Effects of Jump Training on Bone Mineral Density in Young Adult Females

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EFFECTS OF JUMP TRAINING ON BONE MINERAL DENSITY IN YOUNG ADULT FEMALES

A Thesis
Presented to
The Faculty of the Department of Kinesiology, Recreation & Sport
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Kinesiology

By
Battogtokh Zagdsuren

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EFFECTS OF JUMP TRAINING ON BONE MINERAL DENSITY IN YOUNG ADULT FEMALES

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Physical activity is critical to bone health. However, not all physical activity has optimum effect on bone health and metabolism. The purpose of this study was to determine the effects of a short term progressive jumping protocol on bone mineral density in college age Asian females. Sixteen participants aged 18-28 years enrolled in the study. Participants were assigned to exercise (n=9) and control (n=8) groups. The exercise group completed a two-legged depth jump from an approximate 20cm step-bench followed immediately by a maximum vertical jump using arm swings for five days per week for two weeks. Each depth jump and vertical jump was performed ten times during each session. The exercise intervention progressed from one session per day to three sessions per day in ten days. The bone mineral density (BMD) by dual-energy x-ray absorptiometry (DXA), ground reaction force (GRF), bone specific physical activity questionnaire (BPAQ), and dietary log were administered to the participants pre- and post-intervention. The data were analysed using a dependent t-test and one-way repeated measures. There were no significant changes noted in BMD value in the study. The past BPAQ showed significant correlation to BMD change of left hip (p<0.01) in exercise group. The vertical GRF showed significant increase (p<0.05) in exercise group. It can be concluded from the study that intensity of the progressive jumping was intense enough to stimulate some changes in the bone metabolism.
CHAPTER 1

INTRODUCTION

Osteoporosis is a progressive metabolic bone disease characterized by the loss of bone mineral density (BMD). The World Health Organization (WHO) defined osteoporosis as a reduction of 2.5 standard deviations in T-score (> -2.5 SD) below the normal mean for young females at the age of peak bone mass (Czerwinski, Badurski, Maercinowska-Suckowierska, & Osieleniec, 2007). Another diagnostic measurement for osteoporosis is Z-score. Z-score indicates the bone density relative to patients’ age and sex. If the Z-score is below -2.0, then it is classified as below the expected range for that age, while above -2.0 is considered to be within the expected range for a given age (Gosfield & Bonner, 2000). Age-related bone loss is a major cause of osteoporosis, therefore it is known as a disease of the elderly population. According to Healthy People 2020 program, approximately 5.3 million people over 50 years old are affected by osteoporosis, and women possess the majority of the cases (2012). The disease develops without manifestation until a fragility fracture occurs. Fragility fractures are the dominant adverse outcome of osteoporosis, and these fractures cause many burdens including medical cost, physical and psychological stresses, and even death (Kanis, 2002). The risk of osteoporotic fractures at any site is 30-50% in women and 15-30% in men at or above 50 years of age (US Department of Health and Human Services, 2004). Among the fragility fractures, the hip and spine are the most common sites for osteoporotic fractures (Kanis, Oden, McCloskey, Johansson, Wahl, & Cooper, 2012). Therefore, these sites should be prioritized in any preventive methods.
There are many modifiable factors that influence BMD, such as hormonal regulation, cigarette smoking, alcohol consumption, and level of physical activity (Smith & Gilligan, 1991). The relationship between physical activity and bone health has been studied broadly in the research field. Research has been carried out to evaluate the effectiveness of physical activity on osteoporosis prevention in different age groups. It is plausible to assume prevention at younger ages would be more effective than working on already osteoporotic bone tissues at later ages. Studies have shown that childhood and early adulthood physical activity plays a major role in the prognosis of osteoporosis in later life (Guadalupe-Grau, Fuentes, Guerra, Calber, 2009). However, peak bone mass is reached in the thirties; thus early adulthood physical activity can be the ultimate chance to prevent the disease (Kohrt, Bloomfield, Little, Nelson & Yingling, 2004).

Bone is very active tissue that continually breaks down and rebuilds itself. The architectural modification of bone occurs in response to mechanical loading, as well as due to hormonal and nutritional aspects through the process of bone formation and bone resorption (Kelley & Kelley, 2004). The process of bone formation and bone resorption is known as bone remodeling.

In order to resist increasing mechanical stress, the bone initiates an adaptive response by thickening the bone tissue. Under mechanical loading, the bones remodel themselves to repair the micro damage and increase density to prevent any future damage to the same loading sites. In other words, bone increases the threshold of stress tolerance when encountered with high impact mechanical loading. High impact physical activities that involve ground reaction forces and joint reaction forces have greater loading stimulus on bone, thus generating greater increase in bone density. Some sports
with low mechanical loading, such as swimming, have a negligible effect on bone density (Weeks & Beck, 2008). Dook, James, Henderson, and Price (1997) compared the BMD of a sedentary group with a group of young female adult athletes engaged in basketball, hockey and swimming. The control group and the swimmers had significantly lower whole body BMD than basketball and hockey athletes. Controversially, high-impact ground reaction sports have more influence on BMD than joint reaction types of sports. While the types of exercise are critical, the intensity, frequency and duration of exercise plays an important role as well. Kohrt et al. (2004) suggested that participation in high-impact activities at least three days per week for 10-20 minutes is helpful in prevention of osteoporosis.

The majority of previous studies have involved long-term exercise interventions (Guadalupe-Grau et al., 2009). There are still uncertainties about high-impact exercises and the necessary duration of exercise needed to see measurable changes in bone metabolism. Animal studies demonstrate that high-impact exercises of 3-6 weeks show fast slope changes in bone metabolism; however, the cellular activities reduce after a long term stimulus (Cullin, Smith & Akhter, 2000). The previous studies offer insufficient evidence about the short term effect of high-impact jumping on BMD. More research is needed to determine the quantity and quality of physical activity on the bone health in the prevention of osteoporosis. For most other bodily systems, the benefit of physical activity comes from either or both endurance and strength training. The result of the physical activity can be quantified and qualified in standardized measurements. The skeletal system, however, requires specific activities that cause strain and magnitude on the loaded site of the bone. It is difficult to standardize the results of bone-stimulus
physical activity in terms of duration and intensity, as there are many regulatory factors which influence bone formation and resorption. Skeletal adaptation to any magnitude of strain is high, which could be one of the limitations of long term exercise-intervention studies. Therefore, the purpose of this study is to determine the effects of high-impact exercises on BMD at loaded sites after a two week exercise intervention.

Statement of Purpose

Based on previous studies, vertical jump has been shown to affect the BMD in a positive way. However, it is unclear about the exercise duration and intervals that show a visible, positive change in BMD. To date there has not been a study designed with short term progressive jump training to examine the BMD in young adult women. Few studies have evaluated short term jump training on bone markers (Kishimoto, Lynch, Reiger & YingLing, 2012), and there has not been a study which examined DXA evaluation after two weeks of exercise intervention. The purpose of the study is to determine effects of progressive short-term jump training on bone mineral density.

Statement of Hypotheses

$H_{01}$: There will be no changes in bone mineral density after exercise intervention of two weeks consisting of progressive jumping movement.

$H_{A1}$: There will be significant positive changes in bone mineral density after exercise intervention of two weeks consisting of progressive jumping movement.
Definition of Terms

- **Bone mineral density (BMD):** The amount of mineral matter per square centimeter of bones (g/cm\(^2\)). Bone mineral density is used in clinical medicine as an indirect indicator of osteoporosis and fracture risk.

- **BMI:** Body mass index, calculated as weight in kg/(height in m\(^2\)).

- **Bone mass:** The amount of bone tissue in a bone or skeleton, preferably determined as volume minus the marrow cavity (the mass indicator does not account for bone architecture).

- **Dual-energy X-ray absorptiometry (DXA):** A method of measuring bone mineral density and bone mineral content. The higher attenuation of radiation by the bone refers to higher bone mass.

- **Osteopenia:** Reduced bone mass defined as being between 1 and 1.25SD below the young adult mean.

- **Osteoporosis:** A medical condition associated with decreased bone mass more than 2.5 standard deviations below the young adult mean.

- **Peak bone mass:** The highest amount of bone mass achieved by an individual during the lifetime.

- **T-score:** Bone mineral density in relation to the mean BMD value in young healthy women.

- **Z-score:** BMD results adjusted for age.

Limitations

Limitations to this study include:

Participants’ fitness level may vary.
Researchers may not be able to accurately control participants’ diet conditions.

The validity and reliability of the methods and equations used for determine past osteogenic physical activity.

Delimitations

Delimitations include:

Participants will have a training session prior to the intervention period to become familiar with testing procedures.

Ground Reaction Force will be measured using a force plate.

Participants will have thirty seconds rest in between jumps and at least four hours between each session on multiple session days.

The same instructor will supervise all testing procedures.
CHAPTER 2

REVIEW OF LITERATURE

Introduction

The etiology of osteoporosis can be explained by three mechanisms: low peak bone mass attained at a young age, excessive bone loss after peak bone mass is achieved, and decreased bone formation following resorption (Raisz, 1999). Development of osteoporosis is highly influenced by hormonal factors, lifestyle, nutrition, physical activity and genetics (Sehmisch, Galal, Kolios, Tezval, Dullin, Zimmer, Stuermer & Stuermer, 2009). According to Wolf’s law, the bones remodel themselves under the different of loading to resist the external force. The mechanical loading on bone derives from gravitational force and muscular forces due to different types and magnitudes of human movement (Shenoy, Shadagopan, & Sandhu, 2012). In other words, a certain level of mechanical loading is necessary to maintain healthy bone density. Therefore, exercise that stimulates certain loading on bone can increase bone density at any age. There is evidence that exercise in prepubertal age can significantly reduce the risk of developing osteoporosis in later life (Kato, Terashima, Yamashita, Hatanaka, Honda, & Umemura, 2005). A great deal of studies has also been carried out on postmenopausal women, whereas limited studies have investigated the exercise intervention on young adults, and the results are greatly controversial.

Type of exercise

The application of mechanical loading should be more than the daily living activity in order to enhance the bone mass (Vainionpaa, Korpelainen, Leppaluoto, & Jamsa, 2005). Exercises that are dynamic, high intensity, high frequency and have high
loading effects are shown to be most osteogenic. Jumping activities including vertical
jump, drop jump, jump and jag, and jumping rope are studied extensively in relation to
bone mass and bone mineral density. Heinonen, Kannus, Sievanen, Oja, Pasanen and
Rinne (1996) studied the effect of high-impact jumping on premenopausal women.
Healthy, sedentary female (n=98) participants, aged 35-45 years, were randomized into
training and control groups. For 18 months of exercise intervention, a training group
performed high-impact exercises three times per week. Primary assessments were done
by dual-energy X-ray absorptiometry (DXA) to determine the BMD. The training group
showed significant increase on BMD at the femoral neck than the control group.
However, the non-weight bearing sites did not show significant increases in BMD in
both groups. The high-impact of the training was defined by jumping from a 10-25cm
high platform with the GRF of 2.1-5.6×BW (Heinonen et al., 1996.). Using a similar
exercise protocol, Kato T. et al. (2005) investigated the BMD in young women through
six months intervention. Overall, 36 female college-aged females participated and were
divided into jump training and control groups. The training group (n=18) exercised three
times per week and performed 10 high jumps per day. Bone mineral density was
measured by DXA in the lumbar and proximal femoral site. Researchers also measured
urinary deoxypyridinoline (DPD) level for bone reabsorption. As a result, there was a
significant increase of BMD at femoral and lumbar spine sites in the training group
(p<0.01), whereas in the control group, there was no significant change (Kato et al.,
2005). It can be concluded that progressive high-impact activities increase skeletal mass
in young women. Additionally, improvement in performance and balance also contribute
to the prevention of osteoporotic fractures later in life.
The purpose of the study by Vainionpaa et al. (2005) was to investigate high-impact exercises on the BMD in pre-menopausal women. Women aged between 35-40 years participated in the study. Sixty participants completed the study that was randomized into exercise and control groups. The twelve-month exercise intervention consisted of 60-minute step patterns, stamping, jumping, high knees with or without arm movements, and knee bends three times a week. The exercise protocols were modified every two months in a progressive pattern under supervision of trainers. Bone mineral densities were measured by DXA at lumbar spine (L1-L4) and left proximal femur. Bone mineral density at femoral neck, trochanter, intertrochanter, femoral total and Ward’s triangle increased by 0.093 g/cm² (p<0.01), 0.093 g/cm² (p<0.01), 0.132 g/cm² (p<0.05), 0.115g/cm² (p<0.05), 0.107 g/cm (p<0.001), 0.115 g/cm² (p<0.001) respectively. Also, intergroup evaluation revealed significant increase of BMD in the exercise group in these sites as well. The exercise group showed significant increase in BMD in lumbar L1 (p<0.002), while there were no significant changes in L2-L4 in both groups. The researchers concluded that high-impact exercises are a safe and cost effective approach to prevent osteoporosis in healthy premenopausal women. The study used multiple weight-bearing exercise interventions, which provided dynamic loading effect on the bones. However, the researchers did not mention standardization of the exercise protocol.

As Vainionpaa et al. (2005) reported that there was only a significant increase in L1 at the lumbar site, which may have resulted from the exercise protocol. Winters-Stone and Snow (2006) hypothesized upper and lower body exercise interventions may increase both lumbar and hip sites of BMD. Exercise group participants were randomly
divided into lower body intervention (n=19) and upper and lower body exercise (n=16) groups that were compared with an age-matched control group (n=24). Lower body training included nine sets of 10-12 jumps and nine sets of 10-12 resistance exercises. The jumping performances consisted of four types of jumps: off the ground, drop jump from 8 inch platform, forward and side directions, and single or side directions. Each jump was performed on the gymnastic matt with 15-30 seconds resting. Lower body resistance exercises included squats, lunges and calf raises following after jump training. The progressive intensities of both jump and resistance exercises were achieved by adding on weight vests as calculated by the percentage of body weight. Upper body exercises consisted of 3 sets of 8-12 repetitions of upright row, latissimus dorsi pull down, chest press, chest fly, biceps curl and triceps extension. Each exercise was performed with 1-2 minutes of rest time. Participants in a group of Upper + Lower exercise performed upper body exercises after jump training. Bone mineral densities were measured by DXA. After 12 months of intervention, the upper + lower group showed significant increase in BMD at greater trochanter site and lumbar spine (p<0.03) than the control group. Both exercise groups had significant increase in BMD at the great trochanter site. The researchers concluded that gain in BMD could be achieved by combination of multiple resistance exercise treatments in premenopausal women.

A handful of studies have been carried out on effect of resistance training on bone mineral density. For instance, Nicolas, Sanborn, and Love (2001) examined the effect of resistance training in teenage girls on bone mineral density. The participants were randomly assigned either to an exercise group (n=46) or a control group (n=21). However, the dropout rate was high, specifically by the end of the study. Overall,
sixteen participants completed the study. Each participant in the exercise group completed fifteen different resistant exercises for 30-45 minutes per day, three times per week for fifteen months. Results showed significantly increased BMD at femoral neck site (p<0.01) compared to the control group, but not at the lumbar site. The dietary logs were performed by Nutritionist IV software. The participants were asked to complete 3-day dietary logs. The calcium intake of both groups was lower than the recommended doses throughout the study. The leg strength of the exercise group had increased by 40%, whereas no changes were observed from control group. The study confirmed the hypothesis and showed similar results with other studies in the same field, despite the high dropout rate.

Hinrichs, Chae, Lehmann, Allolio, and Platen (2010) compared the BMD of athletes who participated in seven different sport disciplines: runners, cyclists, triathletes, team sports, combat/power athletes, ballet dancers, and student athletes. The participants had at least 4 years of training in their discipline. The BMD was measured at lumbar spine (L2-L4), femoral neck, trochanter, intertrochanteric region, and Ward’s triangle using DXA scan. In female athletes, combat/power athletes had the highest lumbar BMD, while ballet dancers had lowest lumbar BMD. At the femoral site, team sports had high BMD compared to other disciplines. Similarly, Creighton, Morgan, Boardley, and Brolingson (2000) examined the BMD in female athletes who specialized in basketball, volleyball, soccer, track and swimming compared with sedentary control group. The BMD was measured by DXA at lumbar spine, femoral neck, Ward’s triangle, and trochanter. Urinary cross-linked N-telopeptides and serum osteocalcin were also measured. Athletes who participated in activities such as basketball and volleyball
showed significantly higher BMD at the lumbar spine than control group. The femoral neck, Ward’s triangle, and trochanter sites were significantly higher in the high impact activity athletes than swimming and control group. Additionally, bone formation marker in swimming group was significantly lower than the basketball, volleyball, track, and soccer groups.

Intensity and frequency of the exercise

The strain magnitude is another factor of effective osteogenic stimulus. Many studies have chosen the intensity level by percentage of body weight or by increasing the repetition of the movement. Cullen, Smith, and Apkter (2001) examined the effect of strain magnitude and cycle number on the bone responses in rats. All rats were divided into one control and six treatment groups. The bending device was used to apply forces on the rats’ right legs with 800 and 1000 microstrains at lateral periosteal, 600 and 800 microstrains at endocortical site. Each force was loaded 40,120 or 400 cycles in 3 days per week for 3 weeks. After the training session, the rats’ tibia was collected for analyzing. The increased cycle and load magnitude showed significant increase in bone response. Additionally, the higher number cycle with low force magnitude showed more significant results than high force with high number of cycles. In conclusion, bone adaptation is highly relevant to strain magnitude and number of cycles. However, frequency of strain does not seem to be a necessarily high number. Conversely, low frequency seems to be an important aspect.

Duration

A majority of the studies have examined the effect of long-term exercise on BMD. There are conflicts about how much training time is needed to see visible changes
in BMD after specific exercise intervention. Cullen et al. (2000) studied the changes in bone cells and structure after 6, 12, and 18 months of loading on rats. Adult rats (n=47) were divided into four loading groups calculated by their weight. Group one was loaded 3 days a week for six weeks, while the other three groups were loaded every day for 6, 12, 18 weeks. The external loading was applied by bending devices at 1200-1700 microstrains on one of the legs. After the interventions, the rats were sacrificed and both tibias were collected for cellular analysis. The comparisons were made between the loaded legs and unloaded legs as well as between the groups in tibial formation surface, formation rate and new bone thickness. The study showed significant increases in bone formations at week 6 of intervention. After 12 weeks of loading, bone formation reached steady state. The authors concluded that bone adaptation occurs after a certain amount of time with constant loading and reaches a plateau.

Kishimoto et al. (2012) examined the effect of short-term jumping on bone metabolism biomarkers. Healthy, college-age females (n=26) were randomized into training and control groups. The training protocol included vertical jumping 5 days per week and 10 jumps per day for two weeks. The vertical ground reaction force (VGRF) and serum bone markers were examined. Plasma tartrate-resistant acid phosphatase (TRAP5b) and bone specific alkaline phosphatase (BAP) showed significant change in the jumping group than compared to the control group. There was a significant decrease in BAP and C-terminal telopeptides of Type I collagen (CTX) in jumping group (p<0.05), which indicates bone reabsorption. The CTX value highly related to diet control; the decrease was maybe affected by diet.
Conclusion

Most of the longitudinal studies have stated positive effects of osteogenic physical activity on increasing BMD. The cells undergo an adaptation when introduced to constant stimulus to maintain environmental homeostasis (Robling, Burr & Turner, 2001). This indicates that it is important to design an exercise protocol accurately within the long-term exercise intervention to attain optimal results. Many animal studies pointed out that after a certain amount of time and intensity, the bone formation process reaches a plateau (Cullen et al., 2000). Thus, Robling et al. (2001) concludes that mechanostimulus sessions do not need to be long to generate bone formation, and a longer stimulus session does not extend any extra beneficial effect. Therefore, more studies are in need to examine the variety of exercise protocol within short-term sessions.

Another considerably important factor is recovery time in between the bone loading. Umemura, Sogo, and Honda (2002) examined the effects of the recovery time between jumps and sessions on bone mass in rats. The study suggested 30 second intervals between the jumps were more effective than the 3 second jump intervals. Also, the single session per day was not any different than the two-session per day. However, Robling et al.’s (2000) study showed 8-hour recovery time between sessions was sufficient to restore full mechanosensitivity.

The animal studies reveal that short duration, high-impact exercises with sufficient recovery time are more beneficial in increasing bone mineral density. Overstraining and mechanical imbalance can even reverse bone formation process. Therefore, exercise protocols that allow adequate time to recover, and which also do not exhibit full adaptation can be a “gold” chance to attain optimal bone health.
CHAPTER 3

METHODOLOGY

Participants

The study included sixteen college aged (18-28 years) females from Asian ethnicity. Inclusion criteria consisted of sedentary lifestyle, no regular high-impact training for at least the last six months, nonsmoker, not pregnant, not lactating and no history of bone fractures. Exclusion criteria included significant medical history, currently taking any medication that would affect bone metabolism, and any physical conditions that would contraindicate physical exercise. Potential participants were recruited by posting flyers throughout the campus of Western Kentucky University (WKU). Interested participants who responded to the flyer had the nature, risk, and potential benefits and rights as a research participant explained to them. When the participants agreed to participate in the study and met inclusion criteria, the individuals were scheduled for a study date. The participants were randomly divided into two groups: exercise group (n=9) and control group (n=8). The WKU Institutional Review Board approved all procedures prior to the testing and written informed consent was obtained from each participant.

Instruments

Dual-energy X-ray absorptiometry (DXA) (Hologic, Discovery A) was used to evaluate BMD. Hologic Discovery A is an x-ray based dual-energy bone densitometry with high resolution detective array (Jankowski, Costello, & Broy, 2006). Quality control measurements and calibration of the machine were performed daily before each session using the spine phantom provided by the manufacturer. The precision error
during the calibration did not vary more than ±0.8% of the reference value. The BMD values were obtained at lumbar spine, right and left hip sites. Baseline and post study comparison measurements were analyzed by Hologic Discovery Software.

Ground reaction forces were measured using a 600×400 mm, type BP600400, multicomponent force platform (AMTI, Massachusetts, USA) connected to a six-channel amplifier, MiniAmp MSA- 6 (AMTI, Massachusetts, USA). Force signals were collected at a sampling frequency of 50 Hz with data acquisition software, NetForce (AMTI, Massachusetts, USA). Peak vertical GRF (BW) and rate of force application (BW·s\(^{-1}\)) were analyzed using a Microsoft Excel spreadsheet. Peak vertical GRF was noted as the maximum value occurring during the impact phase of landing, and peak rate of force application was determined as the maximum slope of the force curve occurring between initial contact and the peak vertical GRF. Vertical jump heights were measured using a Vertec jump measurement system (Sports Import, Georgia, USA).

Procedures

Prior to data collection, each participant completed the Physical Activity Readiness Questionnaire (PAR-Q), medical history, bone-specific physical activity questionnaire (BPAQ) and the informed consent. Pre-intervention evaluation included bone mineral density measurement via DXA, vertical jump height, and GRF for all participants. The participants in the control group were instructed to continue their normal daily living activity and avoid participation in high-impact exercise sessions throughout the study time. The exercise group performed progressive maximal jump activity at the Exercise Physiology lab for two weeks. At the beginning of each study session, participants were given precise instructions for each of the exercise protocols. A
demonstration of each exercise protocol was given by the investigators to ensure proper form and execution by the participants. Participants were instructed to practice testing procedures following the demonstration so that they were familiar and comfortable with the movements.

Anthropometrics

Participants’ height was measured using stretch stature method with stadiometer (SECA, Birmingham, UK) to the nearest mm. Weight was measured to the nearest 0.1kg using digital scales (Detecto DR 400, Missouri, USA). Body mass index (BMI) was determined from height and weight measurements (BMI=weight/height\(^2\), kg·m\(^{-2}\))

Bone mineral density

Bone mineral density (g/cm\(^2\)) was measured at lumbar, right and left hip sites. The participants were asked to remove jewelry, body piercings and any metals on the clothes prior to DXA scan. For lumbar spine scans, the participants were in supine position with legs elevated on a foam block with hips and knees flexed. For right and left hip scan, the participants’ leg was rotated inward and a plastic form that was provided by the manufacturer was used to maintain the position. Bone mineral densities were determined from the scan by analysis software (QDR, version 12.4) provided by manufacturer. Regions of interest were defined with cut lines in the analysis program. After placing the cut lines in appropriate positions, the computer analyzed the bone mineral density, bone mineral content and T scores. The BMD evaluations were measured before and after ten days of jump training.
The BPAQ was administered to determine lifetime bone-specific physical activity level (Appendix D). The participants were asked to record type, frequency and duration of current (past 12 months), and past (lifetime) physical activity participation. The current BPAQ scores were calculated using following algorithm:

\[ c_{BPAQ} = [(R + 0.2 \times R \times (n-1)) \times a] \]

- **R** = effective load stimulus (derived from GRF testing)
- **N** = frequency of participation per week
- **A** = age weighting factor (<10 yrs = 1.2; 10-15 yrs = 1.5; 15-35 yrs = 1.1; >35 yrs = 1.0) (Weeks et al., 2008). Past BPAQ were calculated as \( p_{BPAQ} = R \times y \times a \), where
- **R** = effective load stimulus, **y** = years of participation, and **a** = age weighting factor (<15 yrs = 0.25; >15 yrs = 0.10) (Weeks et al., 2008).

The osteogenic index (OI) of exercise protocol was calculated using following algorithm:

- **OI (session/day)** = \( p_{GRF} \times (N+1) \), where **N** = number of loading cycles
- **OI (week)** = \( p_{GRF} \times (N+1) \times \text{days} \) (Turner, & Robling, 2003).

**Ground Reaction Force**

Participants were asked to report to the exercise lab with lose, comfortable clothes and running shoes for the GRF testing. After a brief warm-up, participants were asked to perform a depth jump from a step-bench (approx. 20 cm) followed by maximum vertical jump on force plate platform. Maximum vertical jump heights were pre-determined by Vertec max jump test. Participants were asked to jump above 80 percent of their maximum jump height during GRF test. Both depth jump landing (L1) and vertical jumping landing (L2) GRFs were recorded at acquisition rate of 60 seconds.
Participants practiced a few times to become familiarized with the movement before three consecutive attempts. All force data was averaged across the three attempts.

Exercise program

The exercise group performed a two-legged depth jump from an approximate 20cm step-bench followed immediately by a maximum vertical jump using arm swings for five days per week for two weeks. Each depth jump and vertical jump was performed ten times during each session. The exercise intervention started with one session per day for three days, and from the fourth day the exercise repetition increased to two sessions per day for another three days. During the last four days participants performed three sessions per day. The interval of each jump was 30 seconds and there were at least a four-hour break between each session on multiple session days.

Table 1: The jump group has different training sessions

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<td>Questionnaire (PAR-Q)</td>
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<td></td>
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<td>Medical History</td>
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<tr>
<td></td>
<td></td>
<td>BPAQ</td>
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<td></td>
<td></td>
<td>Anthropometric (Height, Weight, &amp; Body Comp)</td>
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<td></td>
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<td>DXA</td>
</tr>
<tr>
<td></td>
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<td>Study Instructions</td>
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<td>Vertical Ground</td>
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<td>Reaction Force</td>
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<td>Maximum</td>
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<td>Vertical Jump</td>
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<tr>
<td>Day</td>
<td>Group</td>
<td>Exercise Protocol</td>
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</tr>
<tr>
<td>Day 2-4</td>
<td>Jump group</td>
<td>Jump mode: Drop jump from 10 cm platform followed by max. vertical jump (1 set)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repetition: 10 sets of jumps with 30 sec gap; one session per day</td>
</tr>
<tr>
<td>Day 5-7</td>
<td>Jump group</td>
<td>Jump mode: Drop jump from 10 cm platform followed by max. vertical jump (1 set)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repetition: 10 sets of jumps with 30 sec gap; two sessions per day. 6-8hr recovery time between two sessions</td>
</tr>
<tr>
<td>Day 8</td>
<td>Jump group</td>
<td>Rest</td>
</tr>
<tr>
<td>Day 9-12</td>
<td>Jump group</td>
<td>Jump mode: Drop jump from 20 cm platform followed by max. vertical jump (1 set)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repetition: 10 sets of jumps with 30 sec gap; three sessions per day. 4-6hr recovery time between three sessions</td>
</tr>
<tr>
<td>Day 13</td>
<td>Jump group</td>
<td>Anthropometric (Height, Weight, &amp; Body Comp)</td>
</tr>
<tr>
<td>Control</td>
<td>group</td>
<td>DXA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vertical Ground Reaction Force</td>
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<td></td>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vertical Jump</td>
</tr>
</tbody>
</table>

**Dietary log**

Participants were asked not to change their dietary habits. However, in order to specify participants’ habitual dietary intake, participants were asked to complete a four-day dietary log, including the consumption of dietary supplements. The calcium and Vitamin D intake was analyzed through DietPro software, version 11.0 (Lifestyle technologies, Inc., California).
Statistical Analysis

Means and standard deviations were calculated for anthropometrics of the participants. A two-way repeated measure ANOVA was used to determine differences between training and control groups for dependent variables. Statistical analyses were obtained through Statistical Package for the Social Sciences (SPSS, version 21.0, SPSS Inc, Chicago, IL). Significance of the study data was accepted at $p \leq 0.05$ and comparison was two-tailed. The G-Power 3.1.9.2 was used to estimate sample size. Based on the mean differences and standard deviation of a paired t-test for DXA value and GRF value, a power of 0.8 of power would be obtained with a sample size ranging 12-14.
CHAPTER 4

RESULTS

The study was aimed to determine differences in bone mineral density between two groups of college-age Asian females as a result of ten days of jump training. Table 2 shows the characteristics of the participants.

Table 2: Participants’ characteristics (n=16)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Exercise (n=9)</th>
<th>Control (n=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>25±2.44</td>
<td>24.2±6.59</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160±3.13</td>
<td>158.7±9.32</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>54.6±6.59</td>
<td>55.9±10.69</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>21.3±2.19</td>
<td>22.01±2.19</td>
</tr>
</tbody>
</table>

There were no statistically significant differences in age or BMI between the two groups. The anthropometric measurements did not show significant changes throughout the study. Participants’ nutritional data are presented in Table 3. Mean caloric intake, carbohydrates, protein, fat, calcium, phosphorus, vitamin D, and iron were analysed through DietPro software. Both groups had similar nutrient intake data. A one sample t-test was used to analyse the participants' daily nutrient intake to National Recommended Dietary Allowances (RDA) (Food and Nutrition Board, Institute of Medicine, National Academies, 2010). The mean daily intake of both calcium and vitamin D were significantly (p<.05) lower than the RDA recommended level.
Table 3: Daily nutrients intakes

<table>
<thead>
<tr>
<th></th>
<th>Exercise (n=9)</th>
<th>Control (n=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>1345.4±343</td>
<td>1581±380.6</td>
</tr>
<tr>
<td>Protein</td>
<td>49.5±2.6</td>
<td>54.8±12</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>139±36.7</td>
<td>296±263.9</td>
</tr>
<tr>
<td>Fat</td>
<td>40.5±12.6</td>
<td>46.5±23.3</td>
</tr>
<tr>
<td>Calcium</td>
<td>159.1±60</td>
<td>332.4±285</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>6.4±7.1</td>
<td>28.14±15.26</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>399±55.6</td>
<td>354±85</td>
</tr>
<tr>
<td>Iron</td>
<td>10.55±3.2</td>
<td>12±2.76</td>
</tr>
</tbody>
</table>

There were significant (p<0.05) differences between the baseline and post-intervention maximum jump heights on both exercise and control groups. However, there were no interactions between the two groups.

Pre and post values for bone mineral density for both groups are presented in Table 4. Bone mineral densities were comparable between the groups. Based on analysis of the Hologic Discovery software, 69% of the participants were classified as osteopenia based on their T-score values. However, the normative data of BMD was designed on the software was referenced by means of Caucasian females.

Table 4: Mean baseline and post-intervention values for BMD

<table>
<thead>
<tr>
<th>Variables</th>
<th>Exercise</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Lumbar (g/cm²)</td>
<td>0.99±0.82</td>
<td>1±0.82</td>
</tr>
<tr>
<td>Right Hip (g/cm²)</td>
<td>0.89±0.10</td>
<td>0.91±0.92</td>
</tr>
<tr>
<td>Left Hip (g/cm²)</td>
<td>0.91±0.91</td>
<td>0.91±0.09</td>
</tr>
</tbody>
</table>

The changes in BMD are shown in figures 1 and 2. No significant changes in BMD were noted in either group. The average change in BMD at lumbar, left hip and right hip were 0.002 g/cm², 0.015 g/cm², and -0.004 g/cm² respectively in exercise group. Whereas, in
control group the average change were 0.005 g/cm\(^2\) at lumbar, 0.002 g/cm\(^2\) at the left hip, and 0.011 g/cm\(^2\) at the right hip.

**Figure 1:** Pre- and post-intervention BMD value in exercise group

![Exercise Group](image1)

**Figure 2:** Pre- and post-intervention BMD value in control group

![Control Group](image2)
The mean peak vertical GRF in BW was compared within the groups in both landing. Two-way repeated measures showed significant interactions (group×time) in peak GRF in the second landing. The exercise group showed significantly (p<0.05) increased peak GRF. All the participants presented VGRF greater than 3.0 times BW. Osteogenic index (OI) was calculated in exercise group. The OI in vertical jumping was significantly higher (p<0.05) than depth jump. No significant correlations were shown between BMD values and GRF in both groups. The BMD difference (post-pre) in lumbar site in control group showed significant (p<0.05) correlation with calcium intake.

The cBPAQ and pBPAQ was calculated in both groups. The pBPAQ showed significant correlation to BMD change of left hip (p<0.01).
CHAPTER 5

DISCUSSION

The purpose of this study was to determine if there were any significant changes in bone mineral density after ten days of jump training in college-age Asian females. The participants (n=16) were randomly divided into exercise (n=9) and control (n=8) groups. The exercise group completed a two-legged depth jump from an approximate 20cm step-bench followed immediately by a maximum vertical jump using arm swings for five days per week for two weeks. Each depth jump and vertical jump was performed ten times during each session. The exercise intervention progressed from one session per day to three sessions per day in ten days. The interval of each jump was 30 seconds and there was at least a four-hour break between each session on multiple session days.

The BMD value at lumbar, left hip and right hip was assessed on each participant. The VGRFs were analyzed in both landings on every participant. A four-day recall diet intake was recorded and analyzed for habitual mineral intake including daily Calcium and Vitamin D. The daily intake of Calcium and Vitamin D was significantly lower than the national recommended level. Bone mineral densities in lumbar spine, right and left hip did not show any significant change from the baseline value after the intervention in both groups.

Previous studies, which examined the effect of low-repetitive jump training on bone mineral densities in premenopausal women, have commonly shown increases of BMD (Kato et al., 2005); however, there are some studies also have been reported otherwise (Kishimoto et al., 2012). The current study used a relatively short-term
exercise protocol to investigate acute effect of exercises on BMD. There was 0.24% increase in lumbar, -0.37% decrease in right hip, and 1.6% increase left hip (see Figure 1). There are a couple of possible explanations for the lack of increase in BMD value. Kishimoto et al. (2012) examined the bone specific markers after the two weeks of jump training, which showed significant increase in bone resorption markers. Animal studies also revealed the process of bone resorption following microstrains to the bone (Robling et al., 2001). However, there are still uncertainties regarding to training duration and time. The study protocol did not give enough time in training courses to see absolute changes in bone. The nutrition data also showed significantly low calcium and Vitamin D intake, which could be adversely affecting the bone metabolism.

The mean weighted peak ground reaction force normalized to body weight was 3.10 BW at the first landing and 3.35 BW at the second landing. The GRF 2-4BW is classified as moderate intensity (Witzke, & Snow, 1998). The exercise group showed significant increase in peak VGRF after 10 days of training. The second landing showed significantly higher increase in peak GRF and osteogenic index. A previous study reported that jumping off from 10-25cm height with estimated 2.1-5.6 times BW showed significant increase in lumbar spine and femoral neck in premenopausal women (Heinone et al., 1996). In the current study, both jumping movements presented 3-5BW of GRF, which could conclude that the intensity of the movement was enough to induce osteogenic effect on the bone.

There are some limitations in the current study. First, bone-specific biomarker testing, which would have given valuable information in regards to different metabolic phases of the bone formation, was absent in the study. Secondly, the measurement of
strains on the bone was limited with only GRF. The compressive forces at the hip during both jump movements were unable to be analyzed in the current study. Also, the dietary log was based on four-day recall method, which could be subject to reliability and validity errors.

In conclusion, the results of the present study demonstrate that ten days of progressive jump training did not show visible change of BMD value measured by DXA in college-age females. However, there are possibilities that there might have been a visible change in follow-up testing. In future studies, combined biochemical testing and DXA testing of BMD could elicit more definitive results. Also, follow-up testing at various intervals could show more conclusive data.
APPLICATION FOR APPROVAL OF INVESTIGATIONS INVOLVING THE USE OF HUMAN SUBJECTS

The human subjects application must stand alone. Your informed consent document(s), survey instrument, and site approval letter(s) should be attached to the application and referred to in your write up of the appropriate sections so that reviewers may read them as they read your application. Thesis proposals or other documents that are meant to substitute for completing the sections of the application will not be read and should not be attached.

1. Principal Investigator's Name: Battogtokh Zagdsuren
   Email: battogtokh.zagdsuren183@topper.wku.edu
   Address: 557 Topmiller Ave. #A7, Bowling Green, KY 42101
   Department: Kinesiology, Recreation & Sport
   Phone: (270) 745-5857
   Completion of the Citi Program Training? Yes No
   Found at www.citiprogram.org Date __10/03/2012__

   Co-Investigator: Scott Lyons, PhD
   Email: scott.lyons@wku.edu
   Address: 1906 College Heights Blvd # 11089, Bowling Green, KY 42101-1089
   Department: Kinesiology, Recreation & Sport
   Phone: 270.745.6035
   Completion of the Citi Program Training? Yes No
   Found at www.citiprogram.org Date __Spring 2009__

2. If you are a student, provide the following information:

   Faculty Sponsor: Dr.Scott Lyons
   Department: Kinesiology, Recreation & Sport
   Phone: 270.745.6035
   Faculty Mailing Address: 1906 College Heights Blvd # 11089, Bowling Green, KY 42101-1089
   Completion of the Citi Program Training? Yes No
   Found at www.citiprogram.org Date __Spring 2009__
Student Permanent Address (where you can be reached 12 months from now):
557 Topmiller Ave. #A7, Bowling Green, KY 42101

Is this your thesis or dissertation research?      Yes √      No ______

**Policy of Research Responsibility.** The Western Kentucky University Institutional Review Board defines the responsible party or parties of the research project as the Principal Investigator and Co-Principal Investigator. In those cases when a student holds the title of Principal Investigator, the Faculty Sponsor (Advisor, Supervisor, Administrator, or general managing Council) will conduct oversight of the research project and share in the accountability to assure the responsible conduct of research. Researchers outside of the Western Kentucky University campus system are required to provide proof of training to obtain approval for WKU Human Subjects protocols. This proof must be presented by the Compliance Official at the researcher's institution to the WKU Compliance official. When no training requirement exists at the researcher's host institution, training must be conducted through affiliation of Western Kentucky University CITI Program.org requirements. WKU faculty, staff, and students are required to complete the CITI Program Training modules outlined by the WKU IRB.

3. Project Period:     Start ___upon IRB approval___     End ___5/31/2014___

   **Note:** Your project period may not start until after the IRB has given final approval.

4. Has this project previously been considered by the IRB?      Yes   No
   If yes, give approximate date of review:

5. Do you or any other person responsible for the design, conduct, or reporting of this research have an economic interest in, or act as an officer or a director of, any outside entity whose financial interests would reasonably appear to be affected by the research?
   Yes   No

   If "yes," please include a statement below that may be considered by the Institutional Conflict of Interest Committee:

6. Is a proposal for external support being submitted?      Yes   No
   If yes, you must submit (as a separate attachment) one complete copy of that proposal as soon as it is available and complete the following:
   a. Is notification of Human Subject approval required?      Yes   No
   b. Is this a renewal application?      Yes   No
   c. Sponsor's Name: 
   d. Project Period:     From:     To:

7. You must include copies of all pertinent information such as, a copy of the
questionnaire you will be using or other survey instruments, informed consent documents, letters of approval from cooperating institutions (e.g., schools, hospitals or other medical facilities and/or clinics, human services agencies, individuals such as physicians or other specialists in different fields, etc.), copy of external support proposals, etc.

8. Does this project SOLELY involve analysis of an existing database?  
   Yes  No

   If yes, please provide the complete URLs for all databases that are relevant to this application, then complete Section A and the signature portion of the application and forward the application to the Office of Compliance.

   If the database is not available in an electronic format readily available on the internet, please provide evidence that the data were collected using procedures that were reviewed and approved by an Institutional Review Board, then complete Section A and the signature portion of the application and forward the application to the Office of Compliance.

9. Is there a plan to publish or present the findings from the research outside the department or university?  
   Yes  No

In the space below, please provide complete answers to the following questions. Add additional space between items as needed.

I. PROPOSED RESEARCH PROJECT

A. Provide a brief summary of the proposed research. Include major hypotheses and research design.

   Based on previous studies, vertical jump has been shown to affect bone mineral density (BMD) in a positive way. However, it is unclear about the exercise duration and intervals that show a visible, positive change in BMD. To date there has not been a study designed with short term progressive jump training to examine BMD and biochemical markers in young adult women. Few studies have evaluated short term jump training on bone markers (Kishimoto, Lynch, Reiger & YingLing, 2012), and there has not been a study which examined bone markers and DXA evaluation after two weeks of exercise intervention. The purpose of the study is to determine effects of progressive short-term jump training on bone mineral density and biochemical markers for bone formation.

   Research Design and Methods

   Participants

   The investigation will take place in the Exercise Physiology laboratory at Western Kentucky University (WKU). In order to minimize the potential threat
of genetic discrepancies, the research will include the participants from Asian ethnicity. The participants will be randomized into two study groups: (1) progressive intensity jump training, (2) control group. Participants will go through exercise testing before and after two week intervention.

College aged (18-27 years) females of Asian ethnicity will be recruited for this investigation. Inclusion criteria will consist of sedentary lifestyle, no regular high-impact training for at least the last six months, nonsmoker, not pregnant, not lactating and no history of bone fractures. Exclusion criteria will include significant medical history, currently taking any medication that would affect bone metabolism, and any physical conditions that would contraindicate physical exercise. The participants will be randomly divided into two groups: exercise group and control group. To be included in the study, subjects will have to be in a "low risk" category according to the American College of Sports Medicine.

**Study Methods**

Participants will be instructed to wear loose fitting clothing (i.e. shorts, t-shirt, and running shoes) and to report to the Exercise Physiology lab at least 2 hours after eating. Participants will also be instructed to report to the lab well-hydrated. Prior to data collection, each participant will complete the Physical Activity Readiness Questionnaire (PAR-Q), Bone-Specific Physical Activity Questionnaire (BPAQ), Medical History, and sign an informed consent prior to participation. The PAR-Q, BPAQ, Medical History forms, and the informed consent are attached to this document. Pre-intervention evaluation includes bone mineral density measurement via DXA and blood tests for serum bone markers including deoxypyridinoline crosslinks (DPD) and osteocalcin (OC) for all participants. The participants in the control group will be instructed to continue to their normal daily living activity and avoid participation in high-impact exercise sessions throughout the study time. The exercise group will perform progressive maximal jump activity at the Exercise Physiology lab for two weeks. At the beginning of each study session, participants will be given precise instructions for each of the exercise protocols. A demonstration of each exercise protocol will also be given by the investigators to ensure proper form and execution by the participants. Participants will be instructed to practice testing procedures following the demonstration so that they are familiar and comfortable with the movements.

B. Describe the source(s) of subjects and the selection criteria. Specifically, how will you obtain potential subjects, and how will you contact them?

*Are the human subjects - under 18 years of age, pregnant women, prisoners, or fetus/neonates?  Yes  No*

Potential participants will be recruited by posting flyers throughout the campus of WKU, as well as from classes in the Department of Kinesiology, Recreation & Sport. Interested participants will have the nature, risk, and potential benefits and rights as a research participant explained to them. If the participant agrees to
participate in the study and meets inclusion criteria, the individual will be scheduled for an initial testing date.

C. Informed consent: Describe the consent process and attach all consent documents.

On day one of the study protocol, subjects will complete the PAR-Q, BPAQ, medical history, and informed consent. Upon completing the paperwork, it will be determined if the subjects meet the study criteria and if they are considered "low risk" according to the (ACSM, 2010).

D. Procedures: Provide a step-by-step description of each procedure, including the frequency, duration, and location of each procedure.

Pre- and post-intervention evaluation includes bone mineral density measurement via DXA and blood tests for serum bone markers including DPD and OC for all participants. The participants in the control group will be instructed to continue to their normal daily living activity and avoid participation in high-impact exercise sessions throughout the study time. The exercise group will perform progressive maximal jump activity at the Exercise Physiology lab for two weeks. At the beginning of each study session, participants will be given precise instructions for each of the exercise protocols. A demonstration of each exercise protocol will also be given by the investigators to ensure proper form and execution by the participants. Participants will be instructed to practice testing procedures following the demonstration so that they are familiar and comfortable with the movements. Participants will also be asked to complete a daily dietary log. The dietary log will be processed via Total Nutrition Diet Software 4.8 for Windows to evaluate daily habitual nutritional intake.

Exercise program: The exercise group will perform a two-legged drop jump from a ten-inch platform followed immediately by a maximum vertical jump using arm swing for five days/week for two weeks. Each drop jump and vertical jump will be performed ten times during each session. The exercise intervention will start with one session per day for three days, then for the next three days the intervention will increase to two sessions per day. During the last four days participants will perform three sessions per day. The interval of each jump will be 30 sec and there will be at least a four-hour break between each session on multiple session days. Maximum vertical jump will be measured in each jump to evaluate maximal jump heights of each participant.

The jump group has different training sessions. (Table 1)

<table>
<thead>
<tr>
<th>Experiment groups</th>
<th>Training type, duration and intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing</td>
<td></td>
</tr>
</tbody>
</table>

33
<table>
<thead>
<tr>
<th>Day</th>
<th>Group</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jump group</td>
<td>Informed Consent Physical Activity Questionnaire (PAR-Q) Medical History BPAQ Anthropometric (Height, Weight, &amp; Body Comp) DXA Study Instructions Blood collection for serum DPD and osteocalcin Vertical Ground Reaction Force Maximum Vertical Jump</td>
</tr>
<tr>
<td>2-4</td>
<td>Jump group</td>
<td>Jump mode: Drop jump from 10” platform followed by max. vertical jump (1 set) Repetition: 10 sets of jumps with 30 sec gap; one session per day</td>
</tr>
<tr>
<td>5-7</td>
<td>Jump group</td>
<td>Jump mode: Drop jump from 10” platform followed by max. vertical jump (1 set) Repetition: 10 sets of jumps with 30 sec gap; two sessions per day. 6-8hr recovery time between two sessions</td>
</tr>
<tr>
<td>8</td>
<td>Jump group</td>
<td>Rest</td>
</tr>
<tr>
<td>9-12</td>
<td>Jump group</td>
<td>Jump mode: Drop jump from 10” platform followed by max. vertical jump (1 set) Repetition: 10 sets of jumps with 30 sec gap; three sessions per day. 4-6hr recovery time between three sessions</td>
</tr>
<tr>
<td>13</td>
<td>Jump group</td>
<td>Anthropometric (Height, Weight, &amp; Body Comp) DXA Blood collection for serum DPD and osteocalcin Vertical Ground Reaction Force Maximum Vertical Jump</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td></td>
</tr>
</tbody>
</table>
**BMD and bone marker measurements:** BMD (g/cm^2) will be measured by DXA in the lumbar spine and proximal femur in both the anterior and posterior view. The DXA machine will be accessed at the WKU Health Sciences Building on the Bowling Green Medical Center campus, and both groups will be blinded for the radiographer. Serum DPD and OC will be measured for each participant pre- and post-exercise intervention. Blood samples will be collected in the morning of the testing days and centrifuged serum will be stored at -70°C until analysis.

**RESTING MEASURES**

**Height and weight**

The participants' body weight (kg) and height (cm) will be determined using a Detect-Medic Scale and attached stadiometer (Detecto Scales Inc., New York). Subjects will be asked to remove their shoes and will be wearing a t-shirt and shorts.

**Body composition**

The participants' body composition will be measured using calibrated Lange skinfold calipers. The objective is to measure subcutaneous fat to determine body fat. The procedure is explained below.

1. Firmly grasp a double fold of skin and the subcutaneous fat between the thumb and index finger of your left hand and lift up away from the body. The skinfold is lifted 1 cm above the site to be measured.
2. Lift the fold by placing the thumb and index finger 8 cm (3 inches) apart on a line that is perpendicular to the long axis of the skinfold. The long axis is parallel to the natural cleavage lines of the skin. For individuals with extremely large skinfolds, the thumb and finger will need to be separated more than 8 cm in order to lift the fold.
3. Keep the fold elevated while the measurement is taken (do not let go of the skinfold after placing the calipers).
4. Place the jaws of the caliper perpendicular to the fold, approximately 1 cm below the thumb and index finger, and release the jaw pressure slowly.
5. Take the skinfold measurement within 2 seconds after the pressure is released.
6. Open the jaws of the caliper to remove it from the site. Close the jaws slowly to prevent damage or loss of calibration. Let go of the skinfold after removing the calipers.
7. Take a minimum of two measurements at each site. If values vary from each other by more than 4 mm, take additional measurements.
8. Take skinfold measurement in a rotational order rather than consecutive readings at each site.
9. Take the skinfold measurements when the client's skin is dry and lotion-free.
10. Do not measure skinfolds immediately after physical activity because of fluid...
shifts to the skin

**Venipuncture Blood Collection**

Venipuncture blood samples will be obtained using Universal Precautions at rest for a baseline measurement for serum DPD and OC. Approximately 450 microliters of blood will be obtained with each sampling period, twice throughout the study. Blood sample will be drawn from cubital or cephalic vein of the participants arm.

1. Wrap a tourniquet around the patient's upper arm to stop blood flow.
2. Sterilize the puncture site with alcohol
3. Insert the needle into the vein with the bevel up
4. Attach the appropriate test tube to the needle. Allow the blood to fill the test tube.
5. Remove the tourniquet to restore blood flow
6. Place a gauze pad over the site while withdrawing the needle
7. Apply firm pressure to the site until bleeding has stopped.

Blood sample will be incubated at room temperature for 20 min and centrifuge at 3,000 rpm for 10 min at 4°C. After separating the serum samples will be stored at -80°C until processed via ELISA.

**PERFORMANCE TESTING**

The investigators possess specific training, experience, and certifications to safely and effectively conduct the fitness and performance testing listed below. Each testing protocol will be conducted according to American College of Sports Medicine (ACSM) and National Strength and Conditioning (NSCA) Associations rigorous protocols and guidelines.

**Vertical Ground Reaction and Vertical Jump Test**

The procedure using Vertec Apparatus

1. The participants weight is taken and converted into kilograms
2. The participants' reach height is measured and recorded. To do this, adjust the height if the Vertec plastic vanes to be within the participants reach. The shaft that holds the vanes is marked with measurements, and measurement selected should coincide with the bottom vane. Each van represents inches, and each red vane represents an increment of 6 inches. The participant reaches, without lifting
the heels (i.e., flat footed) and touches the highest vane possible with the dominant hand. To prevent confounding results, the participants must stand directly beneath the apparatus and reach as high as possible.

3. Warm-up: After initial familiarization with the test procedure and the Vertec apparatus, the participant performs approximately five minutes of moderate-intensity aerobic exercise (include walking or jogging are preferable), followed by several dynamic range of motion exercises for the hip flexors and extensors, hamstrings, quadriceps, calves, and shoulders. The participant is then allowed several trials without the Vertec apparatus to become familiar with the countermovement jump procedure.

4. The participants' jump height is then measured and recorded. To do this, lift the height of the Vertec stack so that the top vane is higher than the participants estimated jump height. Again, the measurements on the Vertec shaft must be carefully used to ensure an accurate calculation of jump height.

5. For a standard countermovement VJ test, the subject is not permitted to take any lead-up steps (i.e., approach). This test requires the participants to perform a rapid countermovement by quickly descending into a squat (i.e., flexion of the hips and knees and forward and downward movement of the trunk) while swinging the arms down and backward. This rapid countermovement is immediately followed by a maximal vertical jump in which the dominant hand reaches to touch the highest possible Vertec vane.

6. Following each jump, the vanes are moved out of the way for consecutive trials (i.e., the highest vane touched and all vanes underneath are turned to the opposite direction).

7. The best of three trials is recorded to the nearest 0.5 inch.

8. Vertical jump height is recorded as the difference between the highest jump and the previously recorded reach height.

E. How will confidentiality of the data be maintained? (Note: Data must be securely kept for a minimum of three years on campus.)

During and after study participation, research data will be locked in the faculty sponsor's office in a locked file cabinet. A number to maintain confidentiality will identify subjects. The subject's name and contact information will be kept in a separate file to avoid identification. The data will be kept for a minimum of three years after completion of the study.

F. Describe all known and anticipated risks to the subject including side effects, risks of placebo, risks of normal treatment delay, etc.

Venipuncture blood collection can cause minor bruising around the sample area and slight discomfort during the sampling procedure.

Risks of the performance testing can include musculoskeletal injury, which includes bruising, muscle cramps or soreness, muscle strains and sprains or
muscle tears. Risks will be reduced by demonstration of proper technique, allowing participants to practice the technique, and by allowing participants to warm up prior to all protocols.

Participants will be monitored during and after testing, and testing will be terminated if participants exhibit adverse signs/symptoms such as the onset of angina or angina-like symptoms, signs of poor perfusion such as lightheadedness, confusion, ataxia, pallor, cyanosis, nausea, or cold, clammy skin, or if the subject feels for any other reason they need/want to stop (ACSM, 2010). In case of accident or illness, proper care will be given by a CPR certified individual until emergency medical services personnel arrive. Participants will be made aware of these risks and given the opportunity to ask questions or withdraw from the study at any time.

The investigators hold a current certification from the American Heart Association (AHA) in CPR and AED. Each investigator has a card indicating the certification.

G. Describe the anticipated benefits to subjects, and the importance of the knowledge that may reasonably be expected to result.

The participants may have the benefits of knowing their BMD value and knowing their habitual nutritional intake.

H. List of references (if applicable):


Additions to or changes in procedures involving human subjects, as well as any problems connected with the use of human subjects once the project has begun, must be brought to the attention of the IRB as they occur.
APPENDIX B

Exercise Physiology Laboratory

Physical Activity Readiness Questionnaire (PAR-Q)

Now I am going to ask you a few questions to determine if you are eligible to participate in the study.

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

   No ___  Yes ___  If yes, specify: ________________________________

2. Do you feel pain in your chest when you do physical activity?

   No ___  Yes ___  If yes, specify: ________________________________

3. In the past month, have you had chest pain when you were not doing physical activity?

   No ___  Yes ___  If yes, specify: ________________________________

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

   No ___  Yes ___  If yes, specify: ________________________________
5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

   No ___  Yes ___  If yes, specify: _____________________________

6. Is your doctor currently prescribing drugs (for example, water pills) for a blood pressure or heart condition?

   No ___  Yes ___  If yes, specify: _____________________________

7. Do you know of any other reason why you should not do physical activity?

   No ___  Yes ___  If yes, specify: _____________________________
Exercise Physiology Laboratory

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>1. History of heart problems, chest pain, or stroke?</td>
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<td>2. Increased blood pressure?</td>
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<td>3. Any chronic illness or condition?</td>
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<td>4. Difficulty with physical exercise?</td>
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<td>5. Advice from a physician not to exercise?</td>
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<td>6. Recent surgery? (Last 12 months)</td>
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<td>7. Pregnancy? (Now or within the last 3 months)</td>
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<td>8. History of breathing or lung problems?</td>
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<td>9. Muscle, joint, back disorder, or any previous injury still affecting you?</td>
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<td>10. Diabetes or thyroid conditions?</td>
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<td>11. Cigarette smoking habit?</td>
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<td>12. Increased blood cholesterol?</td>
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<td>13. History of heart problems in your immediate family?</td>
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<td>14. Hernia or any condition that may be aggravated by lifting weights?</td>
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<td>15. Do you have any condition limiting your movement?</td>
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<td>16. Are you aware of being allergic to any drugs or insect bites?</td>
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<td>17. Do you have asthma?</td>
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<td>18. Do you have epilepsy, convulsions, or seizures of any kind?</td>
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<td>19. Do you follow any specific diet?</td>
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Please explain in detail any “YES” answers:

Family History

Has any member of you family had any of those listed above?
APPENDIX D

Bone-Specific Physical Activity Questionnaire (BPAQ)

2. Please list the sports or other physical activities (be as specific as possible) you participated in regularly during the last 12 months and indicate the average frequency (sessions per week).

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<tr>
<th>Activity:</th>
<th>Frequency (per week):</th>
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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 for.

| Activities | Age: 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 | 26 | 27 | 28 | 29 | 30 |
|------------|--------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
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APPENDIX E

INFORMED CONSENT DOCUMENT

Project Title: Effect of jump training on bone mineral density in young adult females

Investigator: Brijeshkumar Zapardia, Department of Kinesiology, Recreation & Sport, 270.996.0347

Faculty Sponsor: Dr. Scott Lyons, Department of Kinesiology, Recreation & Sport, 270.745.6835

You are being asked to participate in a project conducted through Western Kentucky University. The University requires that you give your signed agreement to participate in this project.

The investigator will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask her any questions you have to help you understand the project. A basic explanation of the project is written below. Please read this explanation and discuss with the researcher any questions you may have.

If you then decide to participate in the project, please sign on the last page of this form in the presence of the person who explained the project to you. You should be given a copy of this form to keep.

Nature and Purpose of the Project: The purpose of the study is to determine effects of progressive short-term jump training on bone mineral density and biochemical markers for bone formation.

Explanation of Procedures: You will be asked to come to the Exercise Physiology Laboratory at Western Kentucky University twelve times over two weeks. Each session will last no more than 45 minutes. To minimize risks when performing exercise interventions, you will be asked to complete some brief screening documents to ensure that you are classified as "low risk" according to the American College of Sports Medicine (ACSM). If you are classified as "moderate" or "high risk" according to ACSM, then you will be excluded from participation in this research study. Additionally, if you are currently physically active, have a significant medical history, are currently taking any medications that would affect bone metabolism, have any physical conditions that would contraindicate physical exercise, are pregnant, lactating or have a history of bone fractures, you will also be excluded from participating in this research. During each of the study sessions you will perform series of tests including bone mineral density measurements via Dual-energy X-ray Absorptiometry (DXA) and blood tests for serum bone markers including deoxypyridinoline crosslinks (DPD) and osteocalcin (OC). Below is a brief description of each of the testing procedures. Detailed instructions will be provided by the investigator prior to performing each of the procedures.

1. Height and weight will be measured using a standard digital scale.
2. Body composition will be measured using skinfold calipers. The investigator will access sites on your chest, waist, and upper arm, and gently pinch each site using the calipers.
3. DXA evaluation of bone mineral density will be performed on first and in the end of the study session. The DXA is a special type of x-ray machine used for research purposes.
4. A blood sample will be drawn on first day and at the end of the study. The sample will be done with the finger stick method and less than 5 ml of blood will be drawn.
5). You will be asked to perform drop jump followed by maximal vertical jump on ground reaction force platform. The force of each jump will be recorded.
6). You will be asked to perform drop jump followed by maximal vertical jump to measure the vertical jump height.
7). You will be asked to complete a daily dietary log. The dietary log will be processed via Nutrion software to evaluate your daily habitual nutritional intake.

You will perform a two-legged drop jump from a ten-inch platform followed immediately by a maximum vertical jump using arm swing for five days/week for two weeks. Each drop jump and vertical jump will be performed ten times during each session. The exercise intervention will start with one session per day for three days, and from the fourth day the intervention will increase to two sessions per day for another three days. During the last four days participants will perform three sessions per day. The interval of each jump will be 30 sec and there will be at least a four-hour break between each session on multiple session days. Maximum vertical jump and ground reaction force will be measured in each jump to evaluate peak ground reaction force and maximal jump heights of each participant.

Discomfort and Risks: The blood sample collection can cause minor bruising around the sample area and slight discomfort during the sampling procedure. Risks of the performance testing can include musculoskeletal injury, which includes: bruising, muscle cramps or soreness, muscle strains and sprains or muscle tears.

Benefits: You may have the benefits of improving exercise tolerance, knowing their BMD value and knowing their habitual nutritional intake.

Confidentiality: Any information about you obtained from this research will be kept confidential. All records related to your involvement in this research study will be stored in a locked file cabinet. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. You will not be identified by name in any publication of the research results.

Refusal/Withdrawal: Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

_________________________  __________________________
Signature of Participant	Date

_________________________  __________________________
Witness	Date

THE DATED APPROVAL ON THIS CONSENT FORM INDICATES THAT
THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD
Paul Moverrey, Human Protection Administrator
TELEPHONE: (270) 745-2129
REFERENCES


Dietary Reference Intakes (DRIs): Estimated Average Requirements (2010). Food and Nutrition Board, Institute of Medicine, National Academies, retrieved April 10, 2014, from http://www.iom.edu/Activities/Nutrition/SummaryDRIs/~/media/Files/Activity%20Files/Nutrition/DRIs/5_Summary%20Table%20Tables%201-4.pdf


Sciences Journal, 3(1), 129-133.


