximately 1 hour during which time you will complete the consent process and complete the following questionnaires: Health Status Questionnaire, Bone Specific Physical Activity Questionnaire (BPAQ), Physical Activity Readiness Questionnaire (PAR-Q), International Physical Activity Questionnaire (IPAQ), a Calcium Intake Food Frequency Form, and a Menstrual History Questionnaire. These questionnaires will ask you to answer questions about your medical history, types of physical activities you do, foods that you eat that are sources of calcium, and information about your menstrual cycle and hormonal contraceptive use. You also will be shown the equipment used for the jump power test and you will perform some submaximal practice jumps.

The **second visit** will be approximately 1.5 hours and consist of a bone scans and jump power testing. Four BMD assessments by DXA (total body, lumbar spine, dual proximal femur) and three

pQCT scans (three sites of the non-dominant tibia) will be conducted. Jump power testing be performed after the scans.

1. Urine Test for Pregnancy and Hydration Status- This will be performed to ensure that none of the women are pregnant prior to initiating any bone scans and all participants are within normal hydration ranges.

2. Height and Weight- Subjects will be asked to remove their shoes, wear minimal clothing and remove all metal and attenuating material. Height will be measured using a stadiometer and weight will be measured using a digital electronic scale.

3. Bone scans (DXA/pQCT measurements)

a. Series of Dual energy X-ray Absorptiometry (DXA) scans - will be used to determine the bone mineral density of the total body, lumbar spine, the right and left hips. These tests are non-invasive and will take approximately 35 minutes to complete. DXA is a radiation procedure and is for research purposes only. There are risks associated with DXA which will be addressed below.

b. pQCT (peripheral Quantitative Computed Tomography) (20 minutes) - These scans will include 3 scans on your non-dominant leg. The length of your lower non-dominant (non-kicking) leg will be measured in order to determine the correct positioning on the pQCT. The pQCT utilizes radiation and is for research purposes alone. There are risks associated with pQCT which will be addressed below.

4. Jump Testing - Participants will complete three trials of the jump test, recording vertical jump height, time in the air, jump power and velocity. This test will take approximately 10 minutes.

The **third visit** will take approximately 45 minutes and will consist of the participant coming into the laboratory and completing the mid-training questionnaires (IPAQ and BPAQ), measuring body weight, and performing the jump test. Additionally, the jump intervention group will have their jumping form reviewed and corrected if they are not performing the jumps correctly.

The **fourth visit** (about 2 hours) will consist of post-training questionnaires from visit one, a urine test for hydration and pregnancy status, the DXA, pQCT scans, and jump power test.

After the first visit, the participants will be randomly divided into an intervention group and a control group. For eight weeks, the control group will continue living their everyday life without making any changes. The intervention group will jump at home maximally five days a week, Monday-Friday. This is a progressive intervention: the jump group will begin jumping maximally 10 times a day for five days per week and the number of jumps will be increased by five jumps every two weeks over the 8 eight duration. The participants will begin with 10 jumps per day and after two weeks they will increase their jump number to 15, two weeks later they will be instructed to increase to 20 jumps, and the last two weeks will jump 25 times per day. In order to monitor compliance, each individual will be informed to contact the researcher, Alison Kelley, each day after they perform their jumps. If a participant does not contact the researcher by 8:00 pm, the researcher will

reach out to the participant to remind them to engage in their daily jumps. After eight weeks, all participants will return back to the Bone Density Lab for visit four.

How Long Will I Be In The Study?
The study will span 8 weeks and require approximately 5.5 hours to complete. Outside of the Laboratory, if you are randomized to the jump intervention group, you will be asked to spend approximately 65 minutes per week engaging in jumps.

There may be anticipated circumstances under which your participation may be terminated by the investigator without regard to your consent. Your participation may be terminated based on:

* medications impacting bone health
* presence of metal implants
* recent injuries
* Physical Activity Status

You can stop participating in this study at any time. However, if you decide to stop participating in the study, we encourage you to talk to the researcher first.

What Are The Risks of The Study?
While in the study, you are at risk for these side effects; however, there may also be unforeseeable risk with participation. You should discuss these with the researcher prior to providing your consent.

- Risks associated with this study are due to the radiation exposure caused by the 8 DXA and 6 pQCT scans. These devices emit radiation for imaging and the results will be used for research purposes only and are not necessary for medical care.
- Risks and side effects related to jump testing and the jump intervention include discomfort during the exercise, delayed muscle soreness, and musculoskeletal injury. These risks will be minimized by instruction of correct jump form by qualified technicians.

Are There Benefits to Taking Part in The Study?
There are no direct benefits from participating in this study.

What Other Options Are There?
You may choose not to participate in the study.

What about Confidentiality?
Efforts will be made to keep your personal information confidential. You will not be identifiable by name or description in any reports or publications about this study. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. You will be asked to sign a separate authorization form for use or sharing of your protected health information.

There are organizations outside the OUHSC that may inspect and/or copy your research records for quality assurance and data analysis. These organizations include the US Food & Drug Administration and other regulatory agencies, and the OU Department of Health & Exercise Science

and its representatives. The OUHSC Human Research Participant Program office, the OUHSC Institutional Review Board, and the OUHSC Office of Compliance may also inspect and/or copy your research records for these purposes.

What Are the Costs?
There is no cost to you if you participate in this study.

Will I Be Paid For Participating in This Study?
You will receive a $10 gift card upon completing the study.

What if I am Injured or Become Ill while Participating in this Study
In the case of injury or illness resulting from this study, emergency medical treatment is available. However, you or your insurance company may be expected to pay the usual charge for this treatment. No funds have been set aside by The University of Oklahoma Norman campus, to compensate you in the event of injury.

What Are My Rights As a Participant?
Taking part in this study is voluntary. You may choose not to participate. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled.
If you agree to participate and then decide against it, you can withdraw for any reason and leave the study at any time. Please discuss leaving the study with the principal investigator or your regular doctor. You may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled.

We will provide you with any significant new findings developed during the course of the research that may affect your health, welfare, or willingness to continue your participation in this study.

You have the right to access the medical information that has been collected about you as a part of this research study. However, you may not have access to this medical information until the entire research study has completely finished. You consent to this temporary restriction.

Whom Do I Call If I have Questions or Problems?
If you have questions, concerns, or complaints about the study or have a research-related injury, contact Dr. Debra Bemben **24/7** at 405-306-3194 or dbemben@ou.edu . If you cannot reach the Investigator or wish to speak to someone other than the investigator, contact the OUHSC Director, Office of Human Research Participant Protection at 405-271-2045. For questions about your rights as a research participant, contact the OUHSC Director, Office of Human Research Participant Protection at 405-271-2045.

Future Communications
The researcher would like to contact you again to recruit into future studies or to gather additional information.

_____ I give my permission for the researcher to contact me in the future.

_____ I do not wish to be contacted by the researcher again.

Signature:
By signing this form, you are agreeing to participate in this research study under the conditions described. You have not given up any of your legal rights or released any individual or entity from liability for negligence. You have been given an opportunity to ask questions. You will be given a copy of this consent document.

I agree to participate in this study:

_____	_____	_____
PARTICIPANT SIGNATURE (age ≥18)	Printed Name	Date
_____	_____	_____
SIGNATURE OF PERSON OBTAINING CONSENT	Printed Name	Date

AUTHORIZATION TO USE or SHARE
HEALTH INFORMATION[1] THAT IDENTIFIES YOU FOR RESEARCH
An Informed Consent Document for Research Participation may also be required.
Form 2 must be used for research involving psychotherapy notes.

Title of Research Project: **Effects of an Eight Week Maximal Jumping Intervention on Bone Characteristics in College-Aged Females**

Leader of Research Team: **Debra Bemben, Ph.D.**

Address: **1401 Asp Avenue Norman, OK, 73071**

Phone Number**: 405-325-2709**

If you decide to sign this document, University of Oklahoma Health Sciences Center (OUHSC) researchers may use or share information that identifies you (protected health information) for their research. Protected health information will be called PHI in this document.

PHI To Be Used or Shared. Federal law requires that researchers get your permission (authorization) to use or share your PHI. If you give permission, the researchers may use or share with the people identified in this Authorization any PHI related to this research from your medical records and from any test results. Information used or shared may include all information relating to any tests, procedures, surveys, or interviews as outlined in the consent form; medical records and charts; name, address, telephone number, date of birth, race, government-issued identification numbers, and DXA and pQCT scan results.

Purposes for Using or Sharing PHI. If you give permission, the researchers may use your PHI to investigate the changes in bone characteristics in college-aged females in response to an eight week maximal jumping intervention compared to a controlled population.

Other Use and Sharing of PHI. If you give permission, the researchers may also use your PHI to develop new procedures or commercial products. They may share your PHI with other researchers, the research sponsor and its agents, the OUHSC Institutional Review Board, auditors and inspectors who check the research, and government agencies such as the Food and Drug Administration (FDA) and the Department of Health and Human Services (HHS), and when required by law. The researchers may also share your PHI with no one else.

Confidentiality. Although the researchers may report their findings in scientific journals or meetings, they will not identify you in their reports. The researchers will try to keep your information confidential, but confidentiality is not guaranteed. The law does not require everyone receiving the

[1] **Protected Health Information includes all identifiable information relating to any aspect of an individual's health whether past, present or future, created or maintained by a Covered Entity.**

information covered by this document to keep it confidential, so they could release it to others, and federal law may no longer protect it.

YOU UNDERSTAND THAT YOUR PROTECTED HEALTH INFORMATION MAY INCLUDE INFORMATION REGARDING A COMMUNICABLE OR NONCOMMUNICABLE DISEASE.

Voluntary Choice. The choice to give OUHSC researchers permission to use or share your PHI for their research is voluntary. It is completely up to you. No one can force you to give permission. However, you must give permission for OUHSC researchers to use or share your PHI if you want to participate in the research and, if you cancel your authorization, you can no longer participate in this study.

Refusing to give permission will not affect your ability to get routine treatment or health care unrelated to this study from OUHSC.

Canceling Permission. If you give the OUHSC researchers permission to use or share your PHI, you have a right to cancel your permission whenever you want. However, canceling your permission will not apply to information that the researchers have already used, relied on, or shared or to information necessary to maintain the reliability or integrity of this research.

End of Permission. Unless you cancel it, permission for OUHSC researchers to use or share your PHI for their research will never end.

Contacting OUHSC: You may find out if your PHI has been shared, get a copy of your PHI, or cancel your permission at any time by writing to:

Privacy Official University of Oklahoma Health Sciences Center PO Box 26901 Oklahoma City, OK 73190	or	Privacy Board University of Oklahoma Health Sciences Center PO Box 26901 Oklahoma City, OK 73190

If you have questions, call: (405) 271-2511 or (405) 271-2045.

Access to Information. You have the right to access the medical information that has been collected about you as a part of this research study. However, you may not have access to this medical information until the entire research study is completely finished. You consent to this temporary restriction.

Giving Permission. By signing this form, you give OUHSC and OUHSC's researchers led by the Research Team Leader permission to share your PHI for the research project listed at the top of this form.

Patient/Participant Name (Print): _____

_____ _____
Signature of Patient-Participant Date
or Parent if Participant is a minor

Or

_____ _____
Signature of Legal Representative** Date

**If signed by a Legal Representative of the Patient-Participant, provide a description of the relationship to the Patient-Participant and the authority to act as Legal Representative:

_____
OUHSC may ask you to produce evidence of your relationship.

A signed copy of this form must be given to the Patient-Participant or the Legal Representative at the time this signed form is provided to the researcher or his representative.

Appendix C

Health Status Questionnaire

PAR-Q and You

Calcium Intake

Bone Specific Physical Activity Questionnaire

International Physical Activity Questionnaire

Menstrual History Questionnaire

Bone Density Research Laboratory
OU Department of Health and Exercise Science
Health Status Questionnaire

Complete each question accurately. All information provided is confidential.

Part 1. Information about the individual

1._____
Date

2. _____
Legal name Ethnicity

3._____
Mailing address

_____
Home phone Business/cell phone

4.Gender (circle one): Female Male

5. Year of birth: _____ Age _____

6. Number of hours worked per week:
NA (retired) Less than 20 20-40 41-60 Over 60

If not retired, more than 25% of time spent on job (circle all that apply)

Sitting at desk Lifting or carrying loads Standing Walking Driving

Part 2. Medical history

7. Circle any who died of heart attack before age 50:
Father Mother Brother Sister Grandparent

8.Date of: Last medical physical exam: _____Last physical fitness test: _____
Year Year

9. Circle operations you have had:
Back Heart Kidney Eyes Joint Neck Ears Hernia Lung Other _____ **NONE**

10. Please circle any of the following for which you have been diagnosed or treated by a health professional:

Alcoholism	Diabetes	Kidney problem
Anemia, sickle cell	Emphysema	Mental illness
Anemia, other	Epilepsy	Neck strain
Asthma	Eye problems	Obesity
Back strain	Gout	Osteoporosis
Bleeding trait	Hearing loss	Phlebitis
Bronchitis, chronic	Heart problems	Rheumatoid arthritis
Cancer	High blood pressure	Stroke
Cirrhosis, liver	Hypoglycemia	Thyroid problem
Concussion	Hyperlipidemia	Ulcer
Congenital defect	Infectious mononucleosis	Other _____ **NONE**

11. Circle all medicine taken in last 6 months:

Asthma (list type) _____High-blood-pressure medication (list type) _____

Blood thinner	Epilepsy medication	Thyroid
Corticosteroids	Estrogen	Diuretic
Depression	Heart-rhythm medication	Digitalis
Diabetic pill	Insulin	Nitroglycerin
		Other _____ **NONE**

12. Any of these health symptoms that occurs frequently is the basis for medical attention. Circle the number indicating how often you have each of the following:

1 = Practically never 2 = Infrequently 3 = Sometimes 4 = Fairly often 5 = Very often

a. Cough up blood
1 2 3 4 5

b. Abdominal pain
1 2 3 4 5

c. Low back pain
1 2 3 4 5

d. Leg pain
1 2 3 4 5

e. Arm or shoulder pain
1 2 3 4 5

f. Chest pain
1 2 3 4 5

g. Swollen joints
1 2 3 4 5

h. Feel faint
1 2 3 4 5

I. Dizziness
1 2 3 4 5

j. Breathless with slight exertion
1 2 3 4 5

Part 3. Health-related behavior

13. Do you now smoke? Yes No

14. If you are a smoker, indicate number smoked per day:

Cigarettes: 40 or more 20-39 10-19 1-9
Cigars or pipes only: 5 or more or any inhaled Less than 5, none inhaled

15. Weight now: _____lb. One year ago: _____lb. Age 21 (if applicable): _____lb.

16. Do you engage in exercise or hard physical labor at least three times a week? YES NO

IRB NUMBER: 9716
IRB APPROVAL DATE: 09/29/2018

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

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	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. 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?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

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 or GUARDIAN (for participants under the age of majority) _____ WITNESS _____

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.

Supported by: Health Canada Santé Canada

continued on other side...

BONE DENSITY RESEARCH LABORATORY
DEPARTMENT OF HEALTH AND EXERCISE SCIENCE
UNIVERSITY OF OKLAHOMA

CALCIUM INTAKE ESTIMATION

NAME:_____ TODAY'S DATE:_____

Complete this form (where indicated) to represent your dietary intake in the past year.

				I EAT THIS FOOD: EVERY WEEK	EVERY DAY
Tally *(office use only)*	Score *(office use only)*	Food Type	serving size	**write in # servings/week**	**write in # servings/day**
	300	Milk- whole, 2%, skim	1 cup		
	150	Cheese food or spread	1 oz		
	150	Cheese sauce	1/4 cup		
	150	American cheese	1 slice		
	150	Cottage cheese	1 cup		
	250	Ricotta cheese	1 oz		
	150	Blue cheese	½ cup		
	200	Natural cheese (except cream cheese) includes cheddar, Swiss, mozzarella, and so forth	1 oz		
	285	Buttermilk	1 cup		
	300	Yogurt, flavored or plain	1 cup		
	450	Fast Food Milkshake	12 oz		
	165	Cocoa from mix	1 packet		
	330	Eggnog	1 cup		
	280	Chocolate milk	1 cup		
	250	Macaroni and cheese, cheese souffle, lasagna, quiche, cannelloni, pizza	1 serving		
	180	Cream soup or chowder with milk	1 cup		
	115	Almonds	1/3 cup		
	180	Broccoli	1 cup		
	85	Beet greens, spinach	½ cup		
	160	Baked beans	1 cup		
	100	Figs	5 dried		
	140	Scalloped potatoes	1 cup		
	150	Soybeans	1 cup		

PLEASE TURN OVER

	150	Tofu	½ cup		
Tally *(office use only)*	Score *(office use only)*	Food Type	serving size	**write in # servings/week**	**write in # servings/day**
	30	Bread, white or whole grain	1 slice		
	120	Waffle or pancake	1 large		
	50	Muffin, biscuit, cornbread	1 medium		
	40	Rolls, buns	½		
	225	Egg McMuffin	1		
	130	Fast food cheeseburger or hamburger	1		
	110	Enchilada or bean burrito	1		
	125	Creamed fish and meats	1 cup		
	130	Shellfish, cooked	4 oz		
	200	Canned salmon with bones	½ cup		
	200	Sardines, smelts, herring	½ cup		
	100	Fudgesicle	1		
	125	Custard pie	1 slice		
	175	Ice cream or ice milk	1 cup		
	190	Pudding with milk	½ cup		
	200	Frozen yogurt	1 cup		

Please list below any dietary supplements (single and multi-vitamins, calcium, herbal etc.) you take daily/weekly, including the brand name, amount (mg) per dose and total number of doses per day (or per week if not taken daily).

1. _____

2. _____

3. _____

4. _____

5. _____

Subject ID: _____ **Date:** _____

Bone-Specific Physical Activity Questionnaire (BPAQ)

1. Please list any sports or other physical activities you have participated in regularly. Please tick the boxes to indicate how old you were for each sport/activity and how many years you participated.

Sport/Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

2. Please list the sports or other physical activities (be as specific as possible) you participated in regularly in the past 12 months and indicate the average frequency (sessions per week)? On the back of this page is a list of activities you may use as a reference.

Activity: _____ Frequency (per week):_____

Activity: _____ Frequency (per week):_____

Activity: _____ Frequency (per week):_____

Activity: _____ Frequency (per week):_____

Activity: _____ Frequency (per week):_____

Activity: _____ Frequency (per week):_____

Activity: _____ Frequency (per week):_____

Activity: _____ Frequency (per week):_____

BONE-SPECIFIC PHYSICAL ACTIVITY QUESTIONNAIRE
Developed by B.K. Weeks and B.R. Beck
Griffith University, QLD, Australia

IRB NUMBER: 9716
IRB APPROVAL DATE: 09/29/2018

Bone-Specific Physical Activity Questionnaire (BPAQ)

OU Bone Density Research Laboratory

Sport/Activity	Sport/Activity	Sport/Activity
Aerobics (low impact)	Resistance Training	* Other Low impact
Aerobics (high impact)	Rollerblading	* Other Moderate Impact
Badminton	Rowing	* Other High Impact
Ballet	Rugby	
Baseball	Scuba Diving	
Basketball	Shot Put/Discus	
Cheerleading	Skate Boarding	
Cricket	Skiing/Snowboarding	
Cross-Country	Soccer	
Cycling	Softball	
Dancing	Squash	
Diving	Stairmaster	
Field Hockey	Surfing	
Flag Football	Swimming	
Golf	T-ball	
Gymnastics	Table tennis	
Horse-Riding	Tennis	
Ice Hockey	Football	
Ice-Skating	Track	
Judo	Triathlon	
Jump Rope	Ultimate Frisbee	
Kung Fu	Volleyball	
Lacrosse	Walking/Hiking	
Pickle Ball	Waterskiing	
Power Lifting	Wind Surfing	
Racquet Ball	Yoga/Pilates	

BONE-SPECIFIC PHYSICAL ACTIVITY QUESTIONNAIRE
Developed by B.K. Weeks and B.R. Beck
Griffith University, QLD, Australia

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (October 2002)

LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ

International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective.* Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

   ☐ Yes

   ☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

   _____ **days per week**

   ☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

   _____ **hours per day**
   _____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

   _____ **days per week**

   ☐ No moderate job-related physical activity → ***Skip to question 6***

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5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?
_____ **hours per day**
_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**
_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ **hours per day**
_____ **minutes per day**

This is the end of the questionnaire, thank you for participating.

Bone Density Research Laboratory
Department of Health and Exercise Science
University of Oklahoma

MENSTRUAL HISTORY QUESTIONNAIRE

Participant ID:_____Date:_____

We are asking you to give us as complete a menstrual history as possible. All information is strictly confidential.

Are you pregnant (circle your response)

YES- Do not complete the rest of this form
NO- Continue to section A.

SECTION A: CURRENT MENSTRUAL STATUS

1. Approximately how many menstrual periods have you had during the past 12 months?
(please circle what months you have had a period. This means from this time last year to the present month)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

2. What is the usual length of your menstrual cycle (first day of your period to the next onset of your period)?

_____days. Today is day _____ of your present menstrual cycle.

3. What was the date of the onset of your last period?

4. When do you expect you next period?

5. What is the average length (number of days) of your menstrual flow? _____ days

How many of these days do you consider "heavy"?_____days

6. Do you experience cramps during menstruation (dysmenorrheal)? If yes, how many days does this last?

7. Do you experience symptoms of premenstrual syndrome (i.e., weight gain, increased eating, depression, headaches, anxiety, breast tenderness)? If yes, please list the symptoms.

8. Do you take oral contraceptives or any other medication that includes estrogen and/or progesterone? If no, skip to SECTION B.

   If yes, how long have you been taking this medication?_____

   What is the brand name and dosage of this mediation?_____

   At what age did you begin taking oral contraceptives? _____

Has this medication affected your menstrual cycle (regularity, length and amount of flow)? If yes, indicate changes.

9. Have you taken oral contraceptives in the past? If no, skip to SECTION B.

   If yes, what was the brand name and dosage?_____

   At what age did you start taking the pill; for how long; and when did you stop taking it?

10. If you answered yes to 9 or 10, did you experience a weight gain and/or a change in appetite as a result of oral contraceptive use? If so, please indicate amount of weight gained. _____lbs

SECTION B: PAST MENSTRUAL HISTORY

1. At what age did you experience your first menstrual period?

2. Were your periods regular (occurring monthly) during the first two years after menstruation began? If not, at what age did your period become regular?

3. Has there been any time in the past where your periods were irregular or absent? If no, skip to question 4. If yes, did these periods coincide with unusual bouts of training, or with a period of stress?

4. If you have had an irregular period due to training please describe?

5. Have you ever consulted a doctor about menstrual problems (specifically, about irregular or missing periods)? If no, skip to question 6.

   Have you ever been diagnosed as having a shortened luteal phase (the time in between periods)?

6. Have you ever consulted a doctor about any problems relating to your hormonal system? If so, please explain.