THE RELATIONSHIP OF BONE MINERAL DENSITY AND A VARIETY OF FITNESS PARAMETERS IN COLLEGIATE FEMALE ATHLETES

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A Thesis

Submitted to

The Graduate Faculty of

Auburn University Montgomery

In Partial Fulfillment of the

Requirements for the Degree of

Master of Education

Montgomery, Alabama

August 12, 2014

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August 2, 2014

Date of Graduation

ACKNOWLEDGEMENTS

I would like to thank all of the faculty and staff in the AUM departments of Kinesiology and Education. Each one of you has played a vital role in assisting and encouraging me throughout my master's program. I would not be where I am today if it weren't for each one of you. I would like to extend a special thank you to Dr. Michael Esco, Dr. George Schaefer, Dr. Erin Reilly, and Dr. Henry Williford for all of your support, guidance and encouragement. I am indebted to each one of you for challenging me to strive for excellence every step of the way. I would also like to acknowledge my fellow graduate assistants in the Human Performance Lab, both past and present. This study would not have been possible without your assistance. It has truly been my pleasure working with you. In addition, I would like to express my gratitude to all of the athletes and coaches who took part in this study. The effort and time that you put into the data collection process is greatly appreciated. And finally, thank you to all of my friends and family who have been a constant support system for me as I pursued this degree. Your love and encouragement is irreplaceable.

Journal format used: Journal of Strength and Conditioning Research

Computer software used: Microsoft Word, Microsoft Excel

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LIST OF ABBREVIATIONS

BMD	Bone Mineral Density
tBMD	Total Bone Mineral Density
sBMD	Bone mineral density at the spine
lBMD	Bone mineral density of the legs
aBMD	Bone mineral density of the arms
BMC	Bone Mineral Content
PBM	Peak Bone Mass
BMI	Body Mass Index
BM	Body Mass measured in kilograms
FFM	Fat Free Mass
FM	Fat Mass
1-RM	One Repetition Maximum
DEXA	Dual X-Ray Absorptiometry
VO_{2max}	Maximal Oxygen Uptake
PU	Push-up
PCU	Partial Curl-Up
HG	Hand Grip

INTRODUCTION

Bone mineral density (BMD) is an area of growing concern in the health and fitness world. Clinical studies show significantly high correlations between low BMD and the development of osteoporosis (11, 31, 15, 17). Osteoporosis is a disease that results in the weakening of a bone to the point where even the smallest stress, such as coughing, can cause a fracture. While osteoporosis is typically associated with post-menopausal women, it can affect both male and females of all ages. Since bone is a living organ, it is constantly changing; old bone is removed while new bone is being created. Osteoporosis occurs when the production of new bone is no longer able to keep up with the removal of the old bone. A variety of factors play a role in the body's ability to perform this function. For instance, it is well known that weight-bearing exercises can help prevent bone loss as well as enforce the production of new bone (34, 36, 8). As seen in multiple instances throughout the body, the body adapts to the stress that is applied. In essence, stress results in some form of adaptation; in bone's case, excess stress stimulates an increased production of bone. This is often referred to as the overload principle when addressing tissues such as muscle (5). However, applying this principle does not ensure that excess bone loss will be prevented or even halted. In fact, applying too much stress can cause fractures (39). Additional factors such as nutrition, frequency and intensity of physical activity, genetics, body mass, body composition and even hormones have been shown to impact the growth and development of bone as well (38). However, very little is known about the relationships that are related to each variable.

It is, however, known that approximately 80% of a female's BMD is formed by the time they reach puberty (13). Peak BMD usually occurs around the ages within the second decade of life (1, 13). Once this peak BMD has been reached, the body works on maintaining the density of the bone. As the body ages, biological processes begin to slow down and the body becomes less efficient. As this occurs, BMD begins to gradually decrease. This process typically occurs at a much faster rate in females, especially post-menopausal females. If BMD levels are low or never reach an optimal level during peak BMD years, the loss of BMD later in life can be extremely detrimental and can lead to the development of osteoporosis. Therefore, understanding bone metabolism and the variables that influence BMD during adolescence and young adulthood is vital to prevent and inhibit osteoporosis later on in life.

Purpose of Study

The purpose of this study was to examine a variety of health parameters and their relationship with BMD in a healthy female athlete population around the age of peak bone mass accrual.

Hypothesis

It was hypothesized that there would be positive correlations between body mass, fat-free mass (FFM), muscular strength and site specific BMD.

CHAPTER 1

REVIEW OF THE LITERATURE

Relationship between weight and BMD

Numerous studies have been conducted and documented showing that body mass displays a strong relationship with BMD. In a study conducted by Hamilton et. al (2013), 115 overweight premenopausal women were put into a weight loss program using decreased caloric intake as the method for weight loss for 6 months. The participants then maintained the new weight for an additional year and site-specific BMD scores were compared to their baseline measures as well as to their scores immediately post-weight loss. The results showed an increase in BMD relative to body weight during the initial weight loss phase. However, during the year of maintenance that followed, z-scores showed a decrease in site specific BMD relative to body weight. Despite the decrease, the z-score values were still significantly greater than baseline measures.

A similar study conducted by Hinton et. al (2011) examined changes in bone turnover and BMD in obese women (n=24) who lost ~10% of their weight and then regained 50% of the weight that was lost. The participants were randomly assigned into one of two groups. One group of women was involved in aerobic exercise during the regaining of weight stages while the other participants were part of a no-exercise regimen. The results of this study showed a decrease in BMD of the lumbar spine and hip regions. These findings remained consistent during the regaining of weight phase regardless of whether exercise was being performed or not. Increases in bonemarkers *osteocalcin and C-terminal peptide of type I collagen* were seen with weight loss and remained consistent during weight regain independent of exercise.

Jensen et. al (2001) studied bone mineral changes during weight loss while manipulating calcium supplementation. Participants included 62 obese women who were placed on a low caloric diet for 3-months. Dual-Energy X-ray Absorptiometry (DEXA) was used to measure BMD and a series of calcium-regulating hormones and biochemical markers of bone turnover were recorded over the 3-month span. Thirty of the participants were given a daily supplement of 1 g of calcium throughout the 3-month program. A subgroup of 48 females (n=24 from each group), were re-measured following an additional 3-months. The calcium-supplemented groups showed a greater decrease of BMC at the lumbar spine than the non-supplemented group. The researchers concluded that the majority of the bone loss could be associated with reduced mechanical loading. This loss may be inhibited by the supplementation of calcium during weight loss.

Findings that show a positive relationship between BMD and weight are consistent and results have been reproduced on numerous occasions. Researchers have thus begun exploring other potential influences on BMD in an attempt to help explain the metabolism of bone. Research has also established estimations of bone formation and degradation in relation to age. Developmental studies have shown majority of bone accrual to take place prior to and during puberty (1). The results from these studies are beneficial with regard to bone formation prior to the hormonal sex changes that occur in males and females during puberty. This knowledge allows for the minimization of hormonal influence on BMD and permits focus to be directed to the relationship of other variables. Therefore, numerous researchers have focused on BMD values in adolescents, in particular the athletic/physically active population.

Development of BMD during Adolescence

Results have shown sports participation during adolescence to provide beneficial influences on BMD, bone mineral content (BMC) and bone geometry. High-impact loading has long been known to be beneficial with the accruement and maintenance of bone mineral density while repetitive low-impact activities during youth have shown favorable changes in BMC. However, non-impact sports such as swimming do not seem to show additional benefits in bone health and some studies have even shown destructive changes in the bone geometry at the hip. Adolescents who regularly participate in impact activities show a greater accumulation of BMD/BMC than their inactive peers. In addition, even those individuals who do not continue participating in such activities following peak bone accrual, have shown higher rates of BMD/BMC retention than those who did not regularly participate in impact loading activities during adolescence and early adulthood (34).

More specifically, by analyzing various health parameters in children, Baptista et. al (2012) attempted to determine their importance in predicting skeletal health. They compared the effects of regular physical activity and lean mass as well as aerobic and muscle capacity on BMC and size of lumbar spine, femoral neck, 1/3 radius and total body in both boys and girls from ages 7-10 years of age. Fitness scores did not seem to explain for bone variability nor did physical activity (PA) in the girls. However, individuals with greater lean mass also displayed 12-19% greater BMC values. After controlling for outstanding variables, lean mass showed to be the most important predictor of bone size and mineral content in both genders.

Courteix et. al (1998) also demonstrated a relationship between fat-free mass (FFM) and BMD during a study consisting of forty-one pre-pubertal girls. Among the participants, ten were swimmers, 18 gymnasts and 13 non-athletes. DXA was used to measure body composition. In agreement with previous studies, body weight showed a positive correlation with BMD. However, when fat mass (FM) and FFM were examined, stepwise regression analysis revealed that FFM accounted for the majority of the correlation.

A cross-sectional study took 278 adolescents, both male and female, and evaluated them using DXA and a variety of six physical fitness tests to predict body composition, flexibility, various forms of strength, speed, and cardiovascular fitness. Consistent with other research, Vincente-Rodriguez et. al (2008) found an independent relationship between bone mass and lean mass. In their model, lean mass accounted for 67% of the total variance in BMC. While relationships were noted between BMC and the other measured fitness variables, once lean mass was controlled for, the relationships disappeared. The researchers concluded that the differences found between males and females may be explained by differences in lean mass and physical fitness.

These findings of association between lean mass and BMD have not just been noted in pre-pubertal female athletes, it has been repeated in postmenarcheal and female athletes as well. In addition to findings of lean mass associations with BMD, correlations have been displayed with physical activity, loads of impact, disordered eating and menstrual status.

Influence of Joint Loading Activities and Other Health Variables

Sports participation, in particular impact-loading activities, have been associated with BMD values. Egan at. al (2006) examined BMD values and body composition among female athletes participating in three different sports as well a sedentary control group. All athletes displayed higher BMD values than the sedentary controls. Significant correlations were also found between BMD and fat-free soft tissue mass as well as BMD and training load.

A controlled study, performed by Torstveit et. al (2005), with a random sample of female Norwegian volunteers, showed higher mean total BMD values in athletes (n = 186) than in the non-athletic, age-matched control group (n = 145). Consistent with other studies, the athletes involved in higher impact loading sports possessed higher BMD values than athletes participating in low impact sports. Body fat percentage and eating disorders showed a negative relationship with total BMD while weight and joint-loading activities presented a positive relationship. The authors noted that within their sample, low BMD was two to three times more likely to be present in non-athletic premenopausal women than in their athletic peers.

Heinonen et. al *(1995)* analyzed site specific BMD in female athletes competing in different load-impacted sports (squash, aerobic dance, and speed skating). All values were compared to a sedentary peer-reference group. Once values were adjusted for weight, the squash athletes displayed significantly higher BMD values than the other two sports groups. All three groups displayed higher values than the sedentary group. Their results were consistent with previous findings, demonstrating higher BMD values amongst athletes who experience greater skeletal impact.

Creighton et. al (2001) examined bone formation in regards to impact loading on a more molecular level by examining a common bone resorption marker (NTx). When comparing athletic females participating in different impact demanding sports with females who do not participate in impact loading sports but are still active as well as a sedentary control group, findings aligned with other research of its kind. After adjusting for weight, the high-impact group presented the highest BMD levels, with the medium-impact group showing higher values than the nonimpact and sedentary control groups. No differences were found in the bone resorption marker (NTx- urinary cross-linked N-telopeptides) between the groups. These findings support participation in high-impact activities to enhance BMD in females.

The majority of research consistently agrees that individuals who participate in high-impact activities generally have higher values of BMD than sedentary individuals and even those engaging in low-impact activities. However, numerous studies have also demonstrated trends of low BMD amongst endurance athletes. In fact, some researchers have theorized that excessive physical activity at a young age may even be linked to disorders in bone metabolism (13). Dlugolecka et. al (2011) examined swimmers (n=41) and non-athletic (n=45) girls between the ages of 11-15. Their results suggested that the excessive training required of the swimmers resulted in a delayed onset of menses/irregular cycles and ultimately low bone mass. Barrack et. al (2008) obtained similar results when they examined 93 competitive adolescent cross country runners ages 13-18. DEXA results indicated that approximately 28% of the athletes met the requirements for low BMD. Interestingly, 25.8% reported menstrual irregularities (MI). After adjusting for body weight, the athletes who reported MIs displayed BMD values significantly lower than their peers. Results also suggested that MI, prolonged endurance running (5+ years), BMI, and lean tissue mass were all independent risk factors of low BMD. The number of menses per year was also negatively associated with the number of miles ran.

In agreement with Barrack and colleagues, Nevill et. al (2003), studied forty-nine female endurance runners with a wide-range of experiences. Questionnaires to assess training, dietary and menstrual status were completed by both recreational and elite endurance athletes ranging from 18-44 years of age. DEXA was used to determine BMD at 10 skeletal sites. Results showed that athletes who reported running greater distances displayed higher BMD values in the arms and legs. However, those who reported additional years of training displayed decreased values in the arms and lumbar spine. Similar to Jensen et. al (2001), calcium supplementation showed a positive influence on bone metabolism; showing a positive correlation with bone mass in the legs. Interestingly though, a negative relationship was displayed with all other measured sites.

When considering bone health, a bone's ability to resist fracture is of primary importance. Numerous researchers have demonstrated impact activities to have a greater positive influence on bone properties than non-weighted activities. Ferry et. al (2013) examined short-term changes in postmenarcheal adolescent female soccer and swimming athletes after the completion of an 8-month training program. Following the elite training program changes in body composition, BMD, BMC, and hip geometry were examined and compared between groups as well as with a sedentary peer-referenced group. Results showed a significant increase in BMD in the soccer group. However, these increases were not reciprocated amongst the swimmers. Sub-periosteal width also increased among soccer athletes but not in the swimmers. Consistent with these findings, a training study conducted by Snow-Harder et. al (1992) showed a 1.2% increase in BMD following 8 weeks of resistance training.

A study conducted by Mudd et. al (2007) found that compared to other Division I varsity athletes; runners, swimmers, and divers displayed deficits in total BMD as well as in site-specific BMD. Of the 99 female participants, BMI was similar across the board with the only significant difference being found between runners and rowers. When predicting total BMD, as well as BMD at the pelvis and legs, body mass and sport demonstrated significant correlations. However, BMD of the lumbar region was also associated with gynecologic age. While not analyzed in this study, it is important to note that 23 out of the 99 participants (approximately 23%) reported dysfunctional or absent menstrual cycles.

Pollock et. al (2010) examined 44 elite female endurance runners. Low BMD was reported in approximately 34% of the athletes with almost 16% of those concurrently reporting disordered eating and menstrual dysfunction. Longitudinal analysis showed positive correlations between a reduction in BMD at the lumbar spine and training volume.

In the interest of specifically examining menstrual cycle influences, Ackerman et. al (2011) conducted a study among adolescent females designed to compare the micro-architecture of bone in non-athletes, amenorrheic (AA) and eumenorrheic athletes (EA). The nonathletic group was used as the control. While EA displayed the highest BMD scores and the hip and femoral neck, athletes in general showed greater bone area than their nonathletic peers. However, AA displayed lower values of cortical area and thickness than EA. AA also trended to have more spacious trabecular bone. These findings suggest that abnormal menstrual cycles during adolescence can lead to impaired bone micro-architecture.

Bennell et. al (1997), examined bone turnover and it was assessed using serum osteocalcin while resorption was assessed via urinary pyridinium crosslinks. This study examined differences in BMD at sites of loading, bone turnover and bone resorption between power athletes, endurance athletes and non-athletes following 12-months of training. Power athletes gained a significantly greater amount of BMD than did the other participants. Lumbar spine BMD was the only site that showed direct relationship with training status. Bone turnover and resorption markers were not elevated in any one group and levels of bone turnover were not good predictors of changes in bone mass.

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CHAPTER 2

The Relationship between BMD and a Variety of Fitness Parameters in Collegiate Female Athletes

ABSTRACT

Introduction: It is estimated that 40% of women and 13% of men will experience a fracture directly related to osteoporosis at least once in their lifetime. Many studies suggest that approximately 90% of bone mass is obtained by 20 years of age. Frequency and duration of impact loading, menstrual status, age, body weight, body composition and nutrition have all been independently correlated with BMD. However, very few studies have been conducted that explore the relationships and influence of all of these variables in regards to BMD. **Purpose:** The purpose of this study was to explore the relationship between BMD and a variety of health parameters. **Subjects:** Participants were healthy collegiate female athletes from a variety of sports; tennis (n=7), basketball (n=8), soccer (n=7), cross country (n=2), cheer (n=2), and volleyball (n=4). **Methods:** Prior to testing, all athletes completed a health questionnaire. Each subject reported to the AUM Human Performance Lab twice during a one-week span. During the first testing session, subjects completed a menstrual and sports history survey. They were evaluated for height, weight, a DEXA scan, handgrip strength, 1-RM bench press strength, and 1-RM squat strength. Muscular endurance was measured via modified push-ups and partial curl-ups. The athletes were also given a nutritional log to complete on 3 consecutive days including one weekend day. The second session included the evaluation of VO_{2max}

obtained from a graded exercise test and open circuit spirometry. **Results:** Significant positive correlations were found between BMD and each of the muscular strength measures. Using a Pearson correlation, bench press strength displayed the greatest r-value with BMD ($r = 0.826$). Significant relationships were also found between BMD and FFM ($r = 0.739$), maximal squat strength ($r = 0.666$), and handgrip strength ($r = 0.597$). Negative relationships were found between BMD and partial curl-ups ($r = -0.387$) and VO_{2max} ($r = -0.3603$). A stepwise regression model selected bench press strength as the single most important variable for predicting total BMD. All other variables were eliminated from the model. **Conclusions:** The relationships between BMD and FFM were consistent with other studies. The negative relationships found between BMD and endurance measures also supported previous research showing lower BMD values in endurance athletes. The relationship between BMD and strength measures suggests the use of resistance training as a method to increase and maintain BMD.

INTRODUCTION

There are many phrases and terms that are typically associated with discussing bone health. A variety of these terms (e.g. bone mass, bone density, bone mineral density) are used interchangeably, which can make deciphering the literature confusing. Other terms, for example bone mineral content, have entirely different meanings and are used in a variety of applications. For this particular study, bone mineral density (BMD) is the primary focus. BMD is most commonly used as a means of predicting bone strength and diagnosing the onset and development of diseases such as osteoporosis. According to the *Working Group of the World Health Organization,* osteoporosis is defined as "T-scores at or below 2.5 (2.5 SDs below normal peak values for healthy young adults) and osteopenia is defined as having a T-score between -1.5 and -2.5 (6). In lamens terms, osteopenia is the initial stage of osteoporosis and osteoporosis is "the gradual reduction in bone strength with advancing age, particularly in women post menopause, such that bones fracture with minimal trauma."*(7).* Typically, osteoporosis is perceived to only be an area of concern with frail elderly women. However, the reality is that women of all ages can be victims of reduced bone strength.

Bone strength is determined by a variety of components, in particular the total amount of bone, size of the bone, geometry, and density *(7).* While all of these factors are important and shouldn't be completely disregarded, BMD has been directly correlated with fracture risk. In fact, BMD is considered to be the single most important factor for predicting this risk (16).

Studies conducted in the female population have consistently shown relationships between BMD and factors such as body mass, hormones, nutrition, and joint loading activities. In the postmenopausal female population, studies have shown an increased loss of BMD immediately following menopause and a continual decline with age (12). Hormonal therapies and calcium supplements have been shown to counteract this decline (16, 10). Further research in female athletes has shown positive correlations between LEA, MI and low BMD (17, 19, 11). These findings suggest that proper nutrition along with hormone supplementation after the onset of menses play a large role in the development and maintenance of BMD in females. Other studies have shown BMD to be positively associated with weight; heavier individuals presenting higher BMD levels. Consistent with these results, weight-loss studies in women have shown decreases in BMD following weight loss procedures ranging from diet and exercise to surgical methods (8, 15, 10). In addition to these findings, relationships also exist between BMD and joint loading. As one might assume, athletes in general tend to display higher levels of BMD than their sedentary peers. Significant differences in BMD have been found between athletes participating in a variety of impact loading sports (1, 11, 9). Adolescence, including prepubescent females have been shown to benefit from the addition and implementation of joint loading activities (4, 20).

However, despite these findings, female athletes who undergo prolonged repetitive joint loading such as endurance runners have been identified as a high-risk group for low BMD. Such findings have led to increased interest in the potential factors that directly and indirectly influence BMD in female athletes. While it is known that all of the above mentioned factors play a significant role, very little research has been conducted to evaluate what variables have the greatest influence on BMD values.

PURPOSE

The purpose of this study was to examine the relationship between BMD and a variety of health parameters that have been shown, through previous research, to influence bone metabolism.

METHODS

Each participant reported for testing at the AUM Human Performance Lab. All procedures were completed during two seperate visits within one week. Prior to testing, each individual completed a health questionnaire and an informed consent form. Following this, height (using a stadiometer), weight (using a digital scale), and handgrip strength (using a handheld dynamomter) were obtained. The stadiometer was used to obtain height measurements to the nearest half inch and the digital scale to determine weight to the nearest tenth of a pound. Each subject underwent body composition measurements via the dual x-ray absorptiometery machine (DEXA). The DEXA values were used as the criterion measures of body fat percentage as well as bone mineral density values for each subject.

Using the guidelines determined by the National Strength and Conditioning Association (NSCA), the following muscular strength testing procedures were performed. The handgrip strenght was determined using a handheld dynamometer. Each participant was given three attempts for each hand and the greatest score was recorded. A 1-repetition maximum (1-RM) bench press and squat test were then performed to estimate strength values . Proper lifting procedures were explained and demonstrated to ensure the subject's safety. A warm-up set that easily allowed for 5-10 repetitions was performed. The weight was gradually increased and fewer repetitions were performed with each additional set, allowing for rest between each trial. Additional weight was added until the subject was only able to complete one full repetition. The goal was to reach a 1-RM within 5 testing sets (2). The American College of Sports Medicine (ACSM) procedures for performing modified push-ups and partial curl-ups were used to evaluate muscular endurance (18). Participants were instructed to perform the maximal amount of push-ups possible without resting between repetitions. If their form became impaired, the investigator stopped the test and that number was recorded. Partial curl-ups were performed for one minute. The subject was instructed to perform as many full repetitions as possible during the allotted time.

The second visit consisted of a graded exercise test (GXT), following a standard Bruce protocol was performed on a treadmill to evaluate peak VO_2 (18). Expired gas (oxygen and carbon dioxide) fractions were continuously sampled at the mouth, with a pneumotach on an open-circuit metabolic system (Parvomedics). The GXT was symptom limited and the subjects were able to stop at any time. If at any time, the subject experienced angina, leg cramps, lightheadness, nausea, or if heart rate failed to increase with intensity, the test was terminated.

RESULTS

A Pearson product-moment correlation (r) showed significant correlations between the measured parameters and BMD. Consistent with previous findings, positive relationships were noted between FFM and all measured values of BMD (Table 1, Fig. 1.). A significant positive relationship was also displayed between BMD and muscular strength measures. Bench press strength indicated the strongest relationship with total BMD ($r = 0.826$) where $P < 0.01$ (Fig. 3) In addition, positive significant relationships were found between bench press strength and all site specific BMD measures (Table 1.). A significant relationship was also seen between tBMD and maximal squat strength ($r = 0.666$) as well as handgrip strength with aBMD ($r = 0.485$) where $P < 0.01$ (Fig. 2, Table 1). Similar to bench press strength, squat strength showed significant positive correlations with lBMD and sBMD (Table 1.). A significant negative relationship was found between tBMD and PCU ($r = -0.387$) at a level of $P < 0.05$. At a level of $P < 0.01$, aBMD and VO_{2max} were negatively correlated ($r = -0.515$). A stepwise regression model determined bench press strength to be the single most important variable for predicting tBMD, eliminating all other variables from the model (Table 2). A negative relationship was also noted between PSH and BF% ($r = -0.4501$).

DISCUSSION

The results from this study showed positive relationship between BMD and weight, FFM, and muscular strength (Fig.1, 2 and 3). The significant correlations with weight and FFM are consistent with other studies and support research that has shown lean mass to be a better predictor of BMD than body mass. Muscular strength and aerobic fitness showed no significant relationship with BMD. In fact, muscular endurance correlations proved to be slightly negative. This supports other research that has found endurance athletes to have lower BMD values than their peers who participate in high-impact activities. Endurance athletes train in a way to promote muscular and aerobic endurance. Therefore, these findings support other findings associated with endurance athletes (14, 13, 3).

Bench press strength values accounted for a significant amount of variance in BMD (R^2 = 6818). The current study found maximal bench press strength to be significantly related to total BMD (Fig. 3). The stepwise regression model found bench press strength to be the only significant variable to significantly predict BMD when all variables were entered into the model (Table 2). While maximal squat strength displayed significantly high correlations, it was eliminated in the regression model. The lack of resistance training experience may have influenced the outcome. The majority of athletes tested were not consistently resistance trained and some had very little if no experience performing squats. Leg strength measured via a leg press machine may have been a better and safer alternative to squats as a measure of leg strength.

There were not enough individual participants from each sport to be able to assess sport specific differences with this study. However, mean tBMD values compared between sports showed basketball athletes to portray the highest values while cross country runners displayed the lowest mean values (graph 1). All but three athletes reported regular menstrual cycles making it impossible to analyze the influence MI. The nutrition logs for all athletes tested suggested that all athletes in this study were consuming adequate amounts of fats, carbohydrates and protein. Future studies may want to further assess nutrition by analyzing calcium and macronutrient intake in addition to caloric intake.

In conclusion, consistent with other studies, FFM is a strong indicator of BMD. In addition, muscular strength was found to be strongly related to both total BMD and site specific BMD. However, aerobic fitness and muscular endurance values were found to negatively correlate with BMD. These findings support strength training, opposed to endurance training, as a more effective method in relation to BMD.

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GRAPHS, TABLES AND FIGURES

Graph 1. – Average total BMD values relative to sport

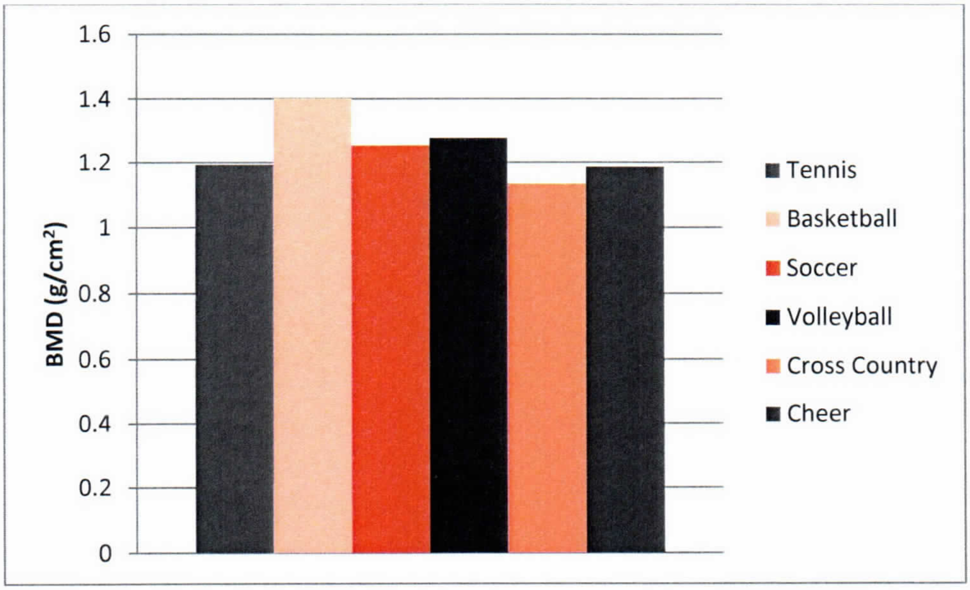

Figure 1.- The relationship between total bone mineral density and fat-free mass

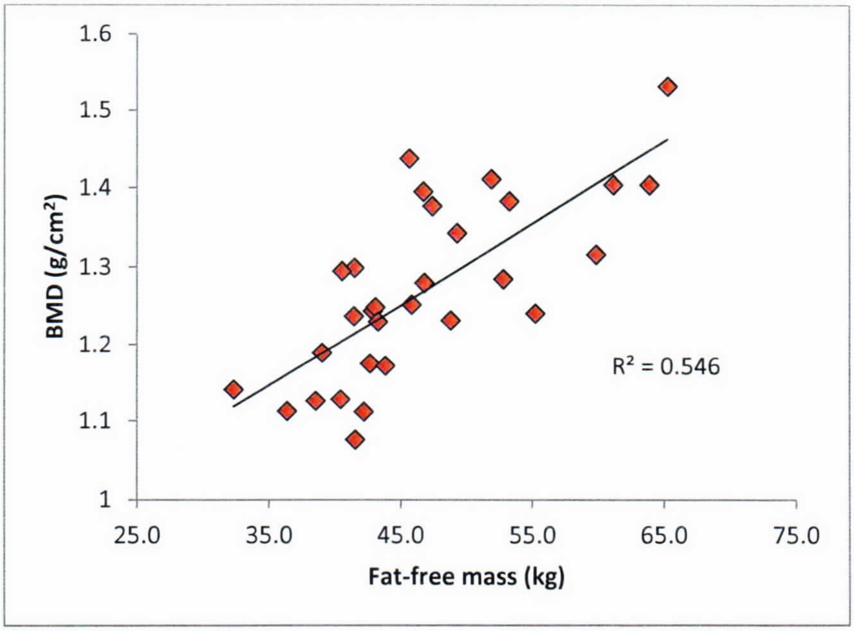

Figure 2. – The relationship between bone mineral density and 1-RM squat strength

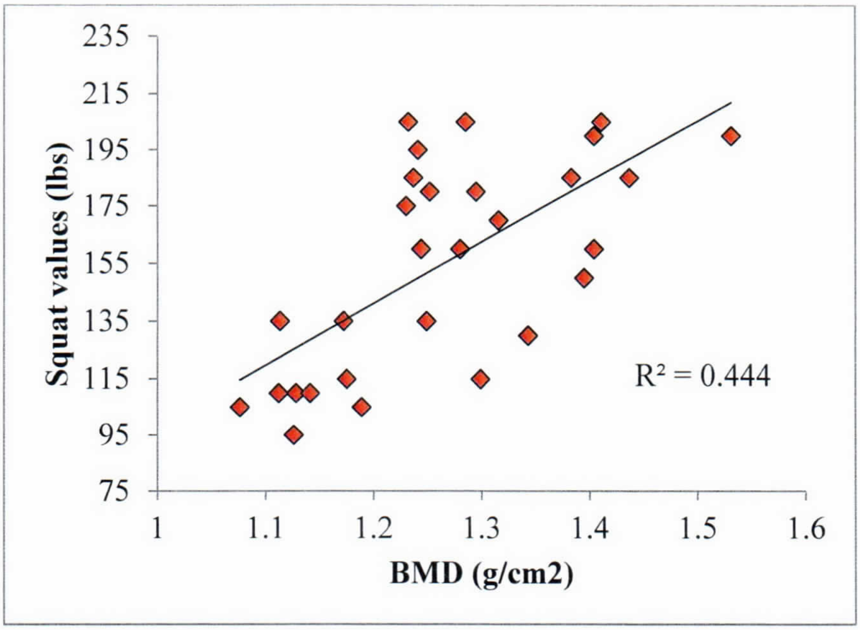

Figure 3. – The relationship between bone mineral density and bench press strength.

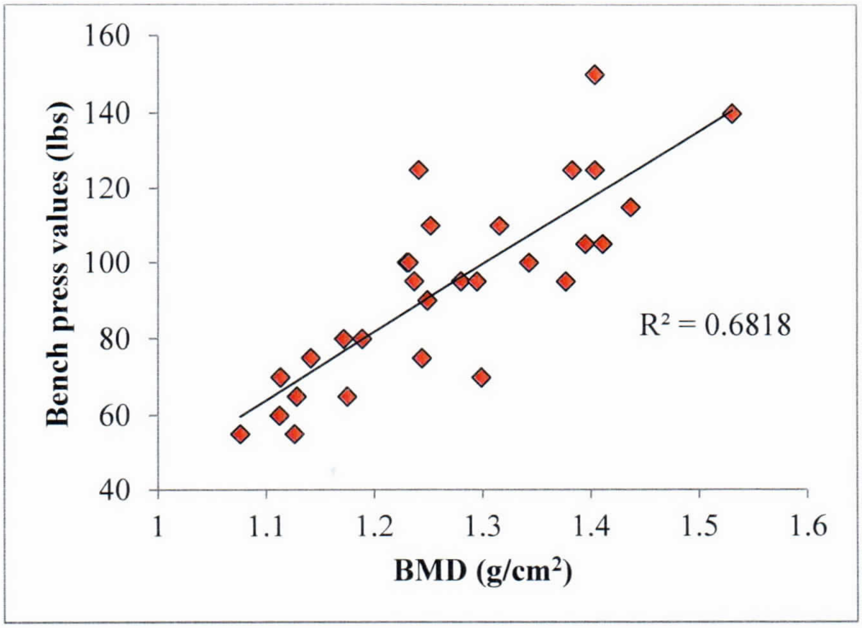

Table 1. Correlation values for site specific BMD

	aBMD	lBMD	sBMD	tBMD
1-RM Bench Press	0.669**	0.752**	0.692**	0.826**
1-RM Squat	0.492**	0.592**	0.646**	0.666**
Handgrip	0.485**	0.465**	0.391*	0.404*
PCU	-0.353	-0.354	-0.122	-0.387*
PU	-0.261	0.041	-0.019	0.033
VO_{2max}	-0.515**	-0.370*	-0.346	-0.360

** Indicates significance at the 0.01 level

*Indicates significance at the 0.05 level

Table 2. Regression Model for predicting total BMD

Model	Unstandared Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Contant)	.873	.044		19.876	.000	.782	.964
BPKG	.009	.001	.889	9.293	.000	.007	.011

a. Dependent Variable: TOTAL BMD

APPENDIX A (Flyer from IRB)

AUBURN
MONTGOMERY

Are you interested in participating in a study that will provide you with information regarding fitness and performance variables?

"The relationship between selected physical fitness parameters and bone mineral density in collegiate female athletes"

We are seeking female athletes between the ages of 18 and 29 to participate in a study to examine the efficacy of resting heart rate measures acquired with a smart phone application are able to reflect performance changes following off-season training. The dates of the study are from January 27, 2014 to April 27, 2014. To participate, the following criteria must be met:

1. **Current collegiate athlete between the ages of 19 to 29 years**
2. **Free from cardiovascular, pulmonary, or metabolic disease**
3. **Not currently taking any prescription medications**
4. **Must not be pregnant**

If you meet the criteria for the study, you will receive free body fat and bone mineral density measures, aerobic fitness and muscular strength and endurance assessments performed by trained exercise professionals. If you decide to participate in the study, you will be asked to visit the Human Performance Laboratory twice to complete the requirements of this study. Each visit will require approximately 1-2 hours. If you are interested in participating in this study please contact:

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Auburn University Montgomery
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APPENDIX B (Informed consent from IRB)

INFORMED CONSENT

The relationship between selected physical fitness parameters and bone mineral density in collegiate female athletes

Auburn University Montgomery

Department of Physical Education and Exercise Science

You are invited to participate in a study that aims to investigate the relationship of bone mineral density, aerobic fitness, muscular strength and muscular endurance. Dr. Henry Williford is the primary investigator conducting this study. You were selected as a possible participant because you volunteered for the study and you fit the criteria of being a collegiate-level female athlete between the ages of 19 and 29 years, not currently taking any prescription medications, free from pregnancy, and are an apparently healthy individual free from cardiovascular, pulmonary and metabolic diseases.

Data Collection Process

If you decide to participate, you will be asked to report to the Human Performance Laboratory at Auburn University Montgomery between 8:00am and 5:00 pm on any day of the week (Monday through Friday) twice within a 7-day span. Each visit will require approximately 1-2 hours. During the first visit, you will complete a health history questionnaire and have the following variables measured: height; weight; body fat percentage; bone mineral density; muscular strength: and muscular endurance. The second visit will consist of a maximal aerobic fitness measurement that will be determined by an exercise test.

Body Composition Measurements

Body fat percentage will be measured by a specialized x-ray device known as a dual energy x-ray absorptiometery (DEXA for short). The DEXA will also measure your bone mineral density. Human performance laboratories that undertake bone mineral density and body composition studies use DEXA as the standard technology due to its specificity, accuracy, and safety. There are usually no complications from this procedure. There is a small amount of radiation exposure, less that 1/10 the dose of a standard chest x-ray. Before conducting the DEXA scan, we will ask you to remove all metallic objects you have on your body and to lie motionless on the scanning bed of the machine. When in proper position, we will secure your legs with Velcro straps around the ankles to make sure they don't move during the assessment. You will be scanned from head to toe, which will take about 5 to 10 minutes.

Muscular Strength Measurements

Muscular strength will be determined using three separate tests: handgrip; 1-RM bench press; and 1-RM squat. The handgrip test will be performed using a handheld dynamometer. You will be asked to hold the dynamometer in your hand with your elbow bent to 90 degrees. You will then be asked to squeeze the dynamometer as hard as you can. This measurement will be taken on both the right and the left hand.

Next, you will complete a 1-RM bench press followed by a 1-RM squat measurement (5-10 minutes of rest will be allowed between the two measurements. The procedure for the 1-RM tests is as follows: you will warm up with light resistance that easily allows 5-10 repetitions. You will then be given a one-minute rest, after which an estimated load allowing for 3-5 repetitions will be performed followed by a 2-minute rest period. You will then perform the lift with a resistance that allows for approximately 2-3 repetitions to be completed, followed by a 2-4 minute rest period. The load will then be increased by 5-10% for upper body and 10-20% for lower body lifts and you will attempt a 1-RM. If successful, you will be given another 2-4 minute rest and the load will be increased again. If your attempt fails, a 2-4 minute rest will be given and the load will be decreased by 5-10 lbs for upper body and 15-20 lbs for lower body. This process will continue until a 1-RM is reached, preferably within five testing sets.

Muscular Endurance Measurements

Following the muscular strength measurements, you will be given a 10 minute rest period to recover. After which, two muscular endurance tests will be performed; push-ups and partial curl-ups. The American College of Sports Medicine (ACSM) procedures for performing push-ups and partial curl-ups will be used. In order to perform the push-up test you will begin in a "knee push-up" position, with hands shoulder width apart using your knees as a pivoting point. You then must lower your body until your chin touches the floor while making sure that your back stays straight at all times. You will proceed to raise your body to a straight arm position. The maximum number of push-ups performed without rest, while using proper form will be recorded.

Next, you will perform the partial curl-up test. You will begin laying on your back with your knees bent to 90 degrees and your arms outstretched along your side. A piece of tape will be placed 10 cm away from the tips of your fingers. You will have 1-minute to complete as many curl-ups as possible. The maximum number of curl-ups will be recorded stopping once the 1-minute mark has been reached.

Aerobic Fitness Measurements

On a separate visit, we will assess your maximal aerobic fitness with a maximal graded exercise test on a treadmill. The treadmill test will begin at a speed of 1.7 mph with a 10% incline. The workload will be increased every 3 minutes until you fatigue or we stop the test. During the test, you will be wearing an oxygen mask which will measure expired gases (oxygen and carbon dioxide) continuously to determine your maximal oxygen consumption (i.e., maximal aerobic fitness). Heart rate will also be continuously analyzed, and blood pressure will be measured during the last 45 seconds of each stage. The test will be terminated when one of the following occurs: you reach a plateau in oxygen consumption, you obtain your maximal heart rate, or you voluntarily reach fatigue. At the termination of the exercise test, you will be allowed a "cool-down" period that consists of slow walking for 3-minutes. You may stop the exercise test at any time because of personal feelings of exhaustion or discomfort associated with exercise.

You will obtain information regarding your body composition and aerobic fitness results via printed reports. The information could be useful when establishing an exercise program.

Subject Safety

Personnel in charge will attempt to minimize all risks. For instance, the test will be terminated if you experience any of the following: chest pain, fatigue, shortness of breath, wheezing, leg cramps, dizziness, or just an uncomfortable feeling. All personnel have been trained in CPR. Emergency procedures are posted in the Human Performance Laboratory. Every effort will be made to minimize risks through preliminary screenings and observations during the test. Some discomforts and inconveniences are possible.

Muscle injury (strain or sprains) could occur. There is a possibility of nausea, dizziness, fainting, and/or fatigue as a result of exercise. Should injury occur as a result of the experimental protocol it would be your responsibility to seek medical attention. Muscle soreness in the lower body could also occur 24 to 48 hours after the test.
Any information obtained in connection with this study in which you can be identified will remain confidential and will be disclosed only with your permission. If you give me your permission by signing this document, your information will be disclosed to Dr. Micahael R. Esco, and Dr. Henry Williford only for the purposes of assisting with data collection. Only group data will be analyzed and used. No individuals will be identified in any final reports.

Your decision whether to participate will not prejudice your future relations with Auburn University at Montgomery. If you are an AUM athlete, your decision to participate will not influence your athletic team status. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time without penalty. If you decide later to withdraw from the study, you may also withdraw any information that has been collected about you.

If you have questions concerning this study please feel free to ask me (Emily Witte) directly or via phone at (334) 244-3472. If you have questions concerning your rights as a human subject please call Debra Tomblin at (334) 244-3250.

YOU ARE MAKING A DECISION WHETHER TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TOPARTICIPATE, HAVING READ THE INFORMATION PROVIDED ABOVE.

Subject's Signature	Date
Investigator's Signature	Date