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Association of Bone Mineral Density with Lean Mass, Fat Mass, and Physical Activity in Young Overweight and Obese Women

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ABSTRACT

International Journal of Exercise Science 15(7): 585-598, 2022. To examine the associations between bone mineral density (BMD), body composition and habitual physical activity in women who are overweight/obese. We measured whole-body bone, and body composition (lean mass, fat mass, and total fat percent) via dual-energy x-ray absorptiometry (model General Electric Lunar whole-body scanner) in a diverse group of women (N=48, age 26.6+/-4.7 years, 63% Black) living in an urban setting. The relations between BMD with total fat percent [%]), lean mass (kg), fat mass (kg), and physical activity were examined using Pearson correlations and multiple linear regression models, adjusted for race, age, and dietary calcium. BMD was positively correlated with lean mass ($r=0.43$, $p=0.002$) and negatively correlated with total fat percentage ($r=-0.31$, $p=0.03$). Multiple linear regression models indicated BMD was positively associated with lean mass (β: 0.007, $p<0.001$), and negatively associated with fat mass (kg) and total fat percentage (β: -0.003, $p=0.03$; β: -0.004, $p=0.03$, respectively). When stratified by race, these relations were maintained in white women but only lean mass in Black women. When stratified by age, the positive correlation between BMD and lean mass was significant in younger women (<30y) only. There were no significant relationships between BMD and any physical activity measures. Our results indicate that in young women who are overweight/obese BMD is significantly associated with body composition, both lean mass and total fat percentage, but not habitual physical activity. An emphasis on lean mass accrual may be valuable for young women, particularly Black women, to improve bone health.

KEY WORDS: Body composition, obesity, bone health, bone mineral density, physical activity

INTRODUCTION

Advancing age is commonly accompanied by bone loss, reflected in diminished bone mineral density (BMD). In some cases, this bone loss progresses to osteoporosis, defined as having a Tscore of ≥ -2.5 (20). Despite BMD being a concern of advancing age, it is important to note that bone mass is accrued throughout childhood, adolescence, and early adulthood. Disagreement exists as to when the greatest mass accrual is achieved. Some sources suggest peak bone mass is achieved soon after cessation of linear bone growth, while others suggest it is achieved at age 30 years (40), while others suggest it can occur up to a decade thereafter (14). Recent research has indicated that significant increases in BMD can occur as a result of physical activity (PA) participation (13). Beneficial outcomes have been observed in late adolescents and early adulthood individuals who partake in large amounts of PA at relatively low intensities, even in the absence of vigorous activity (32).

Mechanostatic theory posits that bone-remodeling is an ongoing adaptative process in which a bone's strength is determined by its adaption to the mechanical loads (11, 29). Although the potential for additional bone mass accrual is present during the third and fourth decades of life, PA participation, particularly habitual daily activity, has been found to decrease in women, predominantly as they transition from university to their careers, have changes in work status, and when they become pregnant (10). As many of those life experiences coexist with peak bone mass accrual around the age of 30 years, it is especially important to focus on this stage of life.

The relationship between obesity and bone health has been investigated with equivocal results; some early studies suggest it may be osteoprotective (39), while others link obesity to decreased bone integrity (33). Obesity, defined as a body mass index (BMI) equal to or greater than 30 has been associated with adverse health outcomes (30), has reached epidemic proportions in the United States (U.S.). Some projection models indicating by the year 2040 51% of U.S. women could be classified as obese (31). Along with the increasing obesity rates, the prevalence of osteoporosis has likewise increased. Moreover, these rates could be underreported; if the current diagnostic criteria was replaced with the National Bone Health Alliance diagnostic criteria the prevalence rates in U.S. women may actually be 2-fold higher than currently reported (45).

The risk factors associated with osteoporosis include age, race, and sex. Additionally, modifiable risk factors (6) include glucocorticoid use, caffeine and alcohol intake, and smoking status (2). Two potentially overlooked risk factors for impaired bone health being increased body fat and decreased PA participation, particularly in young women who are overweight or obese. Although a positive relationship has been reported between BMI and bone mineral density (BMD), when body composition is separated into lean mass and fat mass components, findings are varied. Fat mass has been positively associated with bone health; however, this association did not remain significant after adjustment for total body mass and BMI (22). Total body mass and lean mass have been reported to have positive linear relationships with BMD (35). Lean mass has also been shown to have a greater positive effect on BMD than fat mass (17, 37, 46). Although absolute BMD has been found to be greater in individuals who are obese, whereas various site-specific BMD per kg of total body mass was lower for individuals who were overweight and obese weight when compared to individuals of normal weight (defined as a BMI between 18.9 and 24.9 kg/m^2) (33). As obesity is marked by an excess accumulation of fat mass (30) and women who are obese experience accelerated bone loss compared to their normal weight counterparts (23); it is increasingly important to investigate the relation between BMD and both fat mass and lean mass in young women to mitigate fracture risk particularly in early menopause (15).

The current study aimed to conduct a secondary, exploratory analysis of the relationship between BMD with body composition and PA in young women who are overweight or obese. The focus of this work was to examine both PA and body composition as they are modifiable risk factors that are directly related to BMD. Drawing from the literature, it is hypothesized that BMD would be inversely related to measures of fat mass, including percent total fat, and positively related to measures of lean mass and PA.

METHODS

This secondary data analysis utilized the Project Health dataset, which had a participant recruitment goal of n = 43-113 to maintain power in the parent study (5). As the current study is a feasibility study, independent power analyses were not conducted. The original cross-sectional study, of young Black and white women, was designed to compare sedentary behaviour, PA, and diet with the major aim of identifying differences between metabolically healthy individuals who are obese and metabolically unhealthy individuals who are obese. This age group and these race/ethnicities were recruited during the original, study due to address the gaps in the metabolic literature. Full protocols and main outcome data have been published (5). This secondary analysis focused on body composition measured via dual-energy x-ray absorptiometry scans and PA measured via accelerometers. The University of Massachusetts Boston Institutional Review Board approved the study. The authors of this study have adhered to the ethical policies set by the IJES Editorial Board (27).

Participants

Project Health inclusion criteria were U.S.-born women, age 19-35 years and BMI of 25-40 kg/m^2. Participants were excluded if they were male, were pregnant, or had been pregnant within the past 6 months, planned to become pregnant, breastfeeding, experienced a weight fluctuation >5kg in the past 6 months, had any issues that would preclude them from being active or had a self-reported or physician diagnosis of cardiovascular disease, diabetes mellitus, thyroid disease, or HIV/AIDS. They were also excluded if they were currently taking medications to treat hypercholesterolemia, hypertension or hyperglycemia, or used dietary supplements that might affect cardiometabolic or inflammatory risk factors (i.e., antioxidants, vitamin E, aspirin, fish oil). Recruitment was conducted using flyers, posters, advertisements, social media/networking, and lecture and group announcements. All volunteers were informed about the nature and risks of the experimental procedures before obtaining their written informed consent.

Protocol

We measured body composition via dual-energy x-ray absorptiometry scans to measure whole-body total BMD (g/cm^2), the dependent variable. These scans were performed using a model General Electric Lunar whole-body scanner (General Electric Healthcare, Chalfont St. Giles, UK) and scans were analyzed with the General Electric Software (Encore 2007).

As introduced above, dual-energy x-ray absorptiometry scans were also used to measure the independent variables of lean mass (kg), fat mass (kg), and percentage (%) total fat.

Previous research has shown that a 7-day wear protocol is sufficient to capture typical PA behaviour in adults and that a minimum of 3 valid days (from the 7-day wear protocol) is needed to reliably predict typical weekly PA behaviour in adults (42). PA was measured across a minimum of 7 days, using an ActiGraph GT3X+ accelerometer that was attached to a belt and worn around the participant's waist during all waking hours, except for water activities. Accelerometers were initialized to collect data at a 30 Hz using the ActiLife software (v6.13.3). After download, raw accelerometer data were converted to counts per minute with the low-frequency extension applied. Data were cleaned and examined for valid days (minimum 8 hours of wear time) using the Troiano algorithm (41). To be included in the analysis a participant needed to have a minimum of 3 valid days, including one weekend day. Steps per day and steps per minute were estimated using the ActiLife software and time spent in moderate-to-vigorous PA (MVPA) was estimated using the Matthews cut-point (≥760 cpm) (25). This cut-point has been shown to provide a valid estimate of MVPA during free-living measurements (25, 7).

Age and race were self-reported by participants. Trained technicians conducted all anthropometric measurements. Height and weight were measured using a stadiometer and digital scale (Seca; Chino, CA), respectively, in light clothing without shoes. Duplicate measures of height and weight were taken to the nearest 0.1 cm and 0.1 kg, with a third measurement obtained if the first two measures differed by > 0.5 cm or kg, respectively. Means of the height and weight values were used in all analyses. BMI was calculated by dividing body mass (kg) by height squared (m^2) (5).

Dietary calcium intake was estimated using the 2005 Block Food Frequency Questionnaire (3). Participants self-reported food intake over the past year using a 110-item questionnaire and data was reduced into estimates of food groups and macro- and micronutrients at NutritionQuest (Berkeley, CA).

Statistical Analysis
Descriptive statistics, including mean, standard deviation (SD), number and percentages were computed for all measures. Exploratory data conducted before statistical analysis indicated that FM and LM could be included in the same model without risk of collinearity (mean VIF = 1.14). While FM and LM were found to be significantly correlated, the correlation was small which further verifies that all models could include both terms ($r = 0.35$, $p=0.01$). The variations between stratification groups for BMD, fat mass, lean mass, and key covariates were determined through ANOVA analysis.

Pearson correlation coefficients were used to assess the relationship between total BMD and lean mass, fat mass, total fat percentage, mean daily MVPA, mean daily steps, and mean steps/minute.

The dependent variable in this analysis was BMD (g/cm^2). The associations between FM and LM (independent variables) were assessed using regression coefficients for FM and LM. Hierarchical regression models were built to explore these relationships; Model 1 was adjusted for age and race only, Model 2 additionally adjusted for demographic covariates (height) as well as for behavioral covariates (daily calcium intake, and MVPA), Due to collinearity, percent total fat and percent total lean mass were analyzed in separate models.

Hierarchical regression models were also built with PA measures as the independent variables. Due to the PA variables being highly correlated; they were analyzed in separate models. Previous research indicates that peak bone mass is accrued by 30 years of age (23); thus, age groups were dichotomized into less than 30 years and greater than or equal to 30 years of age. The data was then analyzed separately in age and race dichotomized groups.

While building the models, interaction terms between lean mass, fat mass, and measurements of PA with age and race (e.g., lean mass*age, lean mass*race, fat mass*age, etc.) were tested. However, due to the lack of significance, no interaction terms were kept in the final regression model. All data were analyzed using Stata 17.0. Statistical significance was defined as p<0.05.

RESULTS

Nine participants were excluded resulting in a final analytic sample of 48 participants (84% of the total sample) (Figure 1).

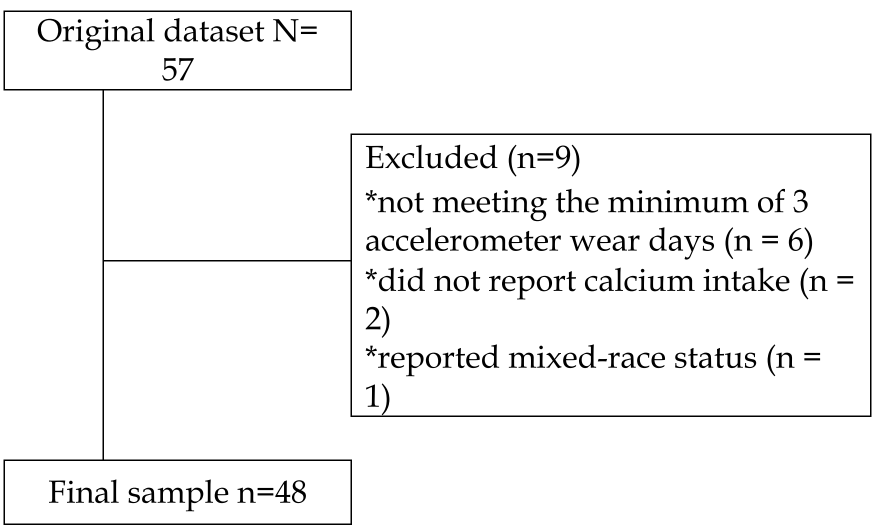

Figure 1. Consort flow diagram for included data.

The study cohort demographics are included in Table 1, of note BMD was not found to be significantly different between race or age categories, white women consumed significantly less calcium, had more steps per day and participated in more minutes of vigorous activity per week (Table 1). The study cohort had a mean BMI of 31.4 ± 3.9 kg/m^2. Sixty-three % (n = 30) were Black and 73% (n = 35) were <30 years of age (26.6 ± 4.7 years) (Table 1). MVPA demonstrated normal distribution (min = 43.3 max = 212.7), whereas steps/day had a slight right skew (min = 8420, max = 25985).

Table 1. Characteristics of the study population by Total Sample, stratified by Race, and stratified by Age.

	Total Sample (n=48)	Black (n=30)	White (n=18)	Age <30 years (n=35)	Age ≥30 years (n=13)
	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
Age	26.6 ±4.7	26.1 ±4.9	27.4 ±4.2	24.3 ±3.1	32.7 ±1.7*
Height (cm)	164.1 ±7.4	163.4 ±7.1	165.3 ±8	163.9 ±7.9	164.8 ±6
Weight (kg)	84.8 ±13.6	85.8 ±14.9	83.1 ±11.3	85.4 ±14.2	83.1 ±12.3
BMI	31.4 ±3.9	32 ±4.3	30.3 ±3.1	31.7 ±4.1	30.5 ±3.5
Percent Total Fat (%)	45.4 ±6.2	46 ±6.9	44.3 ±4.9	45.4 ±6.7	45.3 ±5
Lean Mass (kg)	43.9 ±6.1	43.7 ±6.1	44.1 ±6.2	44.1 ±6.3	43.2 ±5.4
Fat Mass (kg)	37.2 ±9.7	38.3 ±10.9	35.4 ±7.1	37.5 ±10.2	36.4 ±8.5
BMD Total (g/cm2)	1.24 ±0.08	1.26 ±0.07	1.21 ±0.08	1.24 ±0.07	1.24 ±0.09
Dietary Calcium (mg/day)	816 ±438	856 ±499	750 ±314*	816 ±468	818 ±366
Daily Steps/day	14,625 ±4155	14141 ±3150	15432 ±5450*	14803 ±4133	14146 ±4345
Steps/Minute	17.6 ±4.3	17.1 ±3.6	18.3 ±5.3	17.9 ±4.3	17 ±4.5
MVPA minutes/day	119 ±40	116 ±33	122 ±49	119 ±36	117 ±49
Light PA minutes/day	141 ±44	139 ±38	144 ±53	141 ±42	141 ±52
Lifestyle Moderate PA minutes/day	117 ±37	115 ±33	120 ±47	117 ±36	116 ±47
Vigorous PA minutes/day	1.4 ±2.2	1.1 ±1.0	2.1 ±3.3**	1.4 ±2.2	1.6 ±2.3
Sedentary time minutes/day	570 ±84.5	575 ±89	563 ±79	567 ±85	578 ±87

BMD, bone mineral density; BMI, body mass index; MVPA, moderate to vigorous physical activity; PA, physical activity; *denotes significant difference between stratification groups p<0.05; **denotes significant difference between stratification groups p<0.001

Total BMD was positively correlated with lean mass (Pearson r = 0.43, p = 0.002), while negatively correlated with % total fat (Pearson r = -0.31, p = 0.03). When stratified by race, white women maintained the positive and negative correlations seen in the total sample (Pearson r = 0.51, p = 0.03; Pearson r = -0.60, p = 0.008 respectively), Black women only retained the positive correlation between total BMD and lean mass (Pearson r = 0.43, p = 0.02). When stratified by age groups total BMD was positively correlated with lean mass only in women younger than 30 years (Pearson r = 0.52, p = 0.002). No significant correlations were found between BMD and any PA outcome (MVPA, steps per day, or steps/min).

Hierarchical modeling showed a significant positive association between BMD total and lean mass (β: 0.007, p <0.001) and % total lean mass (β: 0.005, p <0.001), and negative associations between BMD total and fat mass (β: -0.003, p = 0.01), and % total fat (β: -0.004, p = 0.01) in model 1, % total lean mass and both fat mass and % total fat maintained their significant relationship with BMD in model 2. None of the analyzed PA outcomes were significantly associated with

BMD total (Tables 2a, 2b, and 2c). When stratified by race the negative associations with fat mass in both groups but only in Black women for % total fat remained. When stratified by age categories they remained only for those <30 years of age with fat mass but both groups with % total fat (Table 3).

Table 2. Regression Analysis Models examining the associations of total bone mineral density with lean mass, fat mass, percent body fat and physical activity measures.

		β	p-value
BMD Total g/cm^2	Lean Mass (kg)*	0.007	**<0.001**
	Fat Mass (kg)*	-0.003	**0.02**
	Percent Body Fat (%) *	-0.004	**0.03**
	MVPA minutes/day**	-0.00009	0.73
	Daily Steps/day**	-0.0000004	0.86
	Steps/Minute**	-0.0003	0.9

*regression model adjusted for age, race, and dietary calcium; ** regression model adjusted for lean mass, fat mass, age, race, dietary calcium, and wear time (minutes)

Table 3. Stratified Regression Analysis Models examining the associations of total bone mineral density with A) measures of body composition and B) measures of physical activity by race and age categories.

A.		**Lean Mass (kg) ***		**Fat Mass (kg) ***		**Percent Body Fat (%) ***	
		β	**p-value**	**β**	**p-value**	**β**	**p-value**
BMD Total g/cm^2	Black (n=30)	0.006	**0.01**	-0.001	0.24	-0.002	0.26
	White (n=18)	0.008	**0.01**	-0.007	**0.01**	-0.009	**0.03**
	<30 years of Age (n=35)	0.006	**0.003**	-0.001	0.33	-0.001	0.41
	≥30 years of Age (n=13)	0.008	**0.04**	-0.006	**0.03**	-0.008	**0.03**

*regression model adjusted for age, race, and dietary calcium; age and race were dropped due to collinearity in respective stratification analyses

B.		**MVPA minutes/day****		**Daily Steps/day****		**Steps/Minute****	
		β	**p-value**	**β**	**p-value**	**β**	**p-value**
BMD Total g/cm^2	Black (n=30)	-0.0001	0.74	-0.000002	0.6	-0.002	0.64
	White (n=18)	-0.0003	0.53	-0.000004	0.4	-0.002	0.7
	<30 years of Age (n=35)	-0.0003	0.29	-0.000002	0.5	-0.002	0.48
	≥30 years of Age (n=13)	-0.00006	0.9	-0.000002	0.79	-0.001	0.83

**regression model adjusted for lean mass, fat mass, age, race, dietary calcium, and wear time (minutes); age and race were dropped due to collinearity in respective stratification analyses

Analyses were repeated for each level of PA individually, however, none were found to be significant (Table 2c), stratification analysis was also insignificant, results not shown. The outcome variable was also explored as a ratio of BMD/kg of body weight (32) (β: 3.7, $p < 0.001$) (results not shown).

DISCUSSION

Obesity and other chronic diseases that are associated with increased adiposity are a major public health concern in the U.S. (1); however, the relationship between adiposity and bone health has not been well defined in young women in their childbearing years who are overweight/obese. PA has been shown to promote bone health (14, 13); however, in populations who are obese the relationship between BMD and PA has been found to be non-significant (9). It is important to note, however, these referenced studies were conducted on women and men that were older on average and represented a variety of BMI categories, which differs from our sample population. The primary associations in the current study suggest that in young, likely premenopausal, women who are overweight/obese BMD decreases as fat mass and total fat percentage increase, and BDM increases when percent lean mass increases. Although the mean steps per day, 14,399.9 (± 4,128.3), surpass the current daily recommendations (10,000) to promote overall health, the relationships between accelerometer measured PA outcomes were not found to be significant after adjusting for age, race, and dietary calcium intake. This sample population also engaged in very little habitual vigorous physical activity with a mean of 10.0 ±4.4 minutes per week (1.4 ±2.2 minutes per day) and only 12 of the 48 meet weekly recommendations of at least 150 minutes of MVPA.

The current study investigates lean mass and fat mass as absolute values (Table 2a) and as percentages (Table 2b). In the analyses with the absolute values, it is important to indicate that the significant associations between BMD total and lean mass became insignificant when adjusting for body size (height, cm). However, investigating these relationships utilizing percent total lean and fat masses are more representative of the relationship. In women who are overweight/obese the higher the percentage of lean mass the higher their BMD total.

Our current analytic sample focused solely on young women who were overweight/obese. Historically, obesity has been associated with increased bone integrity, even to the point of being osteoprotective (39). However, evidence suggests that obesity is associated with poor bone quality and an increased risk of fracture (33). Other studies have found fat mass to be positively associated with measures of bone health (22); however, this association did not remain significant after adjustment for body weight and BMI (22). Due to previous beliefs of a positive association between obesity and bone health, obese women are less likely to receive bone scanning than women in a normal BMI category. Based on U.S. data from 2008-2014 non-Hispanic Black women were less likely to be screened for bone health conditions than their white counterparts, even when they had one or more comorbidities such as obesity (12). The current study found when the model was stratified by race the negative association remained in both groups.

While several studies have focused on other modifiable risk factors, such as caffeine and alcohol consumption, this study aimed to focus on body composition and PA specifically with young women who are overweight/obese, a group that is underrepresented in bone health literature. Although peak bone mass is reached by the age of 30 years, 90% of bone development is completed by the age of 18 years (13). Many studies have examined the changes in BMD either early (around pubescent years) or later in life (around the time of menopausal onset). The Avon Longitudinal Study of Parents and Children investigated the relationship of BMD and functional muscular strength, a marker of lean mass, during infancy and adolescence. Results showed that low functional muscular strength, when adjusted for lean mass in infancy was associated with lower adolescent BMD, suggesting that the association between lean mass and BMD may differ by life stage (18). Because body composition during infancy can affect bone health in adolescence, body composition in early adulthood could have a similar enduring effect on bone health in later years. Research studies, such as ours, can identify potential modifiable factors associated with osteoporosis before menopause.

Particularly in young individuals, calcium intake and physical activity participation have been found to be predictors of bone health (6). Our data collection included both of these variables, however, in our neither of these variables were found to be significant in the models. Some explanations for this could be from the sample population consuming far below the CDC daily recommendations of 1,000 mg of calcium per day (6) and while there are no current recommendations for sedentary time allotment, the mean time spent being sedentary for this sample population was extensive (4,028 ±1,312) minutes per week.

In the current study, BMD was not significantly associated with mean daily MVPA, daily steps, or steps/min. Repeating the analyses in site-specific weight-bearing locations such as leg BMD or pelvic BMD yielded similar results (data not shown). Prior recommendations have been for women who are obese to walk at least 12,500 steps per day to have a significant impact on lean mass, fat mass, and indicators of metabolic disease (21). In our study sample the mean steps per day were over this threshold; these women could likely be getting osteoprotective benefits via more stable lean mass and fat mass levels than directly from ground reaction forces of daily movement. It has previously been reported that there is a significant positive association between metabolically unhealthy obesity and lumbar BMD (26). The current study included women that fall into this category. Because the sample population included women who are metabolically unhealthy, the non-significant outcomes on BMD by lean mass and PA participation found in our findings could be explained by their disease state, in combination with the limited sample size.

BMD has also been associated with a number of mechanical forces (from gravitational forces resulting from body mass and strain forces resulting from lean mass contractions during PA) applied to the bone by the skeletal muscular system (19) in women with less fat mass than our sample. Mechanical forces are placed on the body particularly during weight-bearing activity, an example of the mechanostatic theory; thus, it is important to investigate the relationship between PA and BMD. This functional adaptation is a derivative of Wolff's Law (36). For example, during the gait cycle, force is applied to the body as the heel strikes the ground and the forces experienced are a combination of ground reaction forces (or gravitational forces) and muscular reaction forces (or strain forces). Theoretically, the loading mechanism's effect of bone development suggests that an increased body weight provides tensile forces that strengthen bones to support their body weight (34), which is a demonstration of increased gravitational force. However, the mechanostatic theory suggests that forces impact bone to a greater extent when they are more muscular (or strain) in nature, rather than purely gravitational (44). Whereas some studies have indicated an overall positive relationship between PA and BMD (8, 28), other studies indicate that the effect of PA varies by BMI (9). Moderate-to-vigorous PA (MVPA), especially vigorous PA, has a positive impact on BMD (14).

Boyer et al (2011) found that women weighing ~78.7 kg needed 1,638 steps per day to maintain healthy femoral BMD, however, this level was at a habitual walking pace of 1.0 m/s per day (4). With higher body weight and a faster walking pace greater force is generated, requiring less steps to elicit bone benefiting results. While our study participants far exceeded both the recommendation of 10,000 steps per day for average daily step count, as well as the value reported by Boyer et al, "habitual walking pace" was not assessed; we analyzed daily mean steps/min. Tudor-Locke et al (2011) characterized cadence bands by mean steps/min (43). It is possible that the steps taken in the current study were taken below a threshold cadence fast enough to elicit bone-beneficial results. Tudor-Locke's research could serve as a reference point in future studies to not only investigate total steps taken per day but also what percentage of those steps are taken within these cadence bands are necessary to prompt positive bone health outcomes.

While preserving power in our analyses was important, an independent power analysis was not conducted outside of its parent study. However, due to the significant findings of this feasibility study, they should be viewed as preliminary, and it is reasonable to extrapolate as we increase the number of observations within this sample population of racially diverse young women who are overweight/obese, we could see similar trends as were found in our analyses.

Several limitations in our study are noteworthy. Our data set had a relatively small sample of women, which may have limited our ability to identify associations with PA outcomes were they to exist. Due to this limitation, our study should be considered as a feasibility study invoking further investigation into potential relations between BMD and fat mass and lean mass in a larger cohort. The PA measurements analyzed in this study also do not differentiate between aerobic and resistive activity. Our sample was a convenience sample and was restricted to young women from an urban area. Thus, our results are not generalizable to males or other age groups or regions. Finally, we did not assess menopausal status although our young adult ages (26.6 ± 4.7 years) are younger than the typical menopause onset age. However, despite these limitations, our approach had several strengths. Our study utilized precise and accurate measurements of BMD, lean mass, and fat mass using dual-energy x-ray absorptiometry and an objective measure of PA using accelerometry. Few studies have previously focused specifically on young women who may still be in the bone accrual stages. Our sample was weight-stable, which is of importance. Weight loss in adults who are obese frequently results in BMD loss in weight-bearing locations but not total BMD (38). Particularly due to the cross-sectional nature of this study, ensuring that the sample studied did not have recent changes in weight status mitigates potential confounding effects of weight loss.

In summary, our results indicate that BMD is positively associated with percent lean mass, negatively associated with percent fat mass, and was not associated with any of the accelerometer-derived PA outcomes investigated. While a single study should not alter clinical practice, our results, if confirmed, emphasize the importance of osteoporosis screening among women, particularly Black women, who are overweight/obese. To prevent future osteoporotic risk, maintenance of a higher percent lean mass and lower percent fat mass may be advantageous. Future studies are needed to further investigate and confirm the non-significant relationships between BMD and PA in larger diverse samples of young women as well as to investigate the mechanism of action driving the different relations between BMD and body composition by race.

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