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Original Article

The Association of Lean Mass and Fat Mass With Peak Bone Mass in Young Premenopausal Women

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Abstract

Total body mass is a major determinant of bone mass, but studies of the relative contributions of lean mass (LM) and fat mass (FM) to bone mass have yielded conflicting results. This is likely because of the use of bone measures that are not adequately adjusted for body size and, therefore, not appropriate for analyses related to body composition, which is also correlated with body size. We examined the relationship between body composition and peak bone mass in premenopausal women aged 18–30 yr using both size-dependent and size-adjusted measures of bone density and body composition, as well as statistical models adjusted for size-related factors. We measured total bone mass and areal bone density using dual-energy X-ray absorptiometry, and used established formulas to calculate estimates of volumetric (size-adjusted) bone density. LM tended to be positively associated with bone both before and after adjustment for size-related factors. FM and body fat percentage, however, were positively associated with size-dependent bone measures, but adjusting for size removed or reversed this association. These findings suggest that the association between bone mass and body composition, especially FM, is dependent on the bone measures analyzed, and that determining the most appropriate size-adjustment techniques is critical for understanding this relationship.

Key Words: Body composition; bone mineral density; dual-energy X-ray absorptiometry; peak bone mass; premenopausal women.

Introduction

Low peak bone mass during young adulthood is associated with increased risk of osteoporosis *(1,2)* and of fracture *(1)*, and therefore understanding modifiable factors associated with low peak bone mass is important in formulating osteoporosis-prevention strategies. Although total body mass is recognized as a major determinant of bone mass in women of all ages *(3–5)*, the roles played by the components of body mass (i.e., lean mass [LM] and fat mass [FM]) remain unclear. Epidemiologic studies of the relative contributions of LM and FM to bone mass in women have yielded conflicting results, and although some of this variability can be attributed to differences in the age and menopausal status of study populations *(6–10)*, results within homogenous groups also vary based on the methods used to measure and analyze bone mass and body composition *(11–13)*. In studies of premenopausal women at or near their peak bone mass, LM tends to be positively associated with bone mass measures, whereas the association between FM and bone mass is less consistent. Although several studies report a positive association between FM and bone mass *(10,14–17)*, while others did not observe any association *(6,7,12,17–22)*, and one study reported an inverse association *(11)*.

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These conflicting data are likely the result of confounding by factors related to body size. Existing studies used bone measures that are actually only estimates of true bone density; these measures are not adequately adjusted for body size or bone size and, therefore, are not appropriate for analyses related to components of body composition, which are heavily influenced by body size. Most of these studies *(6,7,14−22)* reported and analyzed bone mass as areal bone mineral density (BMD) in grams per centimeter squared, a measure that is not adjusted for bone thickness and, thus, does not reflect true volumetric bone density. Bone thickness is proportionate to body frame size (i.e., taller individuals tend to have thicker bones), such that areal BMD overestimates true bone density in taller individuals and underestimates true bone density in smaller individuals *(13)*. Differences in bone thickness can, therefore, result in spurious associations between areal BMD and body composition measures, as body composition is also correlated with body frame size *(13,23)*.

Two volumetric bone density estimates have been proposed to replace the areal BMD measure as better estimates of true bone density: height-adjusted bone mineral density (BMD/ht) and bone mineral apparent density (BMAD, Table 1). For both of these measures, bone mass in grams (referred to as bone mineral content, BMC) is adjusted for height and bone area (BA) *(10,24)*. Although these measures do provide some adjustment for bone thickness, the correction factors used (i.e., height and BA) are imperfect surrogates for bone volume *(23)*. Furthermore, use of the volumetric estimates of bone density may not be appropriate for analyses of body composition, as both height and BA are more strongly correlated with LM than with FM. Thus, using the volumetric estimates would tend to underestimate the association of bone mass with LM more than with FM *(11)*.

To address this problem, Prentice et al (1994) *(23)* suggest estimating volumetric bone density by adjusting bone mass for size-related factors in multiple regression analysis. To do this, the unadjusted bone mass measure (BMC) is used as the dependent variable and the body size measures weight, height, and BA are included as independent variables. This approach maximizes the likelihood that appropriate adjustment has been made for differences in bone size and body size and minimizes the possibility of spurious associations based on these size-related factors. Error may be reduced further by using measures of body composition that are independent of body size, such as body fat percentage and percent LM, rather than the size-dependent FM and LM measures.

Few studies of bone mass and body composition in premenopausal women have used size-adjusted measures (e.g., volumetric bone density estimates, body fat percentage) in their analyses, and the true association between peak bone mass and body composition, especially FM, remains unclear. We examined this relationship using both established and size-independent measures of bone mass and body composition as well as statistical methods to adjust for size-related factors.

Methods

Study Design and Population

We conducted a cross-sectional analysis of 186 healthy, premenopausal women aged 18−30 yr who participated in the UMass Vitamin D Status Study from March 2006 through June 2008 at the University of Massachusetts at Amherst. Women were ineligible for the study if they (1) were pregnant or not currently menstruating; (2) were currently experiencing untreated depression; (3) self-reported a history of high blood pressure or elevated cholesterol, kidney or liver disease, bone disease, such as osteomalacia, digestive disorders, rheumatologic disease, multiple sclerosis, thyroid disease, hyperparathyroidism, cancer, type 1 or type 2 diabetes, or polycystic ovaries; or (4) were taking corticosteroids, anabolic steroids, anticonvulsants, cimetidine, or propranolol. All study assessments, including the assessment of clinical and lifestyle factors and anthropometric measures, were completed at a single study visit. Information on lifestyle factors, including menstrual cycle characteristics, diet, and physical activity measures, was self-reported on a standard questionnaire based largely on questionnaires used in the Nurses' Health Study II *(25,26)*.

Bone Mass and Body Composition Assessment

We measured aspects of bone mass (i.e., BMC, areal BMD, BA) and body composition (i.e., LM, FM) directly by dual-energy X-ray absorptiometry (DXA) using the total-body scan mode on a narrow angle fan GE Lunar Prodigy scanner (GE Lunar Corp., Madison, WI). We performed daily calibrations using the standard calibration phantom provided by the manufacturer. We analyzed all scans using the manufacturer's enCORE 2002 software package, version 6.80.002. The in vivo precision of this machine ranges

Table 1
Summary of Bone Mass Measures

Bone measure	Units	Abbreviation	Calculation
Bone mineral content	g	BMC	Measured by DXA directly
Bone area	cm^2	BA	Measured by DXA directly
Areal bone mineral density	g/cm^2	BMD (aBMD)	BMC/BA
Height-adjusted areal BMD	g/cm^3	BMD/ht	BMC/(BA × height)
Bone mineral apparent density	g/cm^3	BMAD	$BMC/(BA^2/height)$

Abbr: DXA, dual-energy X-ray absorptiometry.