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Lean soft tissue contributes more to bone health than fat mass independent of physical activity in women across the lifespan

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ABSTRACT

Objectives: To investigate the association between lean soft tissue (LST) and fat mass (FM) on bone health variables in women across the lifespan, while taking into account the influence of objectively measured habitual physical activity (PA).

Study design: A total of 104 women, 37 young (23.3 ± 2.6 years), 28 middle-age (49.2 ± 5.4 years), and 39 old (68.3 ± 6.4 years) participated in this cross-sectional study. All underwent a DXA scan and wore a pedometer for 7 days.

Main outcome measures: Bone mineral content (BMC) and BMD of the whole body (WB), lumbar spine (LS) and proximal femur (PF), and body composition (FM and LST) were assessed with DXA and PA (steps/day) was assessed from 7 day pedometer counts.

Results: LST was significantly and positively associated with PF and LS BMD ($r = 0.34$; 0.67, $p < 0.05$), and WB, PF and LS BMC (r range = 0.41–0.59, $p < 0.05$) in all age groups and WB BMD in the middle-age group ($r = 0.72$, $p < 0.05$) independent of PA, FM, and hormonal status. FM was not positively associated with any bone variable in any age group when adjusted for PA, LST, and hormonal status. PA was significantly associated with WB BMD in the middle-age group ($r = 0.60$, $p < 0.05$), independent of LST, FM, and hormonal status.

Conclusions: LST contributes more to bone health in women across the lifespan than FM, independent of PA and hormonal status.

1. Introduction

Body weight, body composition, and physical activity (PA) have all been implicated as determinants of bone mineral density (BMD). It is well established that body weight is one of the main determinants of BMD in both pre- and postmenopausal women [1]. Postmenopausal women with low body mass index (BMI) (<19 kg/m^2) are at a significantly greater risk for osteoporosis than normal weight women, and as BMI increases, the risk for osteoporosis decreases [2]. Similarly, PA plays a major role in maximizing and maintaining bone mass during childhood and into adulthood and minimizing the loss as we age [3].

The association between body composition (i.e. fat and lean mass) and bone mineral content (BMC) and BMD is, however, not as conclusive and continues to be of debate. Generally, lean soft tissue (LST) appears to be a greater predictor of BMD [4–8] and BMC [9] than fat mass (FM) in pre- and perimenopausal women, although the opposite has also been reported [10,11]. Studies on postmenopausal women are equivocal regarding the association between LST, FM and BMD and/or BMC as some have reported a greater influence of FM [10,12–14], whereas other have reported a greater influence of LST [4,6,9,15–17], although FM appears to become more important with advancing age [4,6,7]. Furthermore, changes in FM appear to be more important for BMD than changes in LST in postmenopausal women [17], whereas changes in LST appear more important in younger post- and premenopausal women [18].

It is well known that habitual PA has favorable effects on body composition and is associated with reduced weight and body fat mass [19]. Despite this, only limited literature in this area [4,10,14,15,20] has considered the influence of PA on bone health, however, the authors did not include PA in their analysis as PA was not associated with the bone health measures. PA could, in fact, contribute to the discrepancy in the association of LST, FM and bone health variables as a confounder because LST, but not FM, has been reported as a significant predictor of BMD in physically active pre- and postmenopausal women whereas FM and

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LST both correlated significantly with BMD in sedentary controls [10,20,21]. Moreover, from a measurement perspective, most studies have only used questionnaires to assess PA instead of objective measures.

Thus, the purpose of the present study was to investigate the association between LST and FM on bone health variables in women across the lifespan, while taking into account the potential influence of objectively measured habitual PA.

2. Methods

A total of 104 women between 20 and 29 and 40 and 85 years of age were recruited for the study. They were predominantly Caucasian (87.7%), the remaining being Asian-American (6.6%), African-American (2.8%), and Hispanic (2.8%). The women had to be healthy and free-living, non-smokers, and free of uncontrolled cardiovascular problems and orthopedic limitations. Pregnant women or those planning pregnancy were excluded due to the unknown effects of radiation to an unborn fetus. Participants were included regardless of BMI, hormonal use (hormone replacement therapy, birth control) and bone medications. The women were divided into three age groups: young (20–29), middle-age (40–59) and old (60–83 years old). All participants signed an informed consent form prior to participating in the study, which was approved by the University of Illinois Institutional Review Board.

2.1. Anthropometry and health history

Height was measured with a stadiometer (Seca 242, Hamburg, Germany) to the nearest 0.1 cm and weight recorded on a calibrated digital scale (Tanita, Model BWB-627A) to the nearest 0.1 kg without shoes and wearing light weight clothes. The average of three trials was used for data analysis. Self-administered health history questionnaires provided information regarding general as well as bone health (medication, and supplements) and hormone use.

2.2. Body composition and bone mineral density assessments

Whole body LST, FM, BMC and areal BMD were assessed using dual X-ray absorptiometry (DXA) (Hologic QDR 4500A, software version 11.2, Bedford, MA, USA). In addition, BMC and BMD of the lumbar spine (LS; L1-4) and left hip [proximal femur (PF) and femoral neck (FN)] were assessed. The DXA machine was calibrated daily using phantoms as recommended by the manufacturer. The precision for repeated DXA measurements of interest are <1–1.5% in our laboratory.

2.3. Physical activity

Current habitual PA level was assessed with pedometers (Yamax Digi-Walker SW-200, New-Lifestyles, Inc., Lee's Summit, MO, USA) which the participants were asked to wear for 7 consecutive days. The subjects were instructed to attach the pedometer to the waistband on the right or left hip, just above the hip bone and record the total number of steps in an accompanying log for each day as well as the times when the pedometer was put on in the morning and removed at night. Participants were instructed to use the pedometer during all waking hours except if sleeping, bathing, or swimming. Days of recorded data ranged from 4 (one subject) to 7 and the average number of steps per day was used for analysis.

2.4. Statistical analysis

This study was a part of a larger research comparing physical function in young and older women. For that research, it was determined that 35 persons per group were needed to detect an effect size of 0.7 for the variables of interest including BMD, BMC, and PA (80% power, α-level 0.05). Such power allows detection of group differences of 0.1 g/cm^2 (WB, FN, and LS BMD), 210 g (WB BMC), 6 g (LS BMC), 3.5 g (PF BMC) and 2300 steps/day (PA) in this study. Furthermore, it was determined that 35 persons per group would allow detection of medium-to-large (r = 0.3–0.5) effects in regressional analyses. Statistical analysis was performed using SPSS statistical software, version 18.0.0 for Windows. The data was inspected for normality and outliers. Weight and FM were non-normally distributed and were normalized by $\log_{10}$ (weight) and square root (FM) transformations. Analysis of variance (ANOVA) was used to assess age group differences in body composition, physical activity and bone, with Post Hoc comparisons using the modified Bonferroni comparison to account for the family wise error rate. Pearson correlations were performed between PA and bone and body composition variables within each age group. Hierarchical multiple linear regression analysis was performed to determine the association of LST, FM and PA to BMC and BMD, both separately and in the same equation, with adjustments for hormonal status (birth control use in young women, estrogen replacement therapy in middle-age and old women, and menopausal status in middle-age women) and years since menopause in the old women. Additionally, height was also controlled for when BMC was the dependent variable to minimize differences due to body size. No adjustments were made for bone medication/supplements as these variables were not positively related to any bone measure and were taken on advice from a physician in response to poor bone health. Furthermore, controlling for bone medication/supplements resulted in some multicolinearity in the models. Group differences and relationships between variables were determined significant at α-level < 0.05.

3. Results

Subject characteristics are presented in Table 1. In addition to significant age differences by design, significant group differences were observed in height and LST where the old women were shorter and had less LST than both the middle-age and young women. The young group also weighed significantly less and had significantly lower absolute and relative FM than both the middle-age and old women. The old women averaged significantly fewer steps/day compared to the middle-age and young women.

Table 2 presents bone outcomes measured by DXA. As expected, lower FN BMD and BMC with advancing age was observed as the middle-age women had on average 13.9% and 9.3% lower FN BMD and BMC, respectively, compared to the young women ($p < 0.05$), and the old women had 8.7% and 10.3% lower FN BMD and BMC, respectively, than the middle-age women ($p < 0.05$). No other differences in BMC or BMD between the middle-age and young women were observed. The old women had on average 10.1% and 9.9% lower WB BMD, 13.4% and 13.6% lower WB BMC, and 13.0% and 11.6% lower LS BMC than the young and middle-age women, respectively ($p < 0.05$), and 13.2% and 7.3% lower PF and LS BMD, respectively, compared to the young women ($p < 0.05$).

3.1. Relationship between current physical activity, bone variables and body composition

PA was not related to any BMD variable in the young age group (Table 3). In the middle-age group, however, PA was significantly positively related with BMD of the WB and FN. This relationship was independent of body composition (i.e. LST and FM) and hormonal status at the WB ($p = 0.002$), explaining additional 19.9% of the variance in WB BMD. In contrast, a significant negative relationship was found between PA and LS BMD in the old age group (Table 3).