
Influence of Body Composition, Oral Contraceptive Use, and Physical Activity on Bone Mineral Density in Premenopausal Women

VANESSA D. SHERK[†], CLINT D. HOWARD[†], MICHAEL G. BEMBEN[‡], and DEBRA A. BEMBEN[‡]

Department of Health and Exercise Science, University of Oklahoma, Norman, OK, USA

[†]Denotes graduate student author, [‡]denotes professional author

ABSTRACT

Int J Exerc Sci 2(1): 28-37, 2009. In premenopausal women, low bone density may reflect attainment of a lower peak bone mass which can increase risk of osteoporosis after menopause. The purpose of this study was to examine the relationship between total body, lumbar spine, and proximal femur bone mineral density (BMD) and body composition and oral contraceptive (OC) use in 18-30 year old women. Sixty-five healthy women, split into groups of oral contraceptive users (OC, n = 36) and non oral contraceptive users (Non-OC, n = 29), completed Baecke physical activity, calcium intake, and menstrual history questionnaires. Total body, AP lumbar spine, and dual proximal femur scans were performed using Dual Energy X-Ray Absorptiometry (DXA). Body composition measures were obtained from the total body scan analysis. No significant differences were found for BMD in OC users and non-users. Bone free lean body mass (BFLBM) and weight were positively correlated to all BMD sites, and fat mass was related to total body and L1-L4 spine BMD ($p < 0.05$). Stepwise regression analyses determined that weight was a significant predictor for all BMD sites ($p < 0.05$). When separating the two components of body weight, BFLBM was a significant predictor for all BMD sites, and fat mass only predicted total body BMD. In conclusion, this study indicates that weight and BFLBM are significant contributors to BMD in young healthy premenopausal women, and OC use did not influence the relationship between BMD and BFLBM.

KEY WORDS: Hormonal contraceptives, bone free lean body mass, bone density, DXA

INTRODUCTION

Bone loss prior to menopause is being identified more frequently and factors associated with these losses deserve consideration since low bone mineral density (BMD) predisposes women for developing osteoporosis later in life (4, 50). In premenopausal females, low BMD may reflect attainment of a lower peak bone

mass and/or progressive bone loss after peak bone mass (19). Potential causes for low BMD in premenopausal women include insufficient levels of physical activity, low body weight, and hormonal abnormalities; factors which are interrelated. However, their individual associations with BMD are less clear.

Bone responds dynamically to the presence or absence of different forces with changes in size, shape, and density (12). There is strong evidence that weight bearing physical activity is associated with increased BMD values (6, 14, 15, 26, 42, 43). College-aged female athletes with low body weight have been reported to have higher BMD values than age-matched sedentary females of average and low body weight (26). Exercise-induced mechanical loads positively affect BMD either by the impact forces created during the activity, or by developing stronger and more efficient musculature, which is able to exert more force on bones (20). Physical activity and improved muscular function also improve balance and gait to reduce the risk of falls and subsequent fractures often associated with osteoporosis (20).

Body weight affects BMD by affecting the mechanical stresses placed on the skeleton (8, 22, 23, 35). However, composition of the weight may be more important than body weight alone. Previous studies have reported positive associations between lean body mass and BMD in women (18, 38, 43, 45). Wallace and Ballard (44) reported that lean mass predicted as much as 79% of the variance in bone mineral content (BMC) in young eumenorrheic women. Wang et al. (45) also found that bone free lean tissue mass was a stronger predictor of BMD than fat mass in women 20-25 years of age. A recent study in postmenopausal women also documented that bone free lean body mass exerted a greater impact on total body, lumbar spine, and total hip BMD than fat mass (18). According to Reid (35), BMD is influenced by lean mass because of muscular forces placing localized stresses on bone and fat mass because of its loading

effect on the skeleton, and fat acts as a peripheral site for the conversion of androgens to estrogens. Estrogen has a critical regulatory role in bone turnover and calcium homeostasis (24), thus, variations in endogenous and exogenous estrogen levels could potentially affect BMD.

Bone density relates closely to menstrual regularity, and amenorrhea and oligomenorrhea are commonly found in highly active females (2, 36). A study by Cobb et al. (10) found that BMD was 3-6% lower in oligo/amenorrheic runners compared with eumenorrheic runners. In addition, delayed menarche has been associated with increased risk of irregular menstrual cycles in early adulthood and low peak bone mass (2, 46). Effects of oral contraceptives on bone metabolism depend on covariates such as skeletal maturity, physical activity levels, dose and type of oral contraceptive, and the length of OC use (24). Therefore, the effects of oral contraceptives on bone health remain controversial as OC use has been associated with lower BMD (24, 32, 48), positive effects on BMD (24) and no effect on BMD (24).

Understanding the relationships between physical activity, body composition, and OC use and bone density in young women can be of benefit to osteoporosis prevention later in life. The purpose of this study was to examine the relationship between total body, lumbar spine, and proximal femur BMD and body composition in 18-30 year old women. The secondary purpose was to examine the relationship between oral contraceptive use and physical activity and BMD values. It was hypothesized that physical activity and bone free lean body mass would predict BMD.

METHOD

Subjects

Sixty-five healthy females from the Norman, OK area between the ages of 18-30 years volunteered to participate in this cross-sectional study. Subjects were grouped according to oral contraceptive use; females who currently use oral contraceptives (OC, $n = 36$) and those who did not use oral contraceptives (Non-OC, $n = 29$). Subjects were excluded if they were pregnant or had any history of bone disease or current medication use that could affect BMD. All subjects completed a Baecke Questionnaire of Habitual Physical Activity (3), which provides an estimation of current occupational, sport, and leisure time physical activity. A food frequency questionnaire was used to assess current daily calcium intake (28). A menstrual history questionnaire developed specifically for use in our laboratory documented the length and frequency of menstrual cycles, and history, duration, type and dose of OC use. This study was approved by the Institutional Review Board at the University of Oklahoma.

Bone Mineral Density and Body Composition Measurements

Dual Energy X-Ray Absorptiometry (DXA) (Lunar DPX-IQ software version 4.7b, Madison, WI) was used to measure the BMD (g/cm^2) of the total body, the AP lumbar spine, and the proximal femur (femoral neck, trochanter, and total hip). Body composition was measured during the total body scan and was reported as body fat %, fat mass, and bone free lean body mass (BFLBM). Scans were performed by a single technician. In the Bone Density Laboratory, coefficients of variation for *in*

vitro precision and accuracy for the spine phantom are 0.6% and 0.8%, respectively. Technician precision for the spine and total body BMD is 1.0 %, and 0.7% (total hip) for the proximal femur.

Data Analysis

Data are reported as means \pm SE. SPSS for Windows version 15.0 (SPSS, Inc., Chicago, IL) was used to execute all statistical analyses including descriptive statistics. One-way ANOVA was used to compare age, height, weight, physical activity, calcium intake, body composition variables, and BMD and BMC variables for OC users and Non-OC users. Correlation coefficients were used to determine relationships between BMI, fat mass, BFLBM, physical activity, calcium intake, menstrual status, and BMD. Stepwise multiple regression analyses were used to determine the predictability of physical activity levels and body composition to the BMD variables. The independent variables weight, physical activity score, OC use duration, and calcium intake were used as predictors of BMD. Additional regression analyses were run with the independent variables fat mass, bone free lean body mass, physical activity score, OC use, and calcium intake in order to separate the two compartments of body weight. The level of significance was set at $p \leq 0.05$.

RESULTS

OC users reported using oral contraceptives for an average duration of 47.8 ± 6.8 months. Six of the sixty-five (9.2%) women were amenorrheic based on self-report of the number of cycles missed. Three of the amenorrheic subjects were OC users and three were not. Table 1 presents subject

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Table 1. Subject Characteristics (Mean \pm SE)

Variables	All Subjects (n = 65)	OC ^a (n = 36)	Non-OC (n = 29)
Age (yrs)	22.7 \pm 0.4	22.7 \pm 0.4	22.8 \pm 0.6
Height (cm)	164.6 \pm 0.7	163.6 \pm 0.9	165.9 \pm 1.0
Weight (kg)	56.5 \pm 0.8	57.5 \pm 1.1	55.3 \pm 1.1
BMI (kg/m ²)	20.9 \pm 0.3	21.5 \pm 0.4*	20.1 \pm 0.4
Body fat %	27.0 \pm 0.7	28.2 \pm 0.9	25.6 \pm 1.0
Fat mass (kg)	15.2 \pm 0.5	16.1 \pm 0.7*	14.0 \pm 0.7
BFLBM ^d (kg)	37.8 \pm 0.5	37.9 \pm 0.7	37.7 \pm 0.7
Calcium Intake (mg/day)	1001 \pm 59	1081 \pm 89	902 \pm 72
Total PA ^c Index	8.6 \pm 0.2	8.7 \pm 0.3	8.5 \pm 0.3

*p \leq 0.05 Significantly different from Non-OC.

^aOC, Oral Contraceptive Users

^bBFLBM, Bone Free Lean Body Mass.

^cPA, Physical Activity

descriptive characteristics for all subjects and split by OC grouping. BMI and fat mass were significantly (p < 0.05) higher in the OC group. There were no significant group differences in age, height, weight, physical activity levels, or BFLBM. While not significant, OC tended to have a higher

body fat percentage (p = 0.057). As shown in Table 2, BMD and BMC values were not significantly different between groups.

The relationships of BMD sites with physical activity, calcium intake, duration of OC use and body composition variables

Table 2. Bone mineral density (BMD) and bone mineral content (BMC) values based on oral contraceptive use (Mean \pm SE)

Site	All Subjects (n = 65)	OC ^{ab} (n = 36)	Non-OC (n = 29)
Spine L1-L4			
BMD (g/cm ²)	1.162 \pm 0.017	1.183 \pm 0.025	1.136 \pm 0.023
BMC (g)	59.20 \pm 1.12	59.86 \pm 1.48	58.37 \pm 1.72
Femoral neck			
BMD (g/cm ²)	1.077 \pm 0.019	1.098 \pm 0.026	1.051 \pm 0.027
BMC (g)	4.78 \pm 0.10	4.88 \pm 0.16	4.65 \pm 0.12
Trochanter			
BMD (g/cm ²)	0.830 \pm 0.018	0.854 \pm 0.023	0.800 \pm 0.027
BMC (g)	8.88 \pm 0.26	9.07 \pm 0.34	8.64 \pm 0.39
Total Hip			
BMD (g/cm ²)	1.048 \pm 0.021	1.072 \pm 0.029	1.018 \pm 0.030
BMC (g)	30.16 \pm 0.64	30.75 \pm 0.92	29.44 \pm 0.88
Total Body			
BMD (g/cm ²)	1.156 \pm 0.010	1.166 \pm 0.014	1.144 \pm 0.015
BMC (kg)	2.49 \pm 0.04	2.51 \pm 0.06	2.47 \pm 0.06

^aNo significant differences (p > 0.05) between groups.

^bOC: Oral Contraceptive Users

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Table 3. Relationships of bone mineral density with physical activity, calcium intake, and bone free lean body mass for all women.

	Fat Mass	BFLBM ^a	Weight	PA ^b Score	OC ^c Duration	Ca ²⁺ Intake
Total Body BMD ^d	0.31*	0.53**	0.55**	0.31*	0.02	0.16
Spine L1-L4 BMD	0.26*	0.41**	0.45**	0.23	0.14	0.12
Femoral Neck BMD	0.17	0.55**	0.47**	0.31*	0.07	0.01
Trochanter BMD	0.17	0.51**	0.44**	0.23	0.10	0.01
Total Hip BMD	0.21	0.55**	0.49**	0.30*	0.02	-0.02
PA Score	-0.02	0.43**	0.28*	.	0.03	0.07
OC Duration	0.25*	0.04	0.19	0.03	.	0.18

*p < 0.05. **p < 0.01.

^aBFLBM, Bone Free Lean Body Mass.

^bPA, Total Physical Activity Score

^cOC, Oral Contraceptive

^dBMD, Bone Mineral Density

Table 4. Predictors of bone mineral density (BMD) with weight, calcium intake, oral contraceptive use and physical activity as independent variables.

Dependent Variable: BMD (g/cm ²)	Significant Predictors	β	SEE	R ²
Total Body	Weight	0.55	0.069	0.292**
Spine L1-L4	Weight	0.452	0.124	0.192**
Femoral Neck	Weight	0.466	0.136	0.205**
Trochanter	Weight	0.444	0.129	0.184**
Total Hip	Weight	0.488	0.148	0.226**

**p < 0.01

Table 5. Predictors of bone mineral density (BMD) with bone free lean body mass (BFLBM), fat mass, calcium intake, oral contraceptive use and physical activity as independent variables.

Dependent Variable: BMD (g/cm ²)	Significant Predictors	β	SEE	R ²
Total Body	BFLBM	0.490	0.068	0.309*
	Fat Mass	0.228		
Spine L1-L4	BFLBM	0.410	0.127	0.155**
Femoral Neck	BFLBM	0.552	0.128	0.293**
Trochanter	BFLBM	0.506	0.124	0.244**
Total Hip	BFLBM	0.550	0.141	0.292**

*p < 0.05. **p < 0.01.

are shown in Table 3. The correlations between BFLBM and weight with BMD were significant at all BMD sites ($p < 0.01$). Relationships between fat mass and total body BMD and spine L1-L4 BMD were significant ($p < 0.05$). Physical activity levels were related to total body, femoral neck and total hip BMD ($p < 0.05$). Weight and BFLBM were significantly correlated with physical activity ($r = 0.28$ and 0.43 , respectively, $p < 0.05$) scores. Calcium intake and duration of OC use were not significantly related to any of the BMD sites. Duration of OC use was significantly correlated to fat mass ($p < 0.05$).

Stepwise multiple regression analyses were performed to determine significant predictors of BMD. Weight, physical activity levels, duration of OC use, and calcium intake were used as independent variables (Table 4). Additional regression analyses were run with the independent variables fat mass, BFLBM, physical activity levels, duration of OC use, and calcium intake in order to determine predictability of fat mass and BFLBM (Table 5). Weight was found to be a significant predictor for all BMD sites ($p < 0.05$) accounting for 18.4% to 29.2% of variance. As shown in Table 5, BFLBM was found to be a significant predictor for all BMD sites accounting for 15.5% to 30.9% of variance. Fat mass was also a significant predictor for total body BMD.

DISCUSSION

The focus of our study was to look at the combination of body composition, oral contraceptive use and physical activity on BMD in young, premenopausal women. Our study determined that BFLBM was the

most important predictor of BMD; compared to fat mass, calcium intake, OC use, and physical activity levels, accounting for up to 31% of the variance in BMD values. These results confirm previous findings showing LBM, fat free mass, and BFLBM to be significant predictors for all BMD sites in women of various ages (5, 18, 25, 31, 43, 49). Many studies report LBM instead of BFLBM, but LBM includes bone mass, and may artificially inflate the ability of lean soft tissue to predict BMD. Fat mass only significantly predicted BMD for the total body, also in agreement with other studies of premenopausal women that showed limited associations between fat mass and BMD (5, 25, 31). Weight was a significant predictor for all BMD sites, but BFLBM improved the predictability of BMD at the total body and hip sites. Bakker et al. (5) found fat-free mass to be the most important predictor of the 10-year development of bone mineral content and density in young adult men and women, explaining up to 27% of the variance in lumbar BMC. Fat mass was only correlated with lumbar BMD in women, and in a study by Liu et al. (25), fat mass was only related to hip BMD. Fat mass has failed to predict BMC and BMD in studies with adolescent girls (43, 49). These findings support the theory that bone loading comes more from muscular forces, and less from weight (9, 13).

While physical activity was related to BMD, it was not found to be a significant predictor. The lack of predictability may be due to collinearity between activity levels and BFLBM, as BFLBM was more strongly related to BMD, or if activity levels or types of activities performed in our sample were below modeling thresholds, such as in

swimming, which have shown to have little benefit for bone health, as compared to resistance training or impact loading sports (11, 13, 30). A limitation to this study is that we only assessed current physical activity, and did not determine lifetime bone-loading physical activity. Many of the studies showing the importance of physical activity for bone health grouped subjects by activity levels or sport (26), or assessed lifetime physical activity in older age groups (15). The modes of lifetime physical activity are likely a factor on how well physical activity improves BMD, in addition to the amount of physical activity. Recently, Ilich and Brownbill (18) reported that even low-impact physical activity such as walking and heavy housework had beneficial effects on bone in postmenopausal women. In a study by Hagberg et al. (15), postmenopausal women who had been moderately active for many years had higher BMD values than sedentary or endurance trained postmenopausal women. Moreover, Wallace and Ballard (44) found that lifetime weight-bearing PA contributed to 15% of the variation in lumbar spine BMC.

BMD and BMC did not differ between OC use groups, nor did duration of OC use predict BMD. Our results disagree with studies that reported detrimental effects of OC use on BMD (1, 16, 17, 32, 40). Research on the effects of oral contraceptives on bone are not conclusive, as their effects appear to be dependent on the duration of OC use, the type of OC, the age group using OC, whether it is being used to treat amenorrhea, and the BMD site being measured (1, 7, 16, 17, 32, 40, 47, 48). There may also be an interaction effect with exercise and OC use. Weaver et al. (48)

reported that an exercise + OC intervention in women had a negative impact on lumbar spine BMC after 24 months. Although the underlying mechanisms for this negative effect are not clear, calcium deficiency, suppression of endogenous estrogen levels and exogenous progestin effects have been discussed as potential causes (24). In our cross-sectional study, physical activity and OC use did not appear to interact in their effects on BMD. Both OC and Non-OC groups reported wide ranges of physical activities and BMD was similar between the two groups of women. However, this result should be interpreted with caution given the quasi-experimental research design of our study.

Oral contraceptive use did not appear to impact BMD in our cohort of young premenopausal women. Bone free lean body mass was a stronger predictor of BMD than fat mass at all BMD sites, and it was a stronger predictor than body weight for the total body and hip sites. These relationships were not modified by calcium intake, current habitual physical activity levels, or OC use. Our findings suggest that the bone free lean component of body weight exerts important biological effects on the skeleton in young women.

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