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The Relationship between Maximal Oxygen Consumption and Bone Health in College-Aged Men

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ABSTRACT

Croall CA, Dixon CB, Haile L, Andreacci JL. The Relationship between Maximal Oxygen Consumption and Bone Health in College-Aged Men. **JEPonline** 2017;20(5):1-11. The purpose of the present investigation was to examine the relationship between maximal oxygen consumption (VO_2 max) and whole body bone mineral content (WB-BMC) and whole body bone mineral density (WB-BMD) in 44 college-aged men (age: 21.8 ± 1.4 yrs; body mass index: 26.6 ± 4.7 $kg \cdot m^{-2}$). Body composition was measured using dual-energy X-ray absorptiometry (DXA). The VO_2 max test was performed on a motorized treadmill using the Bruce treadmill protocol. Absolute VO_2 max ($L \cdot min^{-1}$) was positively correlated to WB-BMC (r = 0.60) and WB-BMD (r = 0.59). Conversely, no relationship was observed between relative VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$) and WB-BMC or WB-BMD. A significant relationship ($P<0.001$) was observed between body mass and WB-BMC (r = 0.68) and WB-BMD (r = 0.55). The results of this study indicate a moderate relationship between absolute VO_2 max and bone variables of college-aged men.

Key Words: Bone Health, Bone Mineral Content, Bone Mineral Density, Maximal Oxygen Consumption

INTRODUCTION

Osteoporosis is a disease that causes the bones to weaken and degrade, which increases the risk of fractures. Bone health and the prevalence rate of osteoporosis are commonly associated with women rather than men (6). However, Willson et al. (22) point out that as many as one in four men over the age of 50 will develop an osteoporosis-related fracture. Bone degeneration and severity can be diagnosed by a whole-body scan using dual-energy X-ray absorptiometry (DXA). DXA is the most widely accepted method to determine whole body bone mineral content (WB-BMC) and whole body bone mineral density (WB-BMD). Both are used to rank the severity of bone disease.

The clinical diagnosis of osteoporosis is made on the basis of the widely accepted T-score criteria for BMD established by the World Health Organization (22). Peak bone mass is estimated to be achieved prior to the third decade of life (17). Optimizing peak bone mass in early adulthood is one of the most important factors in preventing osteoporosis and related fractures later in life (14). Low peak bone mass and, thus overall bone health is a risk factor for developing osteoporosis (17).

There are many factors that affect bone development such as sex hormones, physical activity level, and body size, with puberty possibly having the greatest effect on bone formation and development in both men and women (22). Bone cells express androgen receptors that account for the increase in bone building during puberty and adolescence in young men (19). Development of osteoporosis in men occurs less because men have larger skeletons and bone loss occurs later and at a reduced rate (15). Osteoporosis is associated primarily with postmenopausal women due to the decrease in circulating estrogen levels (15). Until menopause, women show a greater bone absorption/reabsorption compared to men. Men maintain testosterone levels allowing them to maintain bone integrity longer than women, delaying the onset of osteoporosis.

According to the NIH Osteoporosis and Related Bone Diseases ~ National Resource Center (15), there are two classifications of osteoporosis: (a) primary; and (b) secondary. A classification of an individual having a primary cause of osteoporosis would be age-related osteoporosis, which is more likely to occur as age increases, and is seen in men >70 yrs of age (14,16,18,22). The majority of the secondary causes of osteoporosis in men are behavioral and therefore mostly modifiable. The most notable nutritional cause of osteoporosis is a poor diet that results in low serum levels of vitamin D and calcium. Inadequate calcium significantly contributes to the development of osteoporosis (16). Vitamin D aids in the absorption of calcium. A variety of chronic diseases (such as COPD, arthritis, and hyperthyroidism) are considered secondary causes of osteoporosis in men. Alcohol abuse, tobacco abuse, and a sedentary lifestyle are also secondary causes (22).

Physical activity (PA) is recommended to maintain bone health (10). Physical fitness has been correlated with WB-BMC in multiple studies (3,4,13,17) over the past several decades. Previous reports have used high-impact and resistance training (4) to assess the subjects' fitness levels, while a few studies (4,7,11,12) have analyzed aerobic capacity. Maximal oxygen consumption (VO_2 max) is a direct measure of physical fitness, and relationships have been observed between VO_2 max and both WB-BMC and WB-BMD. Friedlander et al. (8) reported that aerobic and weight training exercise intervention resulted in an increase in

VO_2 max and BMD in young women between 20 to 35 yrs of age. These findings suggest there may be a similar relationship found in age-matched men between VO_2 max and WB-BMD.

Presently, there is conflicting results on whether fat mass or fat-free mass is a greater contributor to the promotion of bone health (3,7,9,18,20,21). Ho-Pham et al. (9) completed a meta-analysis that examined the impact of fat mass (FM) and fat-free mass (FFM) on BMD. Both FM and FFM showed a relationship with BMD, but depending on the sample size and variability, varying results were reported. They concluded FFM is a better predictor for BMD than FM when larger sample sizes were analyzed (9). Caucasian population studies found that FM was strong determinant of BMD; whereas, most Asian population studies showed FFM was a strong determinant (9).

El Hage et al. (7) examined the relationship between VO_2 max and WB-BMC and WB-BMD in a group of young Lebanese adults. They reported that absolute VO_2 max ($L \cdot min^{-1}$) was moderately correlated ($P<0.001$) with WB-BMC ($r = 0.57$) and WB-BMD ($r = 0.53$) in men. In addition, there was a significant correlation ($P<0.001$) between body mass and WB-BMC ($r = 0.71$) and WB-BMD ($r = 0.62$) in men. Liberato et al. (11) examined the relationship between WB-BMC, WB-BMD, body composition, and cardiorespiratory fitness in young Australian men. The authors reported a significant relationship ($P<0.01$) between body mass and WB-BMC and WB-BMD ($r = 0.84$, $r = 0.54$), respectively. They reported that FFM observed strong correlations ($P<0.01$) between WB-BMC ($r = 0.92$) and WB-BMD ($r = 0.62$) (11). They reported that no correlation was observed between VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$) and WB-BMC and WB-BMD.

More recently, Masteller et al. (12) examined the relationship between VO_2 max and WB-BMC and WB-BMD in young women 18 to 31 yrs of age. They reported a moderate correlation between VO_2 max ($L \cdot min^{-1}$) and WB-BMC and WB-BMD ($r = 0.37$, $r = 0.24$, $P<0.001$), respectively. Relative VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$) resulted in no correlation when compared to WB-BMD. The subjects' body mass was moderately correlated with WB-BMC and WB-BMD ($r = 0.62$, $r = 0.36$, $P<0.001$) (12).

Previous research suggests that aerobic fitness may influence WB-BMC and WB-BMD in young women and men (7,11,12) and that FM and FFM may influence overall bone health as well (9). Therefore, the purpose of this investigation was to determine if a relationship exists between VO_2 max and WB-BMC and WB-BMD in young men.

METHODS

Subjects

Forty-nine healthy, college-aged men between 19 and 26 yrs of age participated in this study. Prior to participation, informed written consent was obtained from each subject as required by the Bloomsburg University Institutional Review Board. Also, a physical activity readiness questionnaire and the health and dietary questionnaire were completed following the informed consent. Questionnaires were assessed by the research team to ensure that the subjects qualified to participate in this study. The subjects were asked to come to the laboratory on two separate visits within a 1-wk period, no less than 24 hrs apart.

Procedures

The subjects' height and weight were measured using a wall-mounted stadiometer and calibrated digital scale. Body composition was measured using a DXA scan to determine FM, FFM, percent body fat (%BF), WB-BMC, and WB-BMD. All subjects were instructed to wear tight fitting clothing and to remove all metal from their body prior to the test, per the manufacturer's procedural guidelines.

Each subject was instructed to adhere to the following pretesting guidelines to ensure accuracy of the measures: (a) no physical exercise within 12 hrs of the test; (b) no eating or drinking within 2 hrs of the test; (c) no alcohol consumption within 48 hrs of the test; (d) empty bladder within 30 min of the test; and (e) no diuretic medications within 7 days of the test.

The subject's maximal oxygen consumption (VO_2 max) was assessed using the Bruce protocol (5). The subjects' rating of perceived exertion (RPE) was measured using the OMNI scale (2) at the conclusion of each stage. Heart rate was monitored continuously using a Polar heart monitor for the duration of the test. The subjects' expired gas was collected by a Hans-Rudolph two-way respiratory valve and sampled in a 3 L mixing chamber. Expired concentrations of O_2 and CO_2 were analyzed by open-circuit spirometry in 15-sec intervals using a Parvo Medics TrueOne 2400 Metabolic Measurement System.

The attainment of VO_2 max was accepted when the subject demonstrated 4 of the following 5 criteria: (a) change in VO_2 ≤2.1 $mL \cdot kg^{-1} \cdot min^{-1}$ with increasing workload; (b) RER ≥1.10; (c) RPE ≥8; (d) HR within ±10 beats of their age predicted HR **max**; and (e) volitional fatigue and termination of test.

Statistical Analyses

Pearson-product moment correlations were calculated to determine the relationship between VO_2 max and WB-BMC and WB-BMD and relationships between body mass, FM, and FFM with WB-BMC and WB-BMD using SigmaPlot Version 13.0 (Systat Software, San Jose, CA). Regression equations were formulated to further analyze the relationships between the variables. All values are expressed as mean ± standard deviation unless otherwise noted. The significance level was set at an alpha level of $P \leq 0.05$ for all analyses.

RESULTS

A total of 49 subjects were originally recruited for participation in this investigation. However, 5 subjects failed to achieve the VO_2 max criteria and, therefore, only 44 subjects were included for further analysis. Subject characteristics of the 44 men who participated in this study are reported in Table 1. They displayed a wide range of body mass, body composition, WB-BMC, and WB-BMD (Table 1). Mean absolute and relative VO_2 max values were 3.9 ± 0.50 $L \cdot min^{-1}$ and 47.3 ± 6.4 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively (Table 2).

Table 1. Characteristics of Study Participants (N = 44).

Variables	Mean ± SD	Range
Age (yrs)	21.8 ± 1.4	19.0 – 26.0
Height (cm)	177.1 ± 5.3	164.5 – 188.8
Body Mass (kg)	83.4 ± 14.0	58.0 – 126.6
Body Mass Index ($kg \cdot m^{-2}$)	26.6 ± 4.7	18.8 – 41.0
Body Fat (%)	18.6 ± 7.8	5.0 – 40.5
Fat Mass (kg)	16.1 ± 9.6	4.0 – 51.4
Fat-Free Mass (kg)	65.5 ± 9.4	22.9 – 81.0
WB-BMD ($g \cdot cm^{-2}$)	1.3 ± 0.1	1.0 – 1.5
WB-BMC (g)	3518.8 ± 427.3	2388.9 – 4468.3

All data expressed as mean ± SD. **WB-BMD** = Whole Body-Bone Mineral Density; **WB-BMC** = Whole Body-Bone Mineral Content

Table 2. Physiological Data Obtained from Maximal Oxygen Consumption Test.

	Mean ± SD	Range
Relative VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$)	47.3 ± 6.4	30.0 – 59.4
Absolute VO_2 max ($L \cdot min^{-1}$)	3.9 ± 0.5	2.2 – 4.8
Respiratory Exchange Ratio	1.18 ± 0.07	1.04 – 1.33
Rating of Perceived Exertion	9 ± 1	7 – 10

A moderate correlation ($P<0.001$) was established between absolute VO_2 max ($L \cdot min^{-1}$) and WB-BMC ($r = 0.60$) and WB-BMD ($r = 0.59$) (Figures 1A & 2A). Conversely, no relationship was observed when VO_2 max was expressed relative to body mass ($mL \cdot kg^{-1} \cdot min^{-1}$) in regards to WB-BMC or WB-BMD (Figures 1B & 2B). Correlations between body composition and bone variables are shown in Table 3. A significant relationship ($P<0.001$) was observed between body mass and WB-BMC ($r = 0.68$) and WB-BMD ($r = 0.55$) (Table 3).

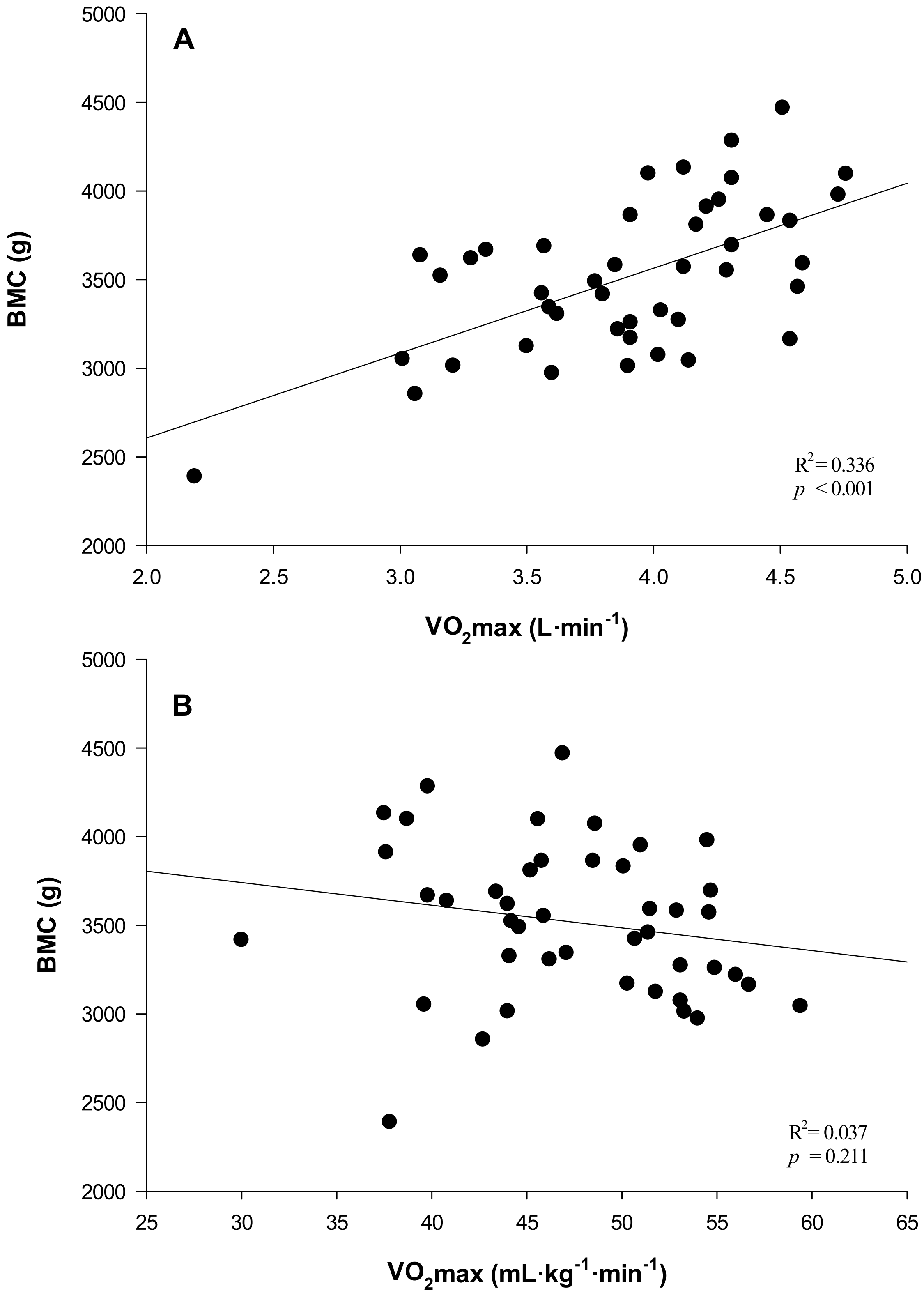

Figure 1. The Relationship between Bone Mineral Content (BMC) and Absolute and Relative Maximal Oxygen Consumption (VO_2 max).

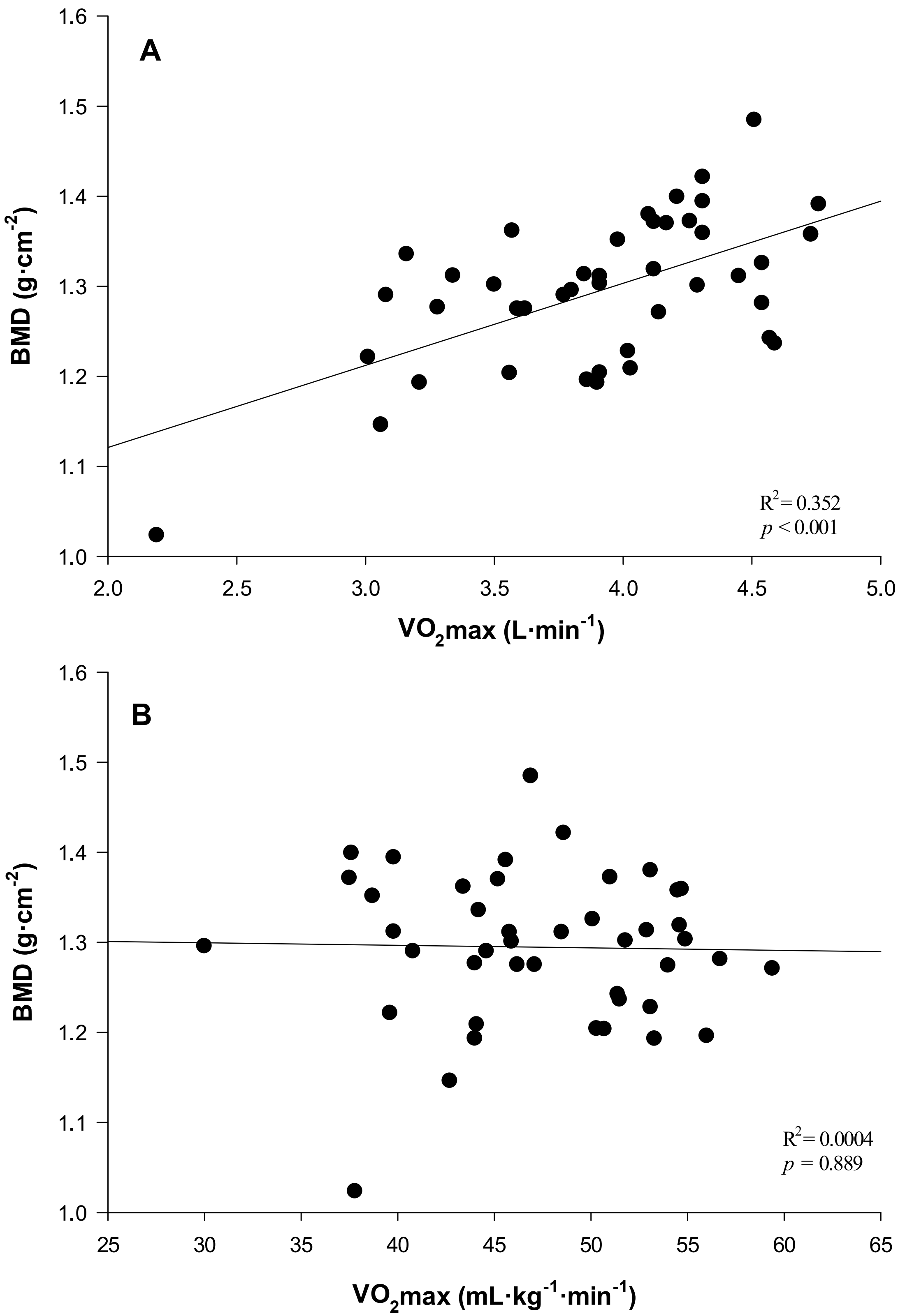

Figure 2. The Relationship between Bone Mineral Density (BMD) and Absolute and Relative Maximal Oxygen Consumption (VO_2 max).

Table 3. Correlations between Body Composition Variables and Bone Variables.

	WB-BMC (g)			WB-BMD ($g\cdot cm^{-2}$)		
	r	r^2	P-value	r	r^2	P-value
Body Mass (kg)	0.68	0.47	0.001*	0.55	0.30	0.001*
Fat-Free Mass (kg)	0.35	0.12	0.002*	0.42	0.18	0.004*
Fat Mass (kg)	0.39	0.15	0.009*	0.26	0.06	0.086

Statistically significant *P<0.05

DISCUSSION

The primary purpose of this study was to examine the relationship between aerobic capacity and bone health in young men. Given previous findings in women, we hypothesized that men with a higher absolute VO_2 max ($L\cdot min^{-1}$) would display a higher WB-BMC and WB-BMD. Our data supported this claim when VO_2 max ($L\cdot min^{-1}$) was correlated to WB-BMC (r = 0.60, P<0.001) and WB-BMD (r = 0.59, P<0.001). Conversely, no relationship was observed between relative VO_2 max ($mL\cdot kg^{-1}\cdot min^{-1}$) and WB-BMC or WB-BMD.

Masteller and colleagues (12) recently reported a relationship (P<0.001) between absolute VO_2 max ($L\cdot min^{-1}$) and WB-BMC (r = 0.37) and WB-BMD (r = 0.24) in 83 young women. No relationship was observed between relative VO_2 max ($mL\cdot kg^{-1}\cdot min^{-1}$) and WB-BMC or WB-BMD. They also reported significant correlations (P<0.001) between FFM and WB-BMC (r = 0.54), WB-BMC (r = 0.45), and FM and WB-BMC (r = 0.60), and WB-BMD (r = 0.31). Masteller et al. (12) stated that in young women VO_2 max may not be as strong of a predictor of bone health as FM and FFM. Interestingly, while they reported FM and FFM are a better predictor of bone health than VO_2 max ($L\cdot min^{-1}$) in young women, our study shows that VO_2 max ($L\cdot min^{-1}$) may be a better predictor of bone health than FM and FFM in young men.

El Hage et al. (7) reported a significant relationship (P<0.001) between VO_2 max ($L\cdot min^{-1}$) and WB-BMC (r = 0.57), and WB-BMD (r = 0.53), and no relationship between relative VO_2 max and WB-BMC and WB-BMD in 37 young Lebanese men. Mean VO_2 max values in the El Hage et al. (7) study were considerably lower than the subjects tested in the present study, although our subjects showed similar anthropometric measures (VO_2 max values: 3.1 ± 0.66 vs. 3.9 ± 0.5 $L\cdot min^{-1}$; 39.7 ± 6.8 vs. 47.3 ± 6.4 $mL\cdot kg^{-1}\cdot min^{-1}$).

Liberato and colleagues (11) reported no relationship between VO_2 max ($mL\cdot kg^{-1}\cdot min^{-1}$) and WB-BMC and WB-BMD in 35 young men with an age range of 18 to 35 yrs. They reported correlations between body mass and WB-BMC (r = 0.84) and WB-BMD (r = 0.54). Absolute

VO_2 max values were not reported. In addition, they reported significant relationships ($P<0.01$) between FFM and WB-BMC ($r = 0.92$) and WB-BMD ($r = 0.54$) (10).

The present study found significant relationships ($P<0.001$) between body mass and WB-BMC ($r = 0.68$) and WB-BMD ($r = 0.55$). This finding was expected and most likely due to larger body mass resulting in a greater load on the skeletal tissue. This relationship between body mass and WB-BMC and WB-BMD has been reported in recent literature (7,11,12). Also, FFM has been reported to impact bone health more than FM in men and women (9). We observed a relationship between FFM and FM and bone variables, which is supported in current literature (7,11,12).

Limitations in this Study

There are several limitations to the present study. A primary limitation is the cross-sectional nature of the study design. Longitudinal data may be better able to contribute to the current body of literature by analyzing possible changes to bone variables and VO_2 max during peak bone mass development. Another possible limitation could be that dietary questionnaires to assess dietary calcium and vitamin D intake were not conducted. Based upon results presented by Masteller et al. (12), they found no relationship between nutrient intake and bone variables.

CONCLUSIONS

This investigation further examined the potential relationship between VO_2 max and bone health in young men. Previous studies have reported relationships between aerobic capacity and bone health in both men and women. Primarily, we found that VO_2 max ($L \cdot min^{-1}$) was a moderate predictor of WB-BMC and WB-BMD, with body mass being the greatest predictor overall.

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