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Original Article

Associations of Fat Mass and Fat Distribution With Bone Mineral Density in Chinese Obese Population

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Abstract

The purpose of the study was to investigate the associations of fat mass (FM) and fat distribution with bone mineral density (BMD) in Chinese obese population. Three hundred and forty-seven Chinese obese females and 339 males aged 20–39 years were analyzed. Lean mass (LM), FM, percent body fat (%BF), android FM, gynoid FM, and total and regional BMD were measured using dual-energy X-ray absorptiometry. Fat distribution was assessed by android-to-gynoid FM ratio (AOI). As a result, increased central body fat had an inverse association with total and leg BMD in females but not in males. Increased FM and %BF were positively associated with arm, trunk, and pelvic BMD in Chinese obese females. Increased FM was positively associated with total, rib, and trunk BMD in Chinese obese males. The results remained almost unchanged after adjusting for LM, and LM was significantly positively associated with spine BMD in female group. FM was positively associated with trunk BMD in male group after adjusting for LM. AOI was inversely associated with total and leg BMD, and %BF was positively associated with arm, trunk, and pelvic BMD when replacing FM with %BF in female group. The results remained almost unchanged after adjusting for LM. There is no significant association in male group when replacing FM with %BF. In conclusion, our findings demonstrate that there are different associations of FM and fat distribution with BMD, and AOI has a negative association with BMD.

Key Words: Bone mineral density; fat distribution; fat mass; obesity.

Introduction

Osteoporosis is a major public health problem with growing prevalence. Approximately 9 million adults in the United States have osteoporosis, and more than 48 million have low bone mass, placing them at increased risk for osteoporosis and broken bones *(1)*. Obesity, another common disease, has been demonstrated to be closely related with osteoporosis *(2–4)*. Bone mineral density (BMD) has been widely accepted as a surrogate measure for the diagnosis of osteopenia and osteoporosis *(5,6)*. BMD is highly related to body weight, such that individuals with higher body weight have increased bone size and bone strength *(7,8)*. However, the relative contribution of lean mass (LM) and fat mass (FM) to the variation in BMD has been highly contentious. Some studies have indicated that LM, not FM, is associated with BMD *(9–16)*; other studies by Reid et al *(17–20)* have demonstrated that FM, not LM, is an important determinant of BMD. Moreover, other studies have found that both FM and LM were significant predictors of BMD *(21–24)*. Although the associations between FM and BMD in different

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ethnicities are inconsistent, most previous studies were based on Caucasian population, and the results cannot necessarily be extrapolated to Asian population. Chinese study has found that increased central body fat had an inverse association with BMD (25). Another Chinese study also demonstrated recently that FM is inversely associated with BMD beyond its weight-bearing effect, whereas abdominal fat in women and limb fat in men seems to have the greatest effect on BMD (26). Moreover, Korean studies demonstrated that abdominal obesity was significantly associated with bone mineral content independent of total FM (27). Indian studies investigated in non-obese adults indicated that total percent body fat (%BF) and regional fat have positive association with BMD at all sites in men and women (28). These conflicting clinical and epidemiologic studies suggest a complex influence of FM and fat distribution on BMD. To the best of our knowledge, there are still few studies engaged directly in obese population to investigate the association between FM and its distribution and BMD.

The above facts prompted us to evaluate the different associations of FM and central fat distribution with BMD directly in Chinese obese adults.

Subjects and Methods

Subjects

A total of 686 Chinese obese adults, whose body mass index (BMI) ≥28, aged from 20 to 39 yr were included in Zhejiang Provincial People's Hospital from January 2009 to August 2013. Those with known metabolic bone diseases or those under any medications likely to influence BMD were excluded from the study. Twenty-three female participants were excluded because of hysterectomy. In the end, 347 females and 339 males were included in the analysis. Written informed consent was obtained, and the study was approved by the Ethics Committee of the Zhejiang Provincial People's Hospital.

Demographic, Anthropometry, and Body Composition Measurement

All subjects completed a demographic questionnaire. Participants who smoked at least 1 cigarette per day or drank alcohol once a week for at least 6 mo were defined as smokers or drinkers. None of the subjects were heavy drinkers. All the females were premenopausal. Physical measurements were obtained based on standardized protocol. Height was measured without shoes to the nearest 0.1 cm, weight with only light clothing to the nearest 0.1 kg (Detecto, Webb City, MO). All values were recorded as the mean of the 3 measures. BMI was calculated as body weight (kg) divided by height (m^2).

Dual-energy X-ray absorptiometry (DXA, software version 13.60.033, GE-lunar iDXA; GE Healthcare Lunar, Madison, WI) was used to measure LM, FM, %BF, android FM, gynoid FM, and total and regional BMD through whole-body scans. For the android region, the lower boundary is at pelvis cut. The upper boundary is above pelvis cut by 20% of the distance between pelvis and femoral neck cuts. Lateral boundaries are the arm cuts. The gynoid region is defined by the upper boundary below the pelvis cut line by 1.5 times the height of the android region. The height of the gynoid region is equal to 2 times the height of the android region. Lateral boundaries are the outer leg cuts. Body fat distribution was assessed by android-to-gynoid FM ratio (AOI). Regional BMD refers to the mean BMD in the regions of head, rib, arm, spine, trunk, hip, and leg. DXA was calibrated daily using a standard phantom provided by the manufacturer.

Table 1
Characteristics of the Subjects by Gender

Variables	Female (n = 347)	Male (n = 339)
Age (y)	31.7 ± 6.7	30.5 ± 7.2
Height (cm)	163.8 ± 5.1	172.5 ± 6.1
Weight (kg)	94.3 ± 15.5	111.4 ± 22.5
BMI (kg/m^2)	35.1 ± 5.4	37.3 ± 6.2
Body composition measures		
FM (kg)	40.8 ± 13.4	40.6 ± 12.2
Android FM (kg)	3.9 ± 1.4	5.1 ± 2.1
Gynoid FM (kg)	6.7 ± 2.3	6.0 ± 2.1
LM (kg)	48.1 ± 6.9	68.1 ± 12.8
%BF	44.5 ± 8.8	36.9 ± 5.2
AOI	0.6 ± 0.1	0.9 ± 0.2
Body mineral density measures (g/cm^2)		
Total body	1.26 ± 0.08	1.33 ± 0.10
Head	2.41 ± 0.28	2.10 ± 0.22
Rib	0.77 ± 0.24	0.74 ± 0.05
Arm	0.97 ± 0.10	1.10 ± 0.13
Spine	1.14 ± 0.14	1.06 ± 0.14
Trunk	1.00 ± 0.07	0.99 ± 0.08
Pelvic	1.20 ± 0.09	1.24 ± 0.13
Leg	1.31 ± 0.08	1.45 ± 0.10
Drinkers (%)	21	27
Smokers (%)	4	42

Abbr: AOI, android-to-gynoid FM ratio; %BF, percent body fat; BMI, body mass index; FM, fat mass; LM, lean mass.

Statistical Analyses

According to our existing knowledge, we specified the partial correlation between the tested predictors and the response, adjusting for any other predictors in the model, to be 0.2. Thus, we calculated that 325 patients per group would suffice to achieve the power of 0.95 with $\alpha = 0.05$. Basic characteristics of subjects were presented as mean ± standard deviation. Male and female obese population were analyzed separately to evaluate the associations of BMD with AOI, FM, and LM in multiple regression models. In model 1, we first explored the associations of FM and AOI with total body and regional BMD. We then added LM into model 1 to investigate the associations of LM with total body and regional BMD with the presence of FM and AOI in the model (model 2). In addition, the regression was rerun