DOES A SOCCER PLAYER’S LEVEL OF COMPETITION HAVE AN EFFECT ON BONE MINERAL DENSITY?

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ABSTRACT

MEGAN MATTECK

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MAY 2017

The purpose of this study was to investigate whether players involved in higher levels of soccer competition would have higher bone mineral density (BMD) than those players in lower levels of competition. Twenty-two current female (18-22 years) students who attend a university in Texas and who participate in different levels of soccer were asked to consent to a measurement of BMD of their total body (TB), lumbar spine (LS; L1-L4), and femoral neck (FN; both right and left). Participants were placed in categories (NCAA and Club) based on their soccer team association. There was no significant difference at any BMD site between the NCAA and Club participants. Mean vales for TB, LS, and FN (right and left) were 1.227, 1.275, 1.167, and 1.173 respectively. In conclusion, the type of competition of soccer players does not seem to affect one's BMD at the TB, LS, and FN sites in college-age women.

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CHAPTER I

INTRODUCTION TO THE STUDY

Maintaining a healthy lifestyle through exercise and nutrition is considered advantageous when discussing longevity of life and overall well-being. It is stated that there are positive physiological, psychological, and sociological benefits that are seen when physical activity is present within a person's daily routine (Physical Activity Guidelines, 2008). In 1996, the U.S. Surgeon General issued a report on physical fitness and health stating that:

(a) Life can be improved through use of moderate daily physical activity.

(b) Additional improvement in lifestyle could be seen if you increase the current fitness regimen you've been following.

(c) These benefits are obtainable for all Americans.

According to the report, 60% of all Americans are not regularly active.

Less physically active individuals are susceptible to developing diseases (Dietz, Douglas, & Brownson, 2016). Osteoporosis, or a disease of the bone, deals with the deterioration of bone tissue which could eventually lead to a risk of fracture due to instability. Based on the United States Census Bureau, the estimated population of the US is 321,418,820, with about 50% of that number being female. According to Kannus et al. (1996), over 50% of women and 20% of men will deal with some type of bone fracture in the latter half of life. By developing weak or brittle bones, leading to risk of fracture, secondary issues such as medical costs, loss of independence, and further health concerns arise. Schurch, Rizzoli, Mermillod, Vasey, Michel, & Bonjour (1996) found that elderly individuals who incurred a hip fracture have a 15-20% chance of mortality within that first year. Currently, about 9% of the US population who is over 50 has been diagnosed with osteoporosis at either the femoral neck or lumbar spine while about half of the population suffers from low bone mass (Looker, Borrud, Dawson-Hughes, Shepherd, & Wright, 2012). The World Health Organization defines the level of bone density as follows:

World Health Organization Definitions Based on Bone Density Levels

Level	Definition
Normal	Bone density is within 1 SD (+1 or −1) of the young adult mean.
Low bone mass	Bone density is between 1 and 2.5 SD below the young adult mean (−1 to −2.5 SD).
Osteoporosis	Bone density is 2.5 SD or more below the young adult mean (−2.5 SD or lower).
Severe (established) osteoporosis	Bone density is more than 2.5 SD below the young adult mean, and there have been one or more osteoporotic fractures.

Figure 1: WHO Bone Mineral Density Levels.

Due to the nature of the disease and its slow progression, action can be taken to improve one's bone mineral density (BMD). One way BMD is improved is when loading forces higher than normal strains are inflicted on the bone (Ratamess, 2008). The type of loading needs to be site-specific and not typical to elicit bone formation. Beck and Snow (2003) created a model of intervention that spans over a typical human life.

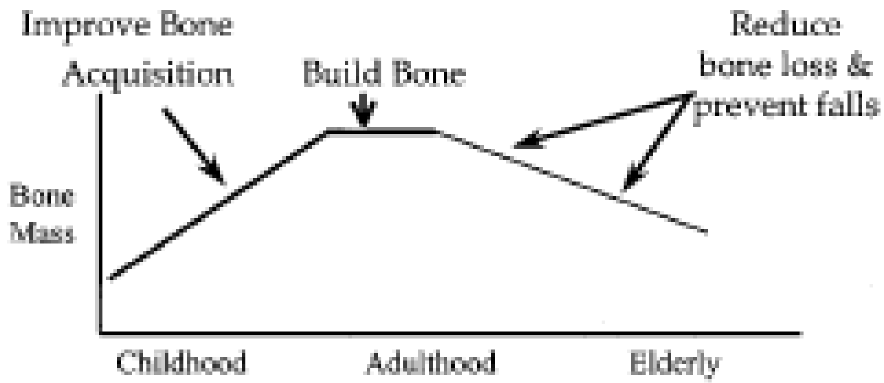

Figure 2: Model of exercise intervention.

Development of peak bone mass by physical maturity, or the third decade of life, is important to strive for. It is during these stages that bone is developed and built through modeling and remodeling in response to mechanical forces. By the beginning of the third decade of life, and into the fourth, bone starts to thin. The focus now shifts to maintaining the bone that was previously created and to minimize bone loss.

The methods of mechanical loading to elicit bone formation are not an exact science. Based off the article by Turner (1998) bone adaptation is driven by dynamic loading, that is short in duration, and that is unique and unusual to the body. Because of this, one would assume that the addition of resistance training or participating in some type of sport would be an osteogenic stimulus. The study by Nichols, Sanborn, and Love (2001) found an increase in BMD of the femoral neck (FN) after introducing a 15 month resistance program to untrained females; however there were no significant changes of the lumbar spine (LS) or total body (TB). Laing et al. (2011) had 51 untrained females who were placed in either the step aerobics group, the strength training group, or the control group. After the 12 month study, no significant changes were observed at the FN or LS. When comparing weight bearing sports (cross-country and triathletes) versus non-weight bearing sports (swimmers and cyclists), Duncan et al. (2002) found that the runners had significantly higher TB and FN BMD than swimmers and higher FN BMD than cyclists.

When comparing a specific activity, such as soccer, to inactive controls, Alfredson, Nordstrom, and Lorentzon (1996) found that soccer players had significantly higher BMD in the LS and the FN. Soccer is particularly interesting due to its worldwide popularity and that individuals of different age cycles have the ability to participate. Because of the unusual loading mechanics involved with soccer, it could be considered an osteogenic stimulus. Soccer players must perform different activities during practice and games that consist of jumping, kicking, tackling, pivoting, starting and stopping quickly, and changing direction. All of these movements create ground reaction forces that are 3-6 times the body weight of the individual (Alfredson et al., 1996).

Purpose of the Study

Physical exercise and mechanical loading are thought to elicit bone formation and can help in preventative measures against the silent disease osteoporosis. However, there is no clear answer as to what type of training module will elicit the best response on bone formation. Typically documented, soccer elicits abnormal loading on bone due to the nature of the movement within the sport. This study serves to analyze the bone mineral density of female collegiate soccer players who compete within the NCAA (National Collegiate Athletic Association) versus club soccer players who compete within the intramural league and to provide insight on whether or not participating in different levels of competition in the game of soccer can have an effect on your BMD at specific loading sites.

Hypothesis

Because the collegiate player belongs to a team that is sanctioned by the NCAA and competes at a national level versus a club player who competes in an intramural league for recreational purposes within the university, the research hypothesis of this study is that collegiate soccer players competing at the NCAA level will have a greater bone mineral density (BMD) at specific loading sites than the club player.

Definitions

For purposes of clarity, the following terms, as intended throughout this thesis are defined as follows:

1. Bone Mineral Density (BMD): The amount of mineral matter per square centimeter of bone. It is used as an indicator of osteoporosis and fracture risk.
2. Bone Remodeling: Process in which bone responds to stimulus from mechanical loading.

3. Club: Voluntary campus organization that is run by a chosen academic advisor. Known as the Pioneer Soccer Club on campus. Participates within an intramural league.

4. Club Player: Individual who competes for the Pioneer Soccer Club.

5. Collegiate Player: Individual who competes within the NCAA.

6. Competition Level: The different leagues, organizations, or teams within which a player can compete. For example, recreational, intramural, high school, collegiate.

7. Dual-energy X-ray absorptiometry (DXA): It is a means of measuring bone mineral density.

8. Intensity: Measurable amount of effort given based off of perceived exertion. Synonyms include strength, power, and effectiveness.

9. Minimal Essential Strain (MES): The threshold stimulus that causes bone to form.

10. NCAA (National Collegiate Athletic Association): Organization that regulates a member university‘s sports teams.

11. Osteoblasts: Cells that form bone.

12. Osteoclasts: Cells that reabsorb bone.

13. Osteocytes: Mechanosensing cells.

14. Osteogenic Stimulus: Unusual load that causes bone growth.

15. Osteoporosis: Severe low bone density. Thinning of the bone which predisposes a person to potential risk of fracture.

16. Peak Bone Mass: The highest amount of bone mass that an individual gains by the age of thirty.

17. Soccer: Team sport that involves jumping, kicking, tackling, pivoting, starting and stopping quickly, and changing direction.

Assumptions

1. The participants were truthful when completing their questionnaire.
2. The participants are active members of said club team/NCAA collegiate team.
3. The participants complete each practice/drill/activity within their competition field as best as possible.
4. The technician kept the DXA scan protocol consistent.
5. The quality assurance (QA) program for the Prodigy Lunar scanner was run every day scans were conducted.
6. The QA passed every time it was run.

Limitations

1. The study did not account for specific soccer playing positions: for example; goal keeper versus field player.
2. The study was not randomized.
3. The study might not apply to another demographic group, especially those that suffer from or are at risk for osteoporosis.
4. Potential confounders related to the female athlete triad are not explored within this study.
5. This study recruits a limited number of subjects.

6. This study only accounts for one specific activity and does not investigate lifestyle choices.

Significance of the Study

The concern for being susceptible to osteoporosis and at risk for fractures leads many to see the need for a healthy lifestyle and to prohibit the onslaught of bone loss. Participating in physical activity can help lessen or prevent the "silent disease" later in life. However, there is little research to investigate whether the competition level of said physical activity really makes a difference. By studying currently active female soccer players within two different realms of competition, an NCAA official division II team versus a collegiate club team, one can see if there is notable difference in their bone mineral density at specific loading sites. With this information, this investigator hopes to evaluate if a certain level of competition creates a better environment for higher BMD.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this study is to decide whether a higher level of competition/intensity will create a higher BMD. There is not much literature about the level of competition and how it affects BMD. If the competition level, or the intensity, as defined by this study, has merit towards increasing ones BMD, it would help us understand how to prescribe the necessary activities needed to help deter osteoporosis or osteopenia later in life. This chapter will review the research literature pertaining to the following topics: (a) physiology of bone, (b) bone growth, (c) factors affecting skeletal development, (d) osteoporosis, (e) mechanical loading and its effects on BMD, and the (f) background of soccer.

Physiology of Bone

Bone, which is considered a dynamic connective tissue, makes up the skeletal architecture of the whole body. According to Seeman (2003) bone, which must be both stiff and flexible and also light, is a contradictory structure. The stiffness of the bone helps move your body against gravity and keeps it intact during mechanical loading. Flexibility is necessary to absorb said loads and not buckle under pressure. The bones must also be light for ease of movement. Each bone in the body has a different mineral mixture based on the function. For example, ossicles are 90% mineral (Seeman, 2003) due to their function and allow sounds to easily vibrate off. These bones are strong, but because of the lack of flexibility would crack under the smallest of loads.

There are two different types of bones: cortical and trabecular. Cortical (compact) bone composes the outer shell of a skeletal structure while trabecular (spongy) bone makes up the inner bone mass. Approximately 80% of the skeletal mass is made up of cortical bone while 20% is made from trabecular bone (Jee, 2001). Cortical bone has a slow turnover rate and is structurally strong as compared to trabecular bone, which is less dense and has a higher turnover rate (Hadjidakis & Androulakis, 2006).

There are three types of cells that are involved in bone metabolism: osteoblasts which are responsible for bone formation, osteoclasts which deal with bone resorption, and osteocytes which are considered to be mechanosensors that direct when and where osteoclasts resorb and when and where osteoblasts need to form (Caetano-Lopez, Canhao, & Fonseca, 2007). When a certain stressor at a specific site causes mechanical loading, osteoblasts migrate towards the location. Once there, osteoblasts begin bone remodeling by secreting collagen (Ratamess, 2008). This protein then forms the bone matrix and eventually becomes mineralized calcium, increasing the diameter of the bone to better handle the external stress placed on the bone (Ratamess, 2008).

The term minimal essential strain (MES) is used when discussing bone loading and bone formation. For one's bones to have any type of growth, the type of loading, or strain, must be above the MES threshold. Normal day to day forces elicited on bone generally do not exceed the MES threshold (Ratamess, 2008). This typical safety mechanism reduces risk of bone fracture. When the threshold is surpassed by unusual loading, the bone becomes more rigid and stiff allowing for the bone to handle the strain of the new stimulus. Once the diameter of the bone begins to grow, the force that once surpassed the MES is now below the threshold. It is very apparent that progressive overload is essential in bolstering bones.

Bone Remodeling

Bone remodeling or bone destruction and regrowth is an important process of the skeleton. It is described as the process of bone turnover. According to Hadjidakis and Androulakis (2006) there are three phases of remodeling that include resorption, reversal, and formation. As stated in the last section, the resorption phase is driven by the osteoclast cells. These cells turn the mineral and organic component of the bone matrix soluble (Jee, 2001) to be absorbed. The formation phase is driven by osteoblasts which synthesize and secrete unmineralized bone matrix. With this, the calcification of bone starts to increase (Jee, 2001) forming new bone. Because of the slow turnover of bone tissue, these three phases typically take at least 6 months to complete. Resorption continues for 2 weeks, reversal happens up to 5 weeks, and formation can continue for 4 months while the new matrix is forming (Hadjidakis & Androulakis, 2006). Watts, 1999, stated that each year remodeling replaces 25% of trabecular bone and 3% of cortical bone.

Peak Bone Mass and Factors Affecting It

Peak bone mass (PBM), defined in this paper, is the highest amount of bone mass that an individual gains by the age of thirty. PBM is determined by several factors such as genetics, hormonal, and environmental. For example, females already have a lower bone density than males due to their predisposed skeletal structure (Golden & Abrams, 2014). Another example would be the higher bone mass seen in black women than white non-Hispanic women (Golden & Abrams, 2014). Figure 3 from the review by Sampson (2002) shows variables that affect PBM.

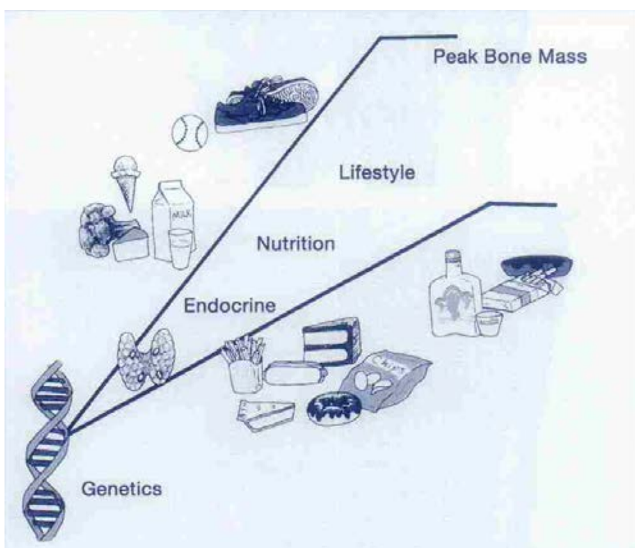

Figure 3: Peak bone mass variables

Genetics

According to Clunie and Keen (2008) genetic components affect PBM. For example, a large number of family-based studies have shown that at least 60% of your attained BMD is based off of your genetic factors (Clunie & Keen, 2008). A study by Barthe et al. (1998) compared mothers and daughters, of which the mothers were identified as osteoporotic, to mothers and daughters whose mothers were not affected by the disease. Individuals were selected based off of certain criteria and case and control mothers were not statistically different in age, weight, or height. Case pairs included 72 mothers and 91 daughters and the controls included 72 mothers and 77 daughters. The case mothers' criteria included having a z-score of below -2 SD. Again, according to WHO, a low bone mass is between -1 and -2.5 SD and osteoporosis is defined as a z-score of -2.5 SD or below. Approximately 98.6% of the case mothers were osteoporotic while 17.8% of control mothers were osteoporotic based on the T-scores calculated from their BMD measurements. After the BMD was tested, Barthe et al. (1998), found that there was a significant difference at the LS between case and control mothers' z-score, -2.51 and 0.23 respectively, and the case and control daughters' z-score, -0.82 and 0.01 respectively. For the FN there was a significant difference between case and control mothers' z-score, -1.19 and -0.15, respectively but not with the daughters. These findings suggest a relationship between genetics and BMD, at least at the LS site. The osteoporotic mothers had daughters who seemed predisposed to lower BMD at the LS while control mothers and daughters had normal range z-scores. For the FN, there was a significant difference between case and control mothers, however it was less evident than in the LS site. The case daughters were also less affected at the FN site. Barthe et al. (1998) suggested that these findings could be attributed to the FN site being less affected by genetics than the LS.

Hormonal

In a study by Drinkwater et al. (1984), the effect of low levels of estrogen on bone mass for prolonged periods was examined. The investigators used 14 amenorrheic and 14 eumenorrheic females matched for basic anthropometry, trainings, and sports and compared their BMD at the LS and the radius. They tested at two radius sites, S1 and S2 which consisted of both cortical and trabecular bone and a majority of cortical bone, respectively. At the radius, average BMD for amenorrheic and eumenorrheic groups were 0.53 and 0.45 for S1 and 0.67 and 0.67 for S2. For the LS, the BMD of the amenorrheic group was 1.12 while the eumenorreic group was 1.30. Average estrogen levels in the amenorrheic group was significantly lower than the eumenorreic group (38.58 and 106.99 pg per milliliter respectively). Drinkwater, et al., found that there was no effects of a lower estrogen level on either radius site but that there was a significant difference at the LS. They went on to suggest that this finding could potentially be due to the type of bone found within each but they only found one other paper to support that statement.

Gilsanz et al. (2011) wanted to study the timing of puberty and its effects on BMD. There is a correlation between the amount of bone gained at puberty to the PBM you'll be able to reach. The investigators stated that random delay in puberty has a reductive affect on PBM. Furthermore, amenorrheic females have a lower BMD than their eumenorreic counterparts. Gilsanz et al. (2011) studied 78 females of various ethnic groups. At the start of puberty, Tanner II stage of sexual development, the BMD at the

TB, LS, upper extremity (nondominant forearm) and lower extremity (left proximal femur) were measured. The results were 0.75, 0.67, 0.57, and 0.90 respectively. Follow-up examinations for BMD once skeletal maturity was reached (defined as Tanner V) yielded measurements of 0.94, 0.98, 0.70, and 1.12 respectively. The average change per year between the two values was 1.6-3.9% depending on the site. In females, the mean age for the onset of puberty is 10.7 years. According to Gilsanz et al. (2011), beginning puberty a year earlier than the average created 2.5% higher BMD values. Beginning a year later created 2.5% lower BMD values. These findings support the original claim that PBM can be affected by pubertal onset.

Environmental

Some environmental factors that have shown to affect peak bone mass are dietary intake and physical activity. According to Weaver et al. (2016), lifestyle choices are the root of 20-40% of peak bone mass. One of the factors Weaver et al. sought to study was calcium (Ca). From the cohort, they found that Ca supplementation had a small effect on BMD. There was a 0.57-5.80% increase in BMD for the group that used Ca as opposed to the placebo group.

Cameron et al. (2004) used 51 pairs of twins, both fraternal and identical, to test whether Ca supplementation would increase BMD. The study lasted 24 months where one twin would receive a 1200 mg Ca tablet while the other would receive a placebo. BMD testing was done at baseline, 6, 12, 18, and 24 months. At baseline, there was no difference for height, age, and BMD measurements between the placebo and Ca groups.

There was also no difference in anthropometric characteristics or BMD measurements within each twin pairing. After adjusting for the differences in age, height, and weight throughout the study, Cameron et al. found that at 6 months there was significant differences within-pair at the FN (1.2%) for the Ca group. At 12 months, there was a greater gain at the LS site (1.6%) but not at the FN. And finally at the 18 and 24 month marks, there was no difference within-pairs. These results are presented in figure 4.

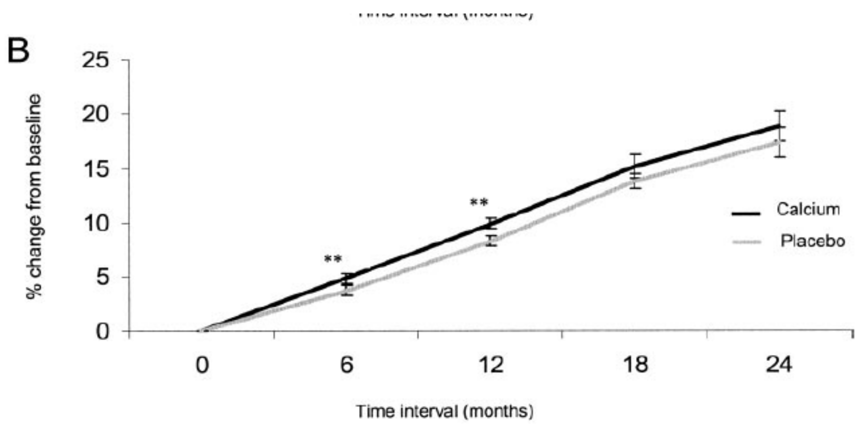

Figure 4: Femoral neck gains in bone mineral density during pubertal growth.

These results lead the investigators to believe that Ca supplementation for the first 12 months of intervention leads to greater bone growth but after the initial year, the effects of Ca waned.

The physical activity that affects BMD is discussed in the Mechanical Loading section.

Osteoporosis

Osteoporosis is defined as a disease affecting the skeletal structure characterized by BMD and bone mass being at critically low levels, which then causes an increased risk of fracture (Ratamess, 2008; WHO, 2003). The bones become thin and fragile, which makes them inclined to easily break. The term osteoporosis comes from the root words osteon meaning bone and poros meaning small holes. This disease is typically termed the "silent disease" since the skeletal integrity slowly diminishes throughout the adult life span. Some individuals might not know they have the disease until they fracture a bone. According to Cooper and Dennison (2008) white women aged 50 years are estimated to have a 17.5% risk of hip fracture, a 15.6% risk of a vertebral fracture and a 16% chance of a forearm fracture. The cause of fracture is due to bone minerals and the structural properties of the skeleton not remodeling quick enough to offset the reabsorption of minerals (Seeman, 2003). A negative deficit is a cause for concern in general populations, more specifically in older women. Because of this, the prevention of, the screening and diagnoses of, and the treatment for osteoporosis are important topics to focus on.

As stated in the previous section dealing with peak bone mass, environmental factors are helpful to focus on when discussing an increased peak bone mass. Johnell and Hertzman (2006) recommend that to help prevent osteoporosis the focus should remain on leading a healthy lifestyle. This includes participating in physical activity, no smoking, moderate intake of alcohol, and intake of beneficial nutrients such as calcium and vitamin D.

According to a study by Coupland, Wood, and Cooper (1993) there is a relationship between physical inactivity, muscle weakness, and the risk of hip fracture. They tested 197 individuals aged 50 year or older which were located in Newcastle, England. The participants were asked to give information pertaining to five indices of physical activity as defined by the authors:

- Amount of time standing indoors
- Amount of time walking outdoors
- Self-reported walking speed
- Frequency of stair climbing
- Duration of outdoor productive activities

They were also asked to test their grip strength using an isometric dynamometer. Based off the results, Coupland et al. (1993) found that there was a significantly positive association between the grip strength and each of the five indices of activity. This in turn, saw a significant association between increased fracture risks with declining grip strength. They also saw an increased fracture risk when the levels of physical activity decreased. Based off of their findings, they concluded that inactivity is a risk factor for hip fracture.

According to Kim et al. (2012) BMD is reduced by 4% for active smokers as compared to nonsmokers. This is due to the nicotine found in cigarettes which is a known inhibitor of bone formation (Kim et al., 2012). In their study, they chose to enlist 925 nonsmoking postmenopausal Korean women aged 55 years or older who were subjected to second hand smoke (SHS). Their findings concluded that the number of cigarettes consumed at home by cohabitants was associated to an elevated risk of femoral neck and lumbar spine osteoporosis in their participants.

A review of research on effects of alcohol consumption on bone by Sampson (2002) concluded that alcohol has an effect on osteoblasts which slow down bone turnover creating fragile bones. Turner, Rosen, and Iwaniec (2009) studied the effect of alcohol on 3-month-old male Sprague-Dawley rats (n = 18=hypophysectomized and n = 7=controls). The introduction of alcohol (ethanol) was increased based off of a percentage of caloric intake (Ex: Day 11=12%, Day 18=23%, and Day 21=35%). Growth hormone (GH) was introduced to half of the trial patients after Day 8. The results of this study showed that rats, which were growth hormone-deficient, had a low bone formation rate. Rats that had the GH introduced were able to increase their rate of bone formation, and rats that had both GH and alcohol introduced into their system did not have a high bone formation rate. All of these results are presented in figure 5 (Turner et al., 2009).

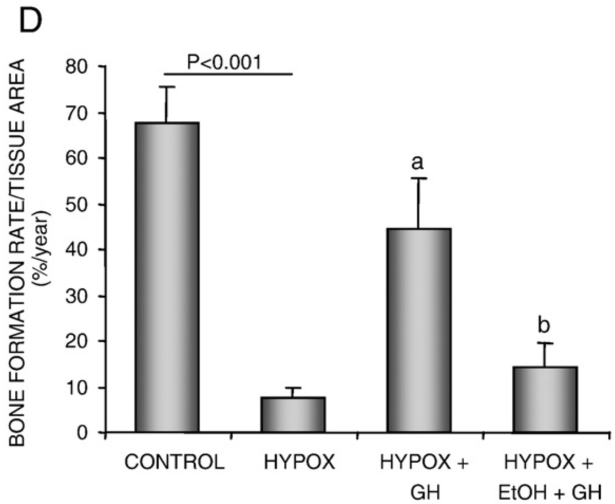

Figure 5: Bone formation rate/tissue area.

Among the inhabitants of the United States aged greater than a year old, the median intake of calcium from all sources (food and supplements) ranges from 918 to 1,296 mg/day (Bailey et al., 2010) as assessed with the 2003-2006 NHANES data. Bailey et al. (2010) listed calcium sources in food such as dairy products (72%), vegetables (7%), grains (5%), legumes (4%), fruit (3%), meat (3%), eggs (3%), and miscellaneous foods (3%). An average of 43% of the US population reported to receive some of their daily calcium intake through supplements (Bailey et al., 2010). The nutrient Vitamin D poses an interesting aspect on intake as it can be synthesized by sunlight in addition to ingestion of foods or supplements. Foods that are natural sources of Vitamin D include fatty fish and egg yolk. Other foods, such as milk, have been fortified to include this important nutrient. Table 1 lists the dietary reference intakes (DRIs) estimated requirements (Ross, 2011).

Table 1

Dietary Reference Intakes (DRIs)

Dietary Reference Intakes (DRIs): Estimated Average Requirements
Food and Nutrition Board, Institute of Medicine, National Academies

Life Stage Group	Calcium (mg/d)	CHO (g/kg/d)	Protein (g/d)	Vit A (µg/d)[a]	Vit C (mg/d)	Vit D (µg/d)	Vit E (mg/d)[b]	Thiamin (mg/d)	Riboflavin (mg/d)	Niacin (mg/d)[c]
Infants										
0–6 mo										
6–12 mo			1.0							
Children										
1–3 y	500	100	0.87	210	13	10	5	0.4	0.4	5
4–8 y	800	100	0.76	275	22	10	6	0.5	0.5	6
Males										
9–13 y	1,100	100	0.76	445	39	10	9	0.7	0.8	9
14–18 y	1,100	100	0.73	630	63	10	12	1.0	1.1	12
19–30 y	800	100	0.66	625	75	10	12	1.0	1.1	12
31–50 y	800	100	0.66	625	75	10	12	1.0	1.1	12
51–70 y	800	100	0.66	625	75	10	12	1.0	1.1	12
> 70 y	1,000	100	0.66	625	75	10	12	1.0	1.1	12
Females										
9–13 y	1,100	100	0.76	420	39	10	9	0.7	0.8	9
14–18 y	1,100	100	0.71	485	56	10	12	0.9	0.9	11
19–30 y	800	100	0.66	500	60	10	12	0.9	0.9	11
31–50 y	800	100	0.66	500	60	10	12	0.9	0.9	11
51–70 y	1,000	100	0.66	500	60	10	12	0.9	0.9	11
> 70 y	1,000	100	0.66	500	60	10	12	0.9	0.9	11
Pregnancy										
14–18 y	1,000	135	0.88	530	66	10	12	1.2	1.2	14
19–30 y	800	135	0.88	550	70	10	12	1.2	1.2	14
31–50 y	800	135	0.88	550	70	10	12	1.2	1.2	14
Lactation										
14–18 y	1,000	160	1.05	885	96	10	16	1.2	1.3	13
19–30 y	800	160	1.05	900	100	10	16	1.2	1.3	13
31–50 y	800	160	1.05	900	100	10	16	1.2	1.3	13

To screen for osteoporosis, one relies on BMD measurements. For BMD measurements, the instrument used to identify high risk individuals is a dual-energy x-ray absorptiometry (DXA) scan. This low-cost, low-risk scan is an important tool utilized by doctors and other health-care providers. Recall Figure 1 in Chapter 1 from the World

Health Organization. The chart defines different levels of bone density expressed in standard deviation (SD) units called T-scores. A DXA report includes the calculated BMD and how the patient‘s BMD measures up to healthy young adult (matched for gender and ethnicity). This number is then reported as a T-score. It is important to discuss that the WHO criteria for T-scores of most areas are not reported if the patient is defined as pediatric (less than 20 yrs old). It's also important to note that "healthy young adult" age is defined as 20-30 yrs old and all matched data is taken from the National Health and Nutrition Examination Survey (NHANES). Another way a patient‘s BMD could be reported is by a Z-score, which is also expressed in SD. Unlike the T-score, the Z-score uses age-matched data, along with ethnicity and gender.

Medicinal treatment for osteoporosis and osteopenia are sometimes sought to combat the effects of the disease. According to the National Osteoporosis Foundation, there are two categories of medicine for osteoporosis: antiresorptive medication or anabolic medication. Antiresorptive medications, which include bisphosphonates, estrogens, selective estrogen receptor modulators (SERMs), calcitonin and monoclonal antibodies (Chen & Sambrook, 2011), help slow the resorption phase of remodeling. Anabolic medications increase the rate of bone formation during remodeling. These medications include strontium ranelate and parathyroid hormone.

Mechanical Loading

As stated previously, maintaining a healthy lifestyle through physical activity could help deter osteoporosis later in life. There are multiple training methods that have been reviewed to obtain their benefit on BMD. Aerobic exercise, resistance training, participation in sports, and recreational activities are all topics that will be discussed in this section.

Aerobic Exercise

The term aerobic is defined as mechanisms that are dependent on oxygen. This type of training could include exercises such as dance, walking, jogging, stair climbing, and bench stepping. According to ACSM (2011), in order for aerobic prescription to benefit the average human one must participate in moderate intensity exercise for 30 min a day, 5 days a week. You could also complete a vigorous intensity exercise for 20-25 min a day, 3 days a week.

Hosny, Elghawabi, Younan, Sabbour, and Gobrial (2012) compared the impact of a caloric restriction diet to one group while restricting calories and adding an aerobic exercise regimen to the second group. Forty obese premenopausal women were recruited and either placed on a decreased caloric diet (decreased calories by 500-1000 kcal/day) labeled as group A, or a decreased caloric diet (same as group A) with the addition of 40 min of walking on a treadmill three times a week, labeled as group B. This regimen lasted 3 months. There were changes between the pre and post BMD measurements of the hip, lumbar spine (LS), and radius for both groups. For the hip, group A decreased 0.05 $g \cdot cm^{-2}$ between the pre and post measurements while group B increased 0.06 $g \cdot cm^{-2}$. For the LS, group A decreased 0.07 $g \cdot cm^{-2}$ between the pre and post measurements while group B increased 0.08 $g \cdot cm^{-2}$. Finally for the radius measurements, both group A and B decreased 0.04 g·cm^{-2} and 0.03 g·cm^{-2} respectively. Hosny et al. concluded that by decreasing body weight for the participants in group A, the BMD in all areas decreased due to lack of their normal mechanical loading that day to day activities placed on them. Group B's BMD increased in weight bearing bones (hip and LS) due to the addition of aerobic exercise that placed unusual strain on their skeletal structure even though their weight had decreased. Finally the radius BMD decreased in both groups, probably due to the lack of upper extremity activities within this study.

Chien, Wu, Hsu, Yang, and Lai (2000) conducted a 24-week aerobic program for osteopenic women. The exercise group, made up of 6 women, were asked to participate in a 50-min exercise session which consisted of alternating treadmill walking and stair stepping three times a week. The control group, including 10 women, were sedentary individuals. BMD values were tested for the LS and the femoral neck (FN). Chien et al. (2000) concluded that the FN BMD had a significant increase of 6.8% in the exercise group as opposed to the 1.5% decrease seen in the control group. At the LS, there was only a slight increase seen for the exercise group (2.0%) but a significant decrease in the control group (2.3%). These results concluded that walking and stair stepping induced enough unusual strain on the neck of the femur which is consistent with the study above. This make since due to the ball and socket mechanism that the FN is a part of. As one takes a step, the head of the thigh bone meets the neck of the femur. This joint is put under stress every time you bear weight. The results of the LS were not consistent with the study above leading this investigator to believe that the strain of walking and stair stepping, without any additional change within the participant's life style, did not meet the MES threshold and therefore did not elicit any gaining affect. This is consistent with the previous study by Nichols et al. (2001) discussed in the introduction. However, the exercise group did deter a significant loss of LS BMD by walking and stair stepping versus their sedentary counterparts who saw a significant decrease.

Finally, Martyn-St James and Carroll (2010) created a meta-analysis of the effects of different impact exercises on BMD in premenopausal women. Nine studies were included in the review; three of those studies used high impact loading with jumping, two studies used group exercise with odd-impact loading, and four studies used circuit/group training with odd-impact loading or high impact loading combined with resistance training/weighted vests. The LS and FN were measured using a DXA scan in all studies. Results found that programs that combined odd or high impact loading with some type of resistance training affected the BMD at both LS and FN areas whereas programs that only introduced high impact loading seemed to have changes in BMD only at the FN. Again, these results are consistent with the previously mentioned studies.

Resistance Exercise

Resistance training (RT) is a method of exercise that produces abnormal force on the skeletal structure through use of machines, free weights, weighted vests, or elastic bands. ACSM (2013) suggests that resistance training should be performed at least twice a week by performing 8-12 repetitions of 8-10 different exercises that target different muscles.

Zhao, Zhao, and Xu (2015) conducted a meta-analysis of the effects of resistance training on prevention of LS and FN BMD in postmenopausal women. Twenty-four studies were included in the review; 14 studies that included only RT and 10 studies that utilized RT combined with other high impact loading or weight-bearing exercise (CRT). The LS and FN were measured using a DXA scan in all studies. The duration of the studies fell between 6 months to 12 years with an exercise frequency of two to three times a week. The overall analysis of both RT and CRT suggested that the addition of resistance training would significantly increase BMD at the LS and FN sites (SD = 0.303 and 0.311 respectively). The subgroup analysis sought to find out if RT or CRT significantly impacted BMD at the LS and FN. For RT with no other protocols, there was no significant effect on preserving BMD (SD = 0.212 and 0.180 respectively). For CRT, the addition of extra loading caused a significant increase on BMD at the LS and FN (SD = 0.411 and 0.431). Based off of the SDs, the BMD gains at the LS and FN could see an increase by 1.9 and 2.4%, respectively, just by combining RT with other high impact loading or weight-bearing exercise.

Shaw and Snow (1998) tested the effectiveness of using a weighted vest while participating in RT. Forty postmenopausal women were split into two groups; the exercise group (n = 18) and the control group (n = 22). The 9-month long study consisted of 60 min, 3 times a week, RT with a weighted vest. RT included stepping, squats, chair raises, lunges (both forward and lateral), and toe raises while wearing the weighted vest. Muscle power, stability, peak force, and BMD were tested. What the authors determined was that the exercise intervention was effective in lowering the possibility of a fall risk, due to the significant changes in muscle power and stability. The exercise group experienced a 30.3% increase in hip adduction, a 16.6% increase in knee flexion, and a 33.3% increase in ankle plantar flexion. However, the effectiveness of preventing fracture risk associated with low BMD was not shown due to the lack of change of BMD at the FN (.683 pre to .684 post). Snow, Shaw, Winters, and Witzke (2000) then extended the premise of their initial study by introducing a long-term design of 5 years while adding high impact jumping while wearing the weighted vest to the original RT regimen. Eighteen women from the original study volunteered to be a part of this new experiment. The exercise group and the control group were split up evenly. Results determined that in all areas of the hip, FN, trochanter, and total hip, the BMD for the exercise group was either increased or maintained (+1.54%, -0.24%, and -0.82% respectively) as opposed to the control group which significantly decreased (-4.43%, -3.43%, and -3.80%). This is consistent with Zhao et al.'s (2015) finding that combined RT seems to be more advantageous when discussing osteogenic stimulus.

Von Stengel, Kemmler, Lauber, Kalender, and Engelke (2007) determined whether the speed of how you completed your RT affected the BMD at the LS and the FN. The resistance training was broken up into two groups; power training (PT) and strength training (ST). No significant difference was seen at baseline for BMD and muscle-strength variables save for the leg press value (ST = 176.9 vs PT = 201.5 kg). Magnitude of the mechanical loading was tested using a force plate.

The PT group showed a higher relative loading magnitude of 16% as compared to the ST group as seen in Figure 6.

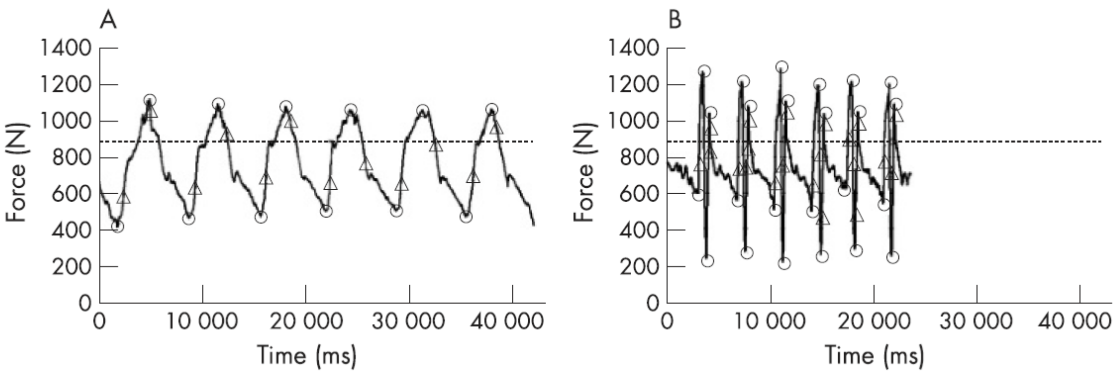

Figure 6: Force-time curves for strength training (A) and power training (B).

At the conclusion of the study, a significant percentage difference was seen at the LS between groups (PT = -0.3%; ST = -2.4%). These results show that when RT's concentric movement is performed as fast as possible (explosively) it can prevent BMD decline as opposed to just loading bone normally.

Sports Specific Activities

When discussing sports activities, it is commonly accepted that some type of strain will be placed on the skeletal structure benefiting bone growth more so than the average individual. For example, Uzunca, Birtane, Durmus-Altun, and Ustus (2005) sought to compare the BMD of retired professional soccer players to characteristically matched control subjects. Twenty-four former players (f) and 25 control (c) subjects were recruited to undergo a DXA scan. The LS and FN were two of the sights to be observed. The authors found that the LS and FN were significantly higher in the retired athletes than the controls (LS: f = 1.223 vs c = 1.048; FN: f = 0.983 vs c = 0.883 g/cm^2) suggesting that being active in sports generates higher osteogenic stimulus than those with no history of an active sports career. Langerndonck et al. (2003) examined how the type of physical activity participated in at adolescence and adulthood contributed to current BMD in 40 year old men. The three categories participants were place in included:

- (HH) High-impact group, n = 18, who participated in sports like basketball, volleyball, and gymnastics during their adolescence and adult years. This group also included moderate impact sports such as tennis and soccer.
- (HN) High-impact/Nonimpact or no sports group, n = 15, who participated in the high-impact sports in their adolescence but then during adulthood either participated in low-impact sports such as jogging or ballroom dancing, nonimpact sports such as biking or swimming, or did not participate in any sports.
- (NN) Nonimpact-no sports group, n = 14, who participated in either nonimpact sports or did not participate in any sports.

Based off of the regression analysis that used body mass, impact scores during adolescence and adulthood and the time spent participating in the sport during both life stages found that the predictors of current BMD include body mass and impact scores only during the adult stages of life. A significant difference of BMD at the LS was seen between the HH group and the HN and NN groups (1.12, 1.01, and 0.99 $g{\cdot}cm^{-2}$

respectively) suggesting that the type of physical activity you participate in impacts your BMD differently at loading sites. The HH group had sustained activity in high and moderate sports well into their adult years, while the other two groups either had switched to a lower impact sport or discontinued their sports participation in general. Because of this, the typical bone loss that is seen after PBM is achieved (at around the third decade of life as stated in Chapter 1's Figure 2) was most likely the reason for the difference seen between the HH group and the NH and NN group.

Soccer versus Other Sports

Soccer has been compared to other sports to see what BMD changes are specific to soccer. McCulloch et al. (1992) sought to compare a weight bearing sport to a nonweight bearing sport. Both males and females were recruited and placed in one of three groups; soccer, selected based on all-star team status, swim, based on national caliber swim team status, and control, of which did not participate in sports activities. The BMD of the trabecular bone was studied and results found that there is a more positive influence on BMD in weight bearing activity than nonweight bearing. The soccer group had the highest trabecular values while the swim group had the lowest, even compared to the control group. Soccer generates abnormal loading on bone as compared to control subjects. This shows that unusual loading from active loading sports (such as soccer) can positively influence bone growth. What this study also shows is that nonweight bearing activity, although benefiting the healthy lifestyle, does not contribute to BMD in a positive way.

Pettersson, Nordstrom, Alfredson, Henriksson-Larsen, and Lorentzon (2000) sought to determine how two different types of high-impact weight-bearing activities, such as soccer and jump roping, effect BMD. The authors compared the ground reaction force for jump roping to that of a basketball rebound, which is 4-6 times their body weight. Soccer's ground reaction force is listed as 3-6 times their body weight. The jumpers showed significant differences in BMD at the TB and LS sites as compared to the controls. The soccer players showed significant differences in BMD at the FN site as compared to the controls. Initially, there was no significant difference found between the high-intensity groups. After testing the subjects, the soccer players had significantly higher lean mass than the jumping group and the controls, and also started their sport-specific training earlier than the jumping group. So taking these results into consideration and adjusting for the differences in these parameters, the jumping group had significantly higher BMD in the TB (6%) and the LS (10.3%). This shows that even though on the surface, high-intensity activities can seem very similar in their osteogenic stimulation of bone, there is potential for an activity to have an effect on your BMD more efficiently than another.

Jallai et al. (2016) sought to compare two high-impact/odd-impact sports; basketball and soccer. They chose these activities due to the lack of comparison between sports that are labeled high-impact. Most studies seek to compare a high-impact versus a low-impact. The researchers used 12 basketball (BB) players and 15 soccer (S) players who were members of their sport appropriate national youth league. Both groups were made up of males who were in adolescence (average of 16 years old). The difference in characteristics between groups were noticeable: basketball players were around 6 ft 1 in tall and weighed close to 178 lbs while the soccer athletes were around 5 ft 10 in and weighed around 146 lbs. They averaged 9.2 hr of training per week. Jallai et al. (2016) hypothesized that because each sport had different technical demands and the athletes had varied anthropomorphic characteristics that there would be significant differences between the groups. Some of the BMD values that were tested included the TB, LS, and right FN. BB values were 1.33, 1.27, and 1.39 $g \cdot cm^{-2}$ respectively while S values were 1.21, 1.10, and 1.25 $g \cdot cm^{-2}$. The significance between these values were .02, .01, and .01 after adjusting for height during the between-groups comparison. There was also a 25-28% difference between the group's upper extremities. Even though the upper extremities are nonweight bearing, BB had a higher BMD value than S. This is probably due to the technical differences seen within sports. BB utilizes their arms during the action of dribbling and shooting along while S, other than the keeper, rarely utilize their extremities.

Background of Soccer

Soccer, or termed football in most countries outside of the United States, is one of the most popular sports in the world. Due to its worldwide popularity it is a good sport to research. Individuals classified within multiple age cycles and both genders have the ability to participate. Soccer focuses on technical skill, tactical knowledge, and physical fitness.

The sport is played with 22 players on the field, with 11 a side. There are different formations that a team can play with their 11 players. Game length can vary depending on the level of competition. For example, a collegiate game consists of two 45-min halves with a halftime that must not exceed 15 min (FIFA, 2016). According to Stolen, Chamari, Castagna, and Wisloff's "Physiology of Soccer" (2005), an elite-level player can run close to 6 miles per game at an average intensity of 80-90% of maximal heart rate. But the overall physiological demands for soccer vary with each position. Positions are broken up into classifications such as forwards, midfielders, defenders, and goalkeepers. Stolen et al. also state that professional players cover longer distances than nonprofessionals. The main difference was that the frequency of standing was significantly higher with nonelite players when compared to elite players. This was studied using time-motion analysis.

Summary

The need to reach one's optimum PBM to offset the risk for osteoporosis later in life is an important goal to strive for. The window for most change to PBM is during puberty, however staying active through one's adolescent years and through adulthood has shown to have beneficial effect on BMD. Different methods of loading have shown either positive osteogenic gains or prevention of loss however there is little research on what competition level is necessary to continue these osteogenic benefits. The purpose of the current study was to decide whether a higher level of competition was associated with a higher BMD at the TB, LS, and FN (both right and left) in female soccer players.

CHAPTER III

METHODS

A DXA was used to measure BMD to better understand whether the competition level of physical activity makes a difference on bone mineral density of two different classifications of female soccer players. The methods of this study are described in the following four sections: Participants, Instruments, Procedures, and Data Analysis.

Participants

A total of 22 current multicultural female college students who attend Texas Woman's University and who participate in two different levels of soccer were recruited for this study (14 participants are current members of the NCAA Division II soccer team and 8 participants are current members of the club soccer team). Approval for this study was obtained from the Texas Woman's University Institutional Review Board prior to the start of this study (Appendix A). Each participant gave her written informed consent prior to any collection of data. A copy of the consent form can be found in Appendix C.

Athletes were selected based on their current sport participation status. Each participant was required to have at least 3 years of playing experience in soccer which was confirmed by the short survey completed during the recruitment process. All athletes were required to have at least 4+ hr of practice and/or game situations per week during the respective season. All potential participants were excluded if they currently had any injuries or health problems or were pregnant.

Instruments

Participants were asked to consent to a one-time visit to the Pioneer Performance Center in the Human Development Building Suite 017 on the campus of Texas Woman's University. The visit lasted approximately 20 min. The data for the questionnaire and the DXA were collected in the early spring.

Questionnaire

All participants were asked to complete a short questionnaire, developed by the investigator, defining their typical training program for soccer. A copy of the questionnaire can be found in Appendix F. The questionnaire included information defining training frequency, typical exercises completed during practice, and voluntary participation in exercise outside of normal soccer practices. The recalled workout summation for each participant was corroborated by the coaching staff or club supervisor.

Anthropometric Measurements

Measurements for each participant included basic anthropometry (height and weight) using a wall-mounted stadiometer that displayed both inches and centimeters and a digital scale.

Dual Energy X-Ray Absorptiometry

Scans of the total body (TB), both femoral necks (FN), and lumbar spine (LS; L1-L4) was taken using a GE Lunar Prodigy DXA scanner to measure areal BMD (g/cm^2). The DXA is central bone densitometer rather than peripheral meaning it measures spine and hip bone density rather than forearm and tibia. The DXA has a large, flat table top where participants lie. There is an "arm" suspended overhead that is the detector (imaging device) while an x-ray generator is located below the participant within the table. The arm and the generator move together to scan a patient by sending a thin, invisible beam of low-dose x-rays through soft tissue and bone. Quality control was maintained throughout testing by adhering to the recommendations by the International Society of Clinical Densitometry.

Procedures

Questionnaire

The short questionnaire was administered by the lead investigator to the club players during an information session. The investigator allowed sufficient time for participants to fill out the questionnaire to the best of their ability. Once the questionnaires had been turned in, the investigator corroborated answers with the club president. The questionnaire was then administered to the current collegiate soccer team prior to a scheduled practice. The investigator collected the papers and confirmed the validity of the answers with the head soccer coach.

Anthropometric Measurements

The participants were asked to remove their shoes during the height and weight measurements. Participants stood underneath the sliding platform facing away from the stadiometer. Their heels were pressed against the wall, and participants were asked to look forward with their chins parallel to the floor. The height measurement was then taken. The participants were then asked to stand on the digital scale while keeping their weight even between both legs, looking forward, and holding their arms next to their torso while weight was recorded.

Bone Mineral Density

Participants were asked to remove all jewelry and shoes prior to lying down on the Prodigy scanner. Once in the supine position, with the cranium positioned at the head of the machine, the participants were asked to pronate their hands beside their bodies. For the TB scan the technician then velcroed the ankles together and checked that the body was positioned within the scanning perimeter. Once the participant's eyes were closed, the scan was started.

Once the total body scan was completed, the arm of the Prodigy scanner was positioned over the LS. To make sure the picture started in the middle of L5, the cross-hairs of the scanner were placed 3 cm below the individual's belly button. The Velcro securing the ankles was removed. Participants were asked to cross their arms over the chest, then the scan was started. Finally, for the FN scan, the arm of the Prodigy scanner was positioned over the thigh of the participants. The technician measured, with her hand, from the top of the pelvic bone, one finger length down and positioned the cross-hairs medially. Participants continued to keep their arms crossed over their chest. A metal triangle with Velcro straps was placed between the feet and feet were secured to the triangle, with the heel of the foot placed on the mat of the scanner, and their knees turned slightly inward. The scan was then run. Once the left FN was scanned, the arm of the prodigy scanner automatically positioned itself over the right FN and another scan was run. Once all four scans (TB, LS, FN both left and right) were complete, the arm of the Prodigy scanner was sent home and the participant was unstrapped and allowed to sit up.

On the computer, the ROIs, or regions of interest, of the TB scan were adjusted to fit snuggly next to the spine and the ribcage, the horizontal lines were adjusted to be just below the cranium and just above the pelvis. The lines of the legs were adjusted to run through the FN. The ROIs of the spine were adjusted to dissect the vertebrae. The ROIs of the FN were adjusted to fit within the FN region. Once these adjustments had been made, the results for each participant were formulated. Lean and fat mass of each participant was also measured with the DXA scanner. The same technician conducted and analyzed all scans.

Data Analysis

The statistical program used was IBM SPSS version 19 for Windows. Descriptive statistics were calculated to provide means, standard deviations, and ranges for age and height. Participants' BMD were compared with one-way analysis of variance (ANOVA). Significance level was set at .05.

CHAPTER IV

RESULTS

The purpose of this study was to investigate whether a higher level of competition was associated with a higher BMD in female soccer players. Four one-way ANOVAs were performed to determine any significant differences between the two groups at the total body, lumbar spine, and the femoral neck (left and right). The data analyzed in this study are discussed under the following headings: (a) Description of the Participants, and (b) Testing the Hypothesis

Description of the Participants

A total of 22 students (all female) participated in the study. The NCAA group consisted of 14 females who were current members of the Texas Woman's University NCAA Division II Collegiate Team. The Club group consisted of 8 females who were current members of the Texas Woman's University Pioneer Soccer Club. The ethnic diversity of the participants is presented in Table 2.

Compliance of the DXA testing was 100%. The scans were scheduled during time slots between February 18^{th} and February 25, 2016. Average time for scans was 14 min (6 min for TB, 4 min for LS, and 4 min for FN) and completing the ROIs by the technician took another 4 min. Results were discussed once the scan was analyzed by the software, and the participants were able to keep a copy of their scan. Table 2 describes the descriptive statistics for both groups in the categories of age, height, and weight. The average age of the participant was 19 years, 9 months old, while the average height in inches and weight in pounds were 64 in. and 139 lbs, respectively.

Table 2

Mean (SD) Values for Participant Characteristics

Variable	NCAA Team (n=14)	Club Team (n=8)	All Participants (n=22)
Age (years)	20.0 (1.0)	19.7 (0.8)	19.9 (0.9)
Height (in.)	64.3 (2.6)	63.8 (3.9)	64.1 (3.1)
Weight (lbs)	133.6 (14.8)	149.8 (31.9)	139.5 (23.2)
Ethnicity (percentage)			
Caucasian	57%	37.5%	50%
Hispanic	36%	62.5%	45%
African American	7%	0%	5%
Lean Mass (lb)	94.3 (12.1)	94.2 (18.8)	94.2 (14.5)
Fat Mass (lb)	37.9 (7.2)	57.4 (19.5)	45.0 (15.8)

Participants completed a short questionnaire defining their typical training program for soccer. Results are presented in Table 3.

Participants were asked to describe their typical training session:

- The description of activities for the collegiate team included a warm up, skill drills, possession, and finishing with a scrimmage.
- The description of activities for the club team included running laps, dribbling, possession, and finishing with a scrimmage.

Participants were asked to describe their extra exercise session:

- The collegiate team also participated in other exercise such as running, weights and strength training, core, zumba, volleyball, and yoga.
- The club team participated in other exercise such as running, weights and strength training, core, and yoga.

Table 3
Questionnaire Answers

Questions	NCAA Team (n = 14)	Club Team (n = 8)
How often do you train or practice soccer?		
Every Day	1	0
5-6 x week	13	1
3-4 x week	0	7
Length of typical soccer training session?		
1 hr	0	0
2 hr	14	7
3 hr	0	1
More than 3 hr	0	0
Less than 3 hr	0	0
Participate in other exercise?		
Yes	12	5
No	2	3
How many times a week do you participate in other exercise?		
Every Day	0	0
5 or 6 x week	1	1
3 or 4 x week	6	1
Fewer than 3 x week	5	3
Length of typical outside exercise session?		
1 hr	11	4
2 hr	1	1
3 hr	0	0
More than 3 hr	0	0
Less than 3 hr	0	0

Testing the Hypothesis

A one-way analysis of variance (ANOVA) was used to determine if any difference in BMD existed between the NCAA and Club group. Statistical Packages for the Social Sciences (SPSS) 19 was used to check the assumptions.

The results of the one-way ANOVA for TB, LS, FN (right and left) bone mineral density are presented in Tables 4, 5, 6, and 7. No significant differences were found between the NCAA and the Club groups. Bar graphs of the results are presented in Figures 7 and 8. For the NCAA group the mean TB, LS, FNR and FNL BMD were as follows: 1.251, 1.373, 1.186, and 1.19 g/cm². For the club group the mean TB, LS, FNR, and FNL BMD were: 1.202, 1.278, 1.147, and 1.156 g/cm².

Table 4

ANOVA Summary Table for Total Body Bone Mineral Density

	Sum of Squares	df	Mean Square	F	p
Between Groups	0.012	1	0.012	1.423	.247
Within Groups	0.17	20	0.009		
Total	0.182	21			

Table 5

ANOVA Summary Table for Lumbar Bone Mineral Density

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.047	1	0.047	2.353	.141
Within Groups	0.396	20	0.020		
Total	0.443	21			

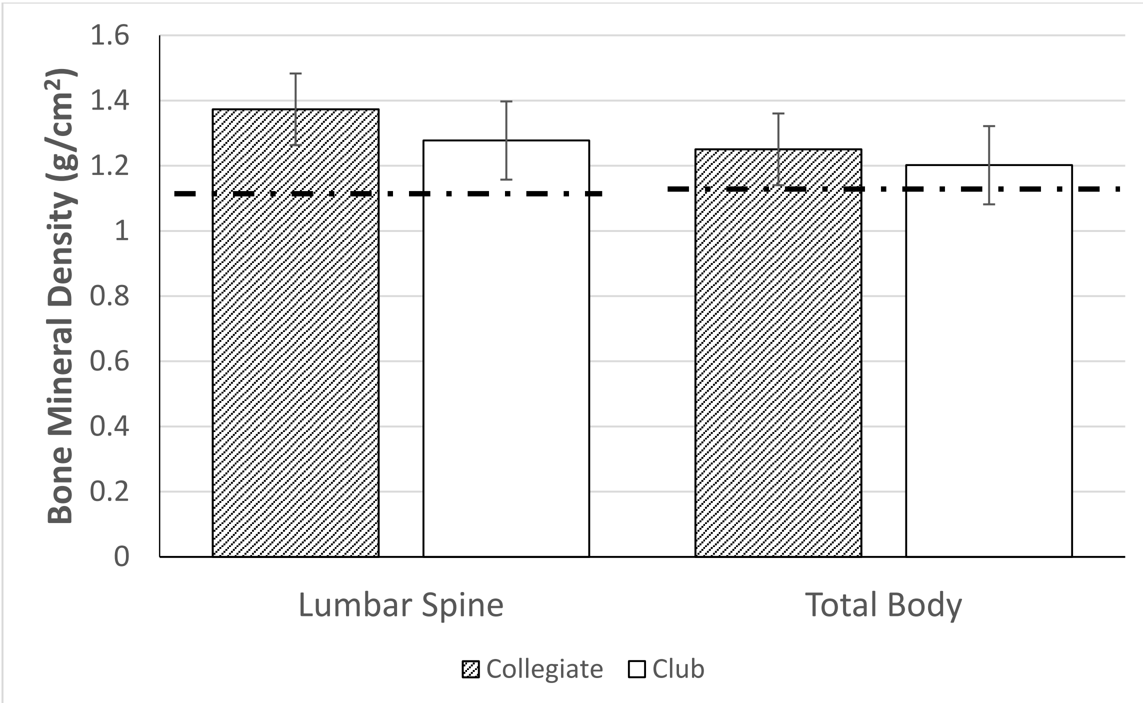

Figure 7: Mean (SD) for total body and lumbar spine
*Dotted lines represent the population normal BMD values for each site

Table 6

ANOVA Summary Table for Right Femoral Neck Bone Mineral Density

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.007	1	.007	.448	.511
Within Groups	.332	20	.017		
Total	.340	21			

Table 7

ANOVA Summary Table for Left Femoral Neck Bone Mineral Density

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.006	1	.006	.331	.572
Within Groups	.356	20	.018		
Total	.362	21			

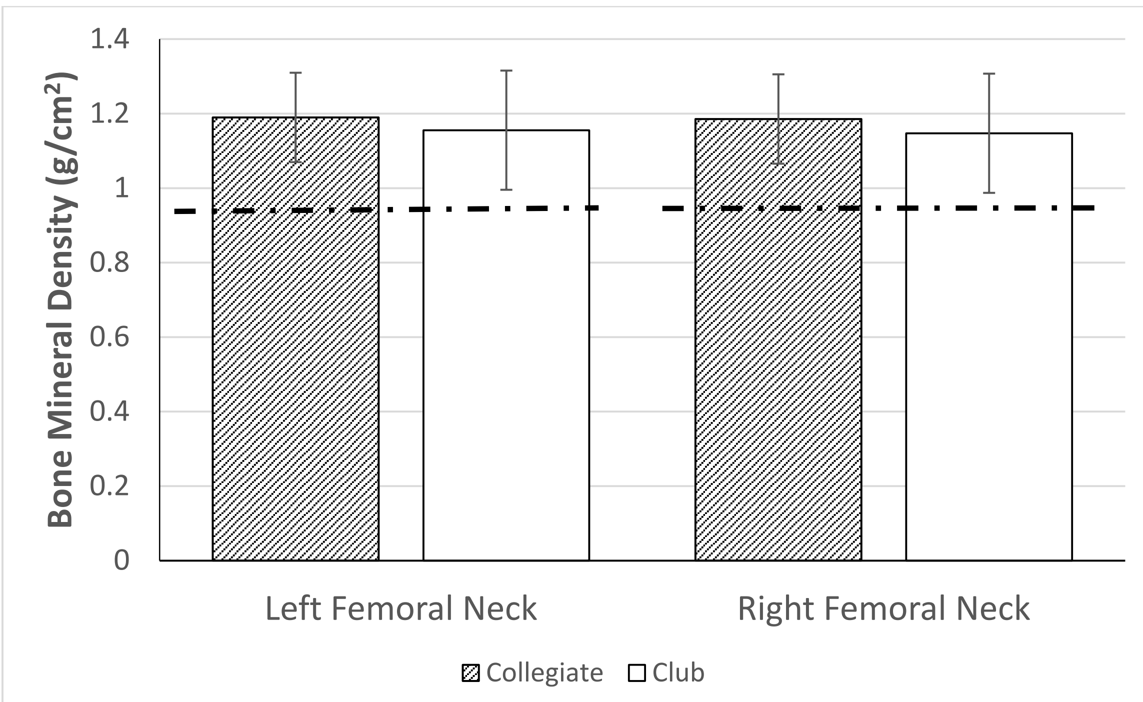

Figure 8: Mean (SD) for both left and right femoral neck
*Dotted lines represent the population normal BMD values for each site

CHAPTER V

DISCUSSION

The purpose of this study was to decide whether a higher level of competition was associated with a higher BMD in female soccer players. The results of this study are discussed in this section under the following headings: (a) Summary, (b) Discussion, (c) Conclusion, (d) Recommendations for Further Studies.

Summary

A total of 22 female soccer players (14 collegiate and 8 club) participated in the study. The ethnic diversity of the participants was approximately 50% Caucasian, 45% Hispanic, and 5% African American.

Anthropometric measurements (age, height, weight, lean mass, and fat mass), bone mineral density (total body, lumbar spine, and both femoral necks), and questionnaires (physical activity within soccer and other than soccer) were recorded. The majority of the NCAA group trained 5-6 times a week while the club group trained 3-4 times a week. The typical length was two hours per training session for all participants. For the NCAA group, 86% participated in outside exercise as opposed to 63% of the club members. The typical length for the outside exercise was an hour and the most commonly referenced activities were strength training and running. Compliance rate of participants who followed through with testing was 100%. Average time for scans was

14 min (6 min for TB, 4 min for LS, and 4 min for FN) and completing the ROIs by the technician took another 4 min.

The dependent variable, bone mineral density (BMD), was measured using a GE Lunar Prodigy DXA scanner. Analysis of variance was performed on all three dependent variables (total body, lumbar spine, and both femoral necks). Descriptive statistics were performed on height, weight, age, lean mass, fat mass, total body BMD, lumbar spine BMD, left femoral neck BMD, and right femoral neck BMD.

The hypothesis is that playing for an NCAA team is expected to generate a higher BMD than playing for a club team. The null hypothesis is that playing for an NCAA team or a club team will show no difference in the amount of BMD. After analysis of the data ($p \leq .05$), the null hypothesis cannot be rejected.

Discussion

The aim of this study was to see if there was notable difference in BMD at specific loading sites between NCAA players and club players at the collegiate level. The amount of literature that investigates the level of competition and its effects on BMD is limited, and therefore this research is an important step towards determining whether one should consider an activity's competition level when choosing a method of exercise.

The basis of this study chose to compare different levels of the same activity, soccer, in hopes that the supposed difference within competition in each organization would generate a difference in BMD at specific sites. However, the competition level of physical activity of groups resulted in no significant difference in BMD of total body, lumbar spine, or both femoral necks. Overall, both organizations, the NCAA team and the club, specified on the questionnaire that the typical length of training was 2 hr long, but the NCAA team trained more days a week than the club team- 5-6 times a week versus 3-4 times a week. Kemmler and Von Stengle (2014) sought to determine how frequent an exercise session should be conducted to see positive effects on BMD. They enlisted 41 postmenopausal females that were placed in two groups based on the frequency of their exercise session: low-frequency exercise group (LEF-EG) consisting of 16 women and the high-frequency exercise group (HEF-EG) consisting of 25 women. They also tested 44 nonactive women and placed them in the control group (CG). The investigators monitored the frequency of exercise for 12 years. At baseline there were no significant differences seen in anthropometric measurements or in BMD at the LS and total hip (TH). The exercise intervention consisted of a warm-up or endurance section, jumping, and resistance exercise. The follow up after 12 years showed that the changes at the LS in the HEF-EG were not significant (1.1 ± 4.7%) and the TH significantly decreased (-4.4 ± 3.9%). For the LEF-EG significant decreases at both sites were seen (LS: -4.1 ± 3.0%; TH: -6.7 ± 3.5%). Overall, more favorable changes were seen in the HEF-EG than the LEF-EG. However, between the LEF-EG and the CG, there were no significant differences. These findings led investigators to believe that the minimum effective frequency should be at least two times a week. For the current study, both groups (NCAA and Club) surpassed this recommendation. This could lead this investigator to conclude that no differences were seen between groups because both groups surpassed the recommended frequency.

Bemben and Bemben (2011) not only tested whether changes in frequency would lead to changes in BMD, but whether the intensity could be a factor. They placed 124 men and women into four different exercise groups: high intensity (80% 1RM)-2 days/week (n = 31); low intensity (40% 1RM)-2 days/week (n = 34); high intensity (80% 1RM)-3 days/week (n = 24); low intensity (40% 1RM)-3 days/week (n = 35). After the 40 week resistance training intervention, there were significant BMD time effects for all training groups combined at the LS, trochanter, and total hip. However there were no interaction effects at these BMD sites as the four training groups had similar responses to the intervention (0.5 to 1% increases in BMD). These findings did not support the Bemben et al. (2011), hypothesis that higher intensity or frequency would lead to greater increases in BMD. All groups were found to have improved BMD regardless of the intensity or frequency. This could lead this investigator to conclude that the intensity does not significantly affect one's BMD as long as the same or similar activities are being performed.

Of the NCAA members, 85% participated in outside exercise while 63% of the club team trained outside of soccer. Zhao, Zhao, and Xu (2015) conducted a meta-analysis of the effects of resistance training on prevention of LS and FN BMD in postmenopausal women. When discussing the overall effect of resistance training (including studies with combined RT and other high impact loading protocol) there was a significantly positive change in both BMD sites, however when running a subgroup analysis, only the RT combined with other exercise protocols generated a significant effect on LS and FN BMD.

Strengths of the current study included its high compliance rate and ease of implementation. The compliance rate was 100%. Conducting the BMD scans on campus allowed participants the ease and flexibility to be tested during their daily schedule.

Because there were no significant differences seen between NCAA and club participants at any sites, one could conclude that despite the variation for days trained and involvement in outside exercise, these interventions were not enough to create a difference in BMD. There is a possibility that the difference in anthropometric measurements, specifically weight, could have created an environment that allowed for increased loading even though there is a noticeable difference in competition level. The average weight for the NCAA participants was 133.6 lbs versus the club players who weighed an average of 149.8 lbs. Peak ground reaction forces are thought to be 1-1.5 times body weight (BW) when walking and 2-3 times BW when running (Nilsson & Thorstensson, 1989). Because the club players were overall heavier, the ground reaction forces (GRF) would be greater. The higher GRF of the club player versus the NCAA player and the higher competitive level of the NCAA player versus the club player could attribute to the similar BMD of both groups in the current studies' findings.

Tucker, Strong, LeCheminant, and Bailey (2015) sought to study how two different prescribed jumping programs would affect hip BMD. They placed 60 premenopausal females into three different categories: control group (CG; n = 23), jump 10 group (J10; n = 23), and a jump 20 group (J20; n = 14). For the J10 group, they were asked to complete 10 jumps twice daily, six days out of the week, for 16 weeks. For the J20 group, the protocol was the same except for the number of jumps performed at a time (20). Both groups had a 30 s rest in-between jumps. The CG was asked to perform stretches six days out of the week. Data was collected at baseline, 8 weeks post, and 16 weeks post. There were no significant differences seen between groups at baseline for hip BMD: CG was 0.907, J10 was 0.935, and J20 was 0.915 g/cm². Controlling for all covariates (age, weight change, and calcium intake), at 8 weeks post, hip BMD was significantly different between the prescribed exercise groups and the controls ($F = 1.15$, $p = .0396$). At 16 weeks post, there were significant differences across the prescribed exercise groups and the controls again ($F = 7.39$, $p = .01$). The J20 group increased their hip BMD by .51% while the J10 group increased .55%. The CG group showed a negative change of 1.30% in hip BMD. This data concludes that since there is no significant change between prescriptions, the amount of jumping (10 times versus 20 times) does not significantly impact BMD. The investigators also took into account GRF. The J10 and J20 groups were shown to have GRFs of 3.8 and 4.0 times BW respectively. These findings could help explain why there was not a difference seen between participants in the current study. Even though the level of competition is different between the NCAA and club group, they were performing the same activities. Just as with Tucker et al., even though there were differences in amount of jumps between groups, there was still no significant difference at the hip BMD between groups.

McKay et al. (2005) measured how 12 types of jumps affected the ground reaction forces in elementary school children. Both counter movement jumps and drop jumps created a GRF 5 times BW while jumping jacks produced a GRF 3.5 times BW. Alternating foot jumps only created a GRF of 2 times BW. From this data, one could generalize that the “higher impact” jumps created a higher GRF. However in a study by Milgrom et al. (2000) it was found that higher impact exercise such as jumps from greater heights did not cause a higher strain in the tibia. Thus the overall effects of GRF on BMD is not entirely clear, but it is possible the higher GRF in the club group in the present study offset their lower level of competition and resulted in similar BMD values compared to the NCAA group

Barela, deFreitas, Celestino, Camargo, and Barela (2014), conducted a study to see the effects of body weight unloading on ground reaction forces (GRF). They had participants use a body weight support (BWS) system while walking on force plates. The participants were connected to the system with 0, 15, and 30% BWS. As the BWS percentage increased, the GRF decreased.

Dietary intake, menstrual cycles, and lifestyle choices were not taken into consideration for the present study. These factors could have impacted the findings of the study. Since BMD is estrogen dependent, those participants who suffer from amenorrhea could have skewed the results. The “female athlete triad” is a known term in the female athletic realm and deals with menstrual irregularity and bone loss. Those sports defined as “lean-build,” such as gymnastics and dance, have regularly been associated with this condition; however, sports like soccer have not been categorized as such. There is little data within the soccer community on the prevalence of amenorrhea within the sport. This seems interesting as soccer is the most played sport in the world. Prather et al. (2016) conducted a study which included 220 elite female soccer athletes from the youth club, NCAA DI, and professional levels. Out of these athletes, 19.3% were classified as having menstrual dysfunction (categorized by this study as missing three menstrual cycles within a 12-month period) although the percentages were similar between the different levels of soccer. This would have been an important covariate to explore within this study based on the effects menstrual irregularity has on bone heath. Bemben, Buchanan, Bemben, and Knehans (2004), stated that levels of estrogen are linearly related to BMD. So lack of estrogen exposure, as seen within amenorrhic females could result in decreased BMD. However, during their study of an impact loading sport (gymnastics) versus an active loading sport (long-distance running) there were no significant differences in BMD at the TB, LS, or FN between athletes who were labeled as eumenorrheic or athletes with a dysfunctional menstrual cycle. They did find a significantly higher levels of BMD ($p < .05$) at all tested sites for the gymnasts than the runners stating that the differences seen are due to the type of mechanical loading seen within the impact loading group.

Limitations of the present study include the number of participants used. Because the selection size is small, the findings might not be suitable to compare to the general population. This study should also have gauged “perceived effort” for each participant and defined what the levels could be. This would have allowed more speculation on the training environment once the data had been analyzed.

Conclusions

In conclusion, the level of competition does not appear to affect BMD. Even though the NCAA group trained more days out of the week and competed at a higher level than the club group, the BMD at the TB, LS, and right and left FN sites did not significantly differ. Studies such as Tucker et al. (2015) and Bemben et al. (2011), where there were no significant differences in BMD seen between groups even with differing exercise prescriptions, support the findings of this study.

Recommendations for Further Studies

The following are recommendations for further research in comparing the level of competition and how it affects bone health:

1. Including different levels of the collegiate game such as NCAA I, II, and III.
2. Studies performed where dietary intake and maturation are included.
3. Studies using other mechanisms such as pQCT to evaluate changes or differences in other bone parameters such as cross-sectional area or section modulus (a measure of bone strength).
4. Assess level of menstrual cycle disturbance.

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APPENDIX A

IRB Approval

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: January 23, 2015

TO: Ms. Megan Matteck
Kinesiology

FROM: Institutional Review Board - Denton

Re: Approval for Does Plyometric Exercise Increase Bone Mineral Density? (Protocol #: 17812)

The above referenced study has been reviewed and approved at a fully convened meeting of the Denton Institutional Review Board (IRB) on 9/5/2014. This approval is valid for one year and expires on 9/5/2015. The IRB will send an email notification 45 days prior to the expiration date with instructions to extend or close the study. It is your responsibility to request an extension for the study if it is not yet complete, to close the protocol file when the study is complete, and to make certain that the study is not conducted beyond the expiration date.

If applicable, agency approval letters must be submitted to the IRB upon receipt prior to any data collection at that agency. A copy of the approved consent form with the IRB approval stamp is enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. A copy of the signed consent forms must be submitted with the request to close the study file at the completion of the study.

Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any adverse events or unanticipated problems. All forms are located on the IRB website. If you have any questions, please contact the TWU IRB.

cc. Dr. Charlotte (Barney) Sanborn, Kinesiology
Dr. David Nichols, Kinesiology
Graduate School

APPENDIX B

IRB File Closed

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: March 29, 2017

TO: Ms. Megan Matteck
Kinesiology

FROM: Institutional Review Board - Denton

Re: File Closed for Does a Soccer Player's Level of Competition/Intensity Have an Effect on Bone Mineral Density? (Protocol #: 17812)

The TWU Institutional Review Board (IRB) has received the materials necessary to complete the file for the above referenced study. As applicable, agency approval letter(s), the final report, and signatures of the participants have been placed on file. As of this date, the protocol file has been closed.

IRB records will be stored for four (4) years from this file closed date.

cc. Dr. David Nichols, Kinesiology
Graduate School

APPENDIX C

Participant Consent Form

TEXAS WOMAN'S UNIVERISTY
CONSENT TO PARTICIPATE IN RESEARCH

Does a Soccer Player's Level of Competition/Intensity have an effect on Bone Mineral Density?

Principal Investigator:
Megan Matteck
Phone (o): 940-898-2884
E-mail: mbibilone@twu.edu

Approved by the
Texas Woman's University
Institutional Review Board
Approved: September 5, 2015

Faculty Advisor:
David Nichols, Ph.D.
Phone (o): 940-898-2575
E-mail: dnichols@twu.edu

Purpose:

This study, to be used for the principal investigator's thesis completion, serves to analyze the bone mineral density for NCAA (National Collegiate Athletic Association) female soccer players versus collegiate club soccer players and to provide insight on whether or not participating in different levels of competition in the game of soccer can have an effect on your bone mineral density (BMD) at specific loading sites.

Procedures:

Your bone mineral density (BMD), or the amount of minerals within an area of bone, will be tested. This will be done by using a duel-energy x-ray absorptiometry (DXA) scan, which is a means of measuring BMD, conducted by a certified DXA technician. Results will be obtained from the Institute for Women's Health in the Exercise and Sports Nutrition Clinic.

You will also be asked to complete a survey that will have you describe your typical training program. These results will be corroborated by the coaching staff /club supervisor.

Time Commitment:

The appointment to scan your whole body BMD, your lumbar spine (L1-L4), and right femoral neck (FN) will last approximately 40 mins. It should take approximately 10 mins to complete the survey.

Risk:

RISK	STEPS TO MINIMIZE RISK

Initials_______

Radiation Exposure	There is no way to minimize the risk of radiation exposure for you, but the amount of exposure will be minimal. A DXA scan is associated with radiation exposure similar to watching television for 4 days. The radiation exposure is exponentially less than a chest x-ray.
RISK	STEPS TO MINIMIZE RISK
Loss of Anonymity	You will be forewarned about your loss of anonymity because of a soccer team's group setting. You will be asked to maintain each other's privacy.
RISK	STEPS TO MINIMIZE RISK
Coercion	Your participation will be voluntary. Whether or not you choose to participate in this study will not affect your status on the soccer team.
RISK	STEPS TO MINIMIZE RISK
Loss of Time	Research procedures will be done at a time convenient for you. All research procedures will be conducted as efficiently as possible to minimize the amount of time.
RISK	STEPS TO MINIMIZE RISK

Approved by the
Texas Woman's University
Institutional Review Board

Approved: September 5, 2015

Initials_______

Loss of Confidentiality	All health sensitive material will be coded as much as possible by assigning each participant with a three digit number. The PI will store everything in a locked file cabinet with limited access. Nothing health related will be sent electronically. All data kept within the filing cabinet of the PI will be destroyed by shredding within 5 years from the end of the study. All bone density data is collected via a computer and the database is on a secure network available only by password; again this data will be coded with the three digit number assigned to each participant. You will be allowed to withdraw from the study at any time. There is a potential risk of loss of confidentiality in all email, downloading, and internet transactions. Confidentiality will be protected to the extent that is allowed by law.

The researchers will try to prevent any problem that could happen because of this research. You should let the researchers know at once if there is a problem and they will help you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

INFORMED CONSENT

You will be given a copy of this signed and dated consent form to keep. If you have any questions about the research study you should ask the researchers; their phone numbers are at the top of this form. If you have questions about your rights as a participant in this research or the way this study has been conducted, you may contact the Texas Woman's University Office of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu.

Signature: ________________________________ Date: ____________________

If you would like a copy of the results of this study, please provide the following information:
Name: ____
Address:____
City/St:____
Zip:_____________

Approved by the
Texas Woman's University
Institutional Review Board

Approved: September 5, 2015

APPENDIX D

Anthropometric and BMD Data

PARTICIPANT	AGE (yr)	HEIGHT (in)	WEIGHT (lbs)	LEAN MASS (lbs)	FAT MASS (lbs)	TB BMD (g/cm²)	LS BMD (g/cm²)	LeftFN BMD (g/cm²)	RightFN BMD (g/cm²)
010	19	66	142	102.44	36.31	1.252	1.271	1.214	1.205
011	19	67.5	141	90.63	45.30	1.302	1.480	1.282	1.243
012	20	64	153	111.1	38.6	1.242	1.197	1.336	1.308
013	21	65	140	97.5	43.0	1.277	1.487	1.175	1.194
014	20	60	123	84.5	34.5	1.203	1.347	1.135	1.180
015	21	63	133	98.2	31.0	1.298	1.413	1.146	1.143
016	21	64	112	83.1	29.3	1.168	1.261	1.139	1.087
017	18	65	135	99.88	30.87	1.383	1.349	1.390	1.400
018	19	61	150	100.78	45.59	1.303	1.659	1.236	1.265
019	19	63	120	85.34	35.03	1.149	1.397	1.016	1.012
020	20	61	116	75.1	42.9	1.164	1.163	0.951	0.959
021	19	67	145	112.45	37.05	1.426	1.528	1.300	1.253
022	20	64	110	75.0	28.4	1.136	1.241	1.205	1.223
023	18	69	150	103.5	53.02	1.206	1.433	1.131	1.125
301	19	63	101	69.42	26.96	1.115	1.123	1.054	1.082
302	19	68	183	111.4	71.67	1.295	1.359	1.432	1.462
303	20	60	124	81.1	39.8	1.087	1.271	1.016	1.069
304	19	64	155	93.37	64.13	1.167	1.113	0.945	0.993
305	19	57	160	83.55	82.31	1.225	1.191	1.107	1.083
306	20	65	140	93	51	1.204	1.532	1.250	1.112
307	18	69	200	129.87	76.99	1.390	1.388	1.253	1.280
308	20	64	135	91.9	46.4	1.132	1.244	1.187	1.097

*Participant numbers beginning with 0 are NCAA players while participant numbers beginning with a 3 are club players.

APPENDIX E

Physical Activity Questionnaire

Date: Name: Training Survey: Defining the participant's typical training program for soccer.

Please take a moment to complete the following survey

1. How often do you train/practice soccer?
   - ☐ Every day
   - ☐ 5 or 6 times a week
   - ☐ 3 or 4 times a week

2. How long does a typical soccer training session last?
   - ☐ 1 hour
   - ☐ 2 hours
   - ☐ 3 hours
   - ☐ More than 3 hours
   - ☐ Less than 3 hours

3. Please thoroughly describe a typical soccer training session (drills and conditioning):

4. Do you participate in other exercise not associated with your typical soccer training session?
   - ☐ Yes
   - ☐ No

5. If question #4 was yes, state how many times a week do you participate in extra exercise?
   - ☐ Every day
   - ☐ 5 or 6 times a week
   - ☐ 3 or 4 times a week
   - ☐ Fewer than 3 times a week

6. If question #4 was yes, how long does a typical training session last?
   - ☐ 1 hour
   - ☐ 2 hours
   - ☐ 3 hours
   - ☐ More than 3 hours
   - ☐ Less than 3 hours

7. If question #4 was yes, please thoroughly describe a typical training session.

Thank you for your participation!

This information has been corroborated by the soccer coaching staff/club supervisor.

Signature: ______________________