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ORIGINAL ARTICLE

Association of body composition with bone mineral density in northern Chinese men by different criteria for obesity

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Abstract

Summary With impressive economic development, obesity has emerged as a critical public health issue in China. Recently it was reported that obesity has taken an adverse effect on osteoporosis. Because there is different body mass index (BMI) for obesity globally, studies based on BMI levels on association of obesity with osteoporosis were quite few. Therefore, we discussed the relationship of body composition with skeletal BMD according to WHO BMI and BMI on Working Group on Obesity in China (WGOC).

Methods A total of 502 adult men aged 20–89 were enrolled as healthy subjects for osteoporosis study at Qianfoshan Hospital, Shandong University between September 2008 and August 2010. According to WHO BMI, all subjects were divided into three groups: normal weight ($18.5 \leq$ BMI < 25 kg/m^2, $n = 202$), overweight ($25 \leq$ BMI < 30 kg/m^2, $n = 242$), and obesity (BMI ≥ 30 kg/m^2, $n = 58$). According to WGOC BMI, normal weight ($18.5 \leq$ BMI < 24 kg/m^2, $n = 137$), overweight ($24 \leq$ BMI < 28 kg/m^2, $n = 225$), and obesity (BMI ≥ 28 kg/m^2, $n = 140$). Total body and regional BMD, lean mass (LM), lean body mass index (LBMI), fat mass (FM), percent body fat (%BF) and fat mass index (FMI) were measured by dual-energy X-ray absorptiometry. Age-partial Pearson correlation analyses between body composition-related parameters and BMD. Multiple regression analyses were performed to explore the associations of BMD with LM, LBMI, FM, %BF and FMI.

Results Fat mass (FM), %BF, FMI, LM and LBMI were positively correlated with BMD at almost sites ($P < 0.001$) in all subjects. However, the relationship was not different among groups. LM, LBMI, FM and FMI were positively correlated with BMD ($P < 0.01$) in normal weight. LM and LBMI appeared significantly positive with BMD in overweight and obesity according to WHO and WGOC criteria. %BF and FMI were negative significance with BMD at total body and some regional BMD according to WHO criteria in overweight ($P < 0.05$). In two obese groups, %BF appeared negatively significant with BMD ($P < 0.05$) according to WGOC criteria, and %BF and FMI appeared negatively significant with BMD ($P < 0.05$) according to WHO criteria. In regression of independent variables as FM and LM, LM showed statistically positively significant relations with BMD at almost sites ($P < 0.05$) in all groups. FM appeared positively significant with BMD in normal groups and overweight group according to WGOC criteria. In regression of independent variables as %BF and FMI, %BF and FMI appeared statistically negatively significant relations with BMD in overweight and obesity, but %BF and FMI were inconsistent in same site.

Conclusions Lean mass (LM) and LBMI could help to determinant of BMD, and %BF and FMI were adverse to BMD in overweight and obesity. Comparing with two criteria, we found the differences in fat-related parameters and BMD according to WHO criteria were more obvious than that according to WGOC criteria. We also found that %BF and FMI were useful to research the relationship between osteoporosis and obesity at the same time.

Keywords Lean mass · Lean body mass index · Fat mass · Fat mass index · Percent body fat · Bone mineral density · Men–body mass index · Obesity

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Introduction

With impressive economic development and rapid urbanization, Chinese people have experienced remarked changes in widespread westernization of lifestyle in recent decades [1–3]. Obesity has emerged as a critical public health issue in China, for obesity could lead to many serious weight-related disorders such as hypertension, diabetes mellitus, cardiovascular disease, certain forms of cancer [4–6]. Recently, Data from the Global Longitudinal Study of Osteoporosis in Women confirmed the increased risk of fracture in underweight women but showed no protective effect of obesity [7]. Even more obesity is a risk factor of osteoporosis and its related fracture: data from the Osteoporotic Fractures in Men Study showed obese men had a significantly higher risk fracture than normal weight men after adjusted for BMD, which was particularly obvious with hip fracture [8–10]. Therefore, when we discussed the relationship between obesity and osteoporosis, we should explore the effect of the body composition such as FM, %BF, FMI, LM and LBMI on BMD. As we all know, LM was a determinant to BMD, and FM appeared controversial. The reason could be due to BMI levels related to all skeletal BMD. Clinical data confirmed low BMI (<18.5 kg/m^2) appeared to be one risk factor for osteoporosis and its related fraction [11–14], and FM could be a protective effect on BMD in underweight. Recent studies showed contradict viewpoint by showing an inverse relationship between FM and BMD in obesity [15–17].

Body mass index (BMI) can be used as a predictor for assessing obesity and related diseases, which shows good resolution among different ages, genders, races, nation, and economic development levels. Because of these reasons, the BMI categories for obesity are quite different globally. WHO international BMI categories for overweight and obesity are 25 and 30 kg/m^2 respectively in Western countries [18]. A WHO expert consultation proposed that the proportion of Asian people with a high risk of type 2 diabetes and cardiovascular disease was substantial at BMIs lower than the existing WHO cut-off point for overweight (≥25 kg/m^2) [19] The revised guidelines categorized overweight as a BMI of 23.0–24.9 kg/m^2 and obesity as a BMI ≥ 25 kg/m^2 for Asian Indians [20]. The ethnicity-specific BMI categories for overweight and obesity are 24 and 28 kg/m^2 respectively in China by Working Group on Obesity in China (WGOC), which was based on surveys on 239,972 people, aged 20–70 in 1990s covering 21 provinces [21–24]. The BMI categories in different nation should be paid more attention, because they are optimal cut-off points to prevent some chronic diseases epidemic which could not compose osteoporosis. In order to explore the association of obesity with osteoporosis in Chinese, it is necessary to select WHO BMI and WGOC BMI respectively and compare them each other. Perhaps a potentially important target on prevention and treatment of osteoporosis and related fracture in Chinese adult men was found.

Materials and methods

Subjects

A total of 515 adult men who were 20–89 years old were enrolled as healthy subjects for bone studies at Qianfoshan Hospital, Shandong University between September 2008 and August 2010. Subjects were recruited from the participants in a community-based osteoporosis prevention study. The protocol was approved by the Ethics Committee, Qianfoshan Hospital, Shandong University and informed consent was obtained from each subjects.

Exclusion criteria included any history of diseases as follows: history of metabolic bone diseases such as chronic renal disease, liver disease, thyroid disease and rheumatoid arthritis; history of disease affecting body composition such as thyrotoxicosis and hypothyroidism; history of having any medications likely to influence BMD and body composition such as thyroid hormones, glucocorticosteroids, bisphosphonates and antiobesity drugs. Besides, five men were excluded due to prostatectomy, and seven men excluded due to BMD at any of regions (≥Mean ± 3 SD). One man was excluded due to incomplete BMD data. In the end, 502 men were included in the analysis.

Each subject was required to finish a detailed questionnaire on demographic and lifestyle information about alcohol consumption, smoking, exercise outside, diet and medical history consisting of past illness and current medication. In the questionnaire, there were two types of drinking: drinkers and nondrinkers. Drinkers used to take an alcoholic beverage about twice a week (alcohol intake <20 g/day), and nondrinkers used to take no beer, wine, or hard liquor. There were two types of smoking: smokers and nonsmokers. Smokers were defined as those who have smoked at least 6 months consistently or cumulative, and whose smoking index (amounts of cigarettes per day × years of smoking) was less than 200, and nonsmokers were defined as those who have never smoked.

Anthropometry and body composition measurement

Dual-energy X-ray absorptiometry (DXA); software version 11.40.004; GE-lunar, WI, USA) was used to measure LM, LBMI, FM, FMI, %BF, total body BMD (TB) and regional BMD through whole-body scans. Regional BMD consisted of arm leg, trunk, pelvis, spine, femoral neck (FN), total femur (TF), and lumbar Spine BMD (L1–L4). For ethical reasons, we did not make any further assessments of the precision error of this equipment. According to the manufacturer brochure, this is a standardized commercial machine with an in vivo precision (%coefficient of variation) of <1 % for anterior–posterior spinal, femoral, total body BMD and body composition. DXA was calibrated using a standard phantom provided by the manufacturer, performed daily and demonstrated long-term (<2 years) CVs of ≤0.8 %.

Weight was measured to the nearest 0.1 kg with a calibrated standard balance beam scale. Height was measured to the nearest 0.1 cm with a wall-mounted stadiometer. All subjects wore light clothing and no shoes, while measured. All values were recorded as the mean of three measures. BMI was calculated as weight (kg)/height (m^2). FMI was calculated as fat mass (kg)/height (m^2), and LBMI was calculated as lean mass (kg)/height (m^2).

We selected WHO BMI and WGOC BMI for obesity to divide all subjects into three groups respectively. According to WHO criteria, all subjects were divided into normal weight ($18.5 \leq$ BMI < 25 kg/m^2, $n = 202$), overweight ($25 \leq$ BMI < 30 kg/m^2, $n = 242$), and obesity (BMI $\geq$ 30 kg/m^2, $n = 58$). According to WGOC criteria, normal weight ($18.5 \leq$ BMI < 24 kg/m^2, $n = 137$), overweight ($24 \leq$ BMI < 28 kg/m^2, $n = 225$), and obesity (BMI $\geq$ 28 kg/m^2, $n = 140$).

Statistical analysis

Statistical analysis was performed using SPSS (version 16.0 for Windows, SPSS Inc., Chicago, IL, USA). Differences in means of continuous variables such as baseline characteristics, body composition and BMD at total body and regional sites (arm, leg, trunk, pelvis, spine, FN, TF and L1–L4) were assessed by One ANOVA. Differences in frequencies (drinker, nondrinker, smoker and non-smoker) for categorical variables in groups were assessed by Chi Square. Because age is a significantly determinant to BMD, Age-adjusted Pearson correlation coefficients were detected to assess linear relationships between body composition-related parameters (LM, LBMI, FM, FMI, %BF) and BMD at total body and regional sites among groups. Because of a significant interaction between body composition-related parameters and BMD, the regression models evaluated, respectively, the associations of BMD with FM and LM, and with %BF and FMI. Linear regression of BMD at sites evaluated the independent associations of FM, LM, age height, smoking and regular alcohol consumption in one model. Linear regression of BMD at sites evaluated the independent effects of %BF, FMI, age, weight, height, smoking and regular alcohol consumption in another model. Determination coefficients, SE of estimate, beta coefficients and *P* value were calculated among groups according to WHO BMI and WGOC.

Results

Descriptive statistics

The basic characteristics of the subjects are shown in Table 1. Age and height appeared no significant differences among groups. The percentages of normal, overweight and obesity were 27.2, 44.8 and 28 % in adult men according WGOC criteria, and 40.2, 48.2 and 11.6 % according WHO criteria. The numbers of normal, overweight and obesity appeared significantly different ($P < 0.01$). LM, LBMI, FM, %BF and FMI were increased with increases in BMI. According to WHO criteria, Comparisons of LM, LBMI, FM, %BF, FMI among normal, overweight, and obesity were significantly different ($P < 0.001$). Compared to normal weight, total body and regional BMD of overweight and obesity were significantly higher (all $P < 0.001$). When comparing overweight with obesity, it showed significant difference ($P < 0.05$) except BMD at arm, leg, FN and TF. According to WGOC criteria, Comparisons of LM, LBMI, FM, %BF, FMI among normal, overweight, and obesity were significantly different ($P < 0.001$). Compared to normal weight, total body and regional BMD of overweight and obesity were significantly higher (all $P < 0.001$). When comparing overweight with obesity, it showed no significant difference except BMD at total body ($P < 0.001$), trunk and pelvis ($P < 0.01$). The number of drinker and smoker appeared not significantly different in groups.

Age-adjusted partial correlation analysis

Age-adjusted partial correlation analyses body composition-related parameters and BMD are provided in Tables 2 and 3. LM, LBMI, FM, %BF, FMI, were positively correlated with BMD at almost sites ($r = 0.193$–0.504; $P < 0.001$) in all subjects.

In normal weight, LM was positively correlated with BMD at trunk, pelvis and spine sites ($r = 0.258$–0.282; $P < 0.01$), and FM was positively correlated with trunk BMD ($r = 0.232$; $P < 0.01$) according to WGOC criteria. LM and LBMI were positively correlated with BMD at almost sites ($r = 0.159$–0.350; $P < 0.01$). FM and FMI had positive associations with BMD at trunk, pelvis, spine and FN ($r = 0.199$–0.309; $P < 0.01$) according to WHO criteria.

In overweight, LM and LBMI were positively correlated with BMD at almost sites ($r = 0.179$–0.369; $P < 0.01$) according to WGOC criteria. LM and LBMI appeared significantly positive with BMD at almost sites ($r = 0.173$–0.432; $P < 0.01$), but %BF and FMI were negative significance with BMD at total body, arm, leg, spine and FN (r = negative 0.141–0.279; $P < 0.05$) according to WHO criteria.

In obesity, LM and LBMI were positively significant with BMD at total body and almost regional sites

Table 1 Characteristics of the subjects by different BMI levels for obesity

	All subjects	Normal (18.5–23.9 kg/m^2)	Overweight (24–27.9 kg/m^2)	Obese (≥28 kg/m^2)	Normal (18.5–24.9 kg/m^2)	Overweight (25–29.9 kg/m^2)	Obese (≥30 kg/m^2)
n (% of all case)	502 (100)	137 (27.2)	225 (44.8)	140 (28)	202 (40.2)	242 (48.2)	58 (11.6)
Age (years)	62.2 ± 16.0	64.7 ± 17.1	61.4 ± 16.2	61.2 ± 14.5	64.0 ± 16.9	61.1 ± 15.7	60.9 ± 13.8
Height (cm)	1.69 ± 0.07	1.68 ± 0.07	1.69 ± 0.06	1.68 ± 0.07	1.69 ± 0.07	1.69 ± 0.06	1.69 ± 0.07
Weight (kg)	73.8 ± 11.1	62.0 ± 6.6	74.0 ± 6.3	84.9 ± 8.6	64.8 ± 7.5	77.8 ± 7.3	89.1 ± 8.1
LBMI (kg/m^2)	17.0 ± 1.8	15.6 ± 1.4	17.0 ± 1.3	18.6 ± 1.4	15.9 ± 1.4	17.5 ± 1.3	19.2 ± 1.4
FMI (kg/m^2)	7.7 ± 2.3	4.9 ± 1.4	7.2 ± 1.4	9.7 ± 1.7	5.3 ± 1.6	8.1 ± 1.4	10.6 ± 1.6
Body composition measures							
FM (kg)	20.6 ± 6.6	13.7 ± 4.1	20.7 ± 4.2	27.2 ± 4.8	15.0 ± 4.7	23.1 ± 4.1	29.7 ± 4.6
LM (kg)	43.5 ± 6.5	44.2 ± 5.7	48.7 ± 5.3	52.5 ± 6.5	45.4 ± 5.9	49.9 ± 5.8	54.0 ± 6.4
%BF (%)	29.3 ± 6.6	23.6 ± 6.1	29.8 ± 5.2	34.1 ± 4.8	24.7 ± 6.3	31.6 ± 4.6	35.5 ± 4.6
Body mineral density measures (g/cm^2)							
TB	1.158 ± 0.100	1.090 ± 0.091	1.173 ± 0.092	1.198 ± 0.099	1.114 ± 0.098	1.180 ± 0.089	1.217 ± 0.086
Arm	0.869 ± 0.094	0.823 ± 0.088	0.880 ± 0.088	0.898 ± 0.094	0.835 ± 0.091	0.887 ± 0.088	0.913 ± 0.093
Leg	1.224 ± 0.124	1.156 ± 0.121	1.242 ± 0.116	1.261 ± 0.114	1.180 ± 0.126	1.246 ± 0.115	1.284 ± 0.109
Trunk	0.960 ± 0.104	0.878 ± 0.094	0.978 ± 0.091	1.001 ± 0.086	0.903 ± 0.101	0.991 ± 0.087	1.024 ± 0.087
Pelvis	1.117 ± 0.136	1.012 ± 0.126	1.139 ± 0.116	1.185 ± 0.115	1.044 ± 0.131	1.158 ± 0.113	1.203 ± 0.123
Spine	1.133 ± 0.100	1.017 ± 0.133	1.138 ± 0.141	1.166 ± 0.132	1.048 ± 0.142	1.148 ± 0.134	1.190 ± 0.141
FN	0.911 ± 0.138	0.838 ± 0.142	0.934 ± 0.131	0.946 ± 0.118	0.862 ± 0.148	0.941 ± 0.120	0.959 ± 0.123
TF	0.981 ± 0.145	0.892 ± 0.150	1.006 ± 0.131	1.029 ± 0.121	0.925 ± 0.156	1.012 ± 0.124	1.049 ± 0.117
L1–L4	1.093 ± 0.164	1.031 ± 0.154	1.115 ± 0.168	1.119 ± 0.151	1.054 ± 0.165	1.109 ± 0.157	1.163 ± 0.154
Drinkers (%)	91 (18.1)	31 (22.6)	37 (16.4)	23 (16.4)	42 (20.5)	40 (16.4)	9 (15.5)
Smokers (%)	225 (44.8)	63 (45.9)	101 (44.9)	61 (43.6)	92 (45.5)	95 (44.9)	38 (42.6)

Mean ± standard deviation or number (%)

LBMI lean body mass index, *FMI* fat body mass index, *BMI* body mass index, *FM* fat mass, *LM* lean mass, *%BF* percent body fat, *TB* total body, *FN* femoral neck, *TF* total femur

Table 2 Age-adjusted partial correlation between body composition-related parameters and BMD

	TB	Arm	Leg	Trunk	Pelvis	Spine	FN	TF	L1–L4
All subjects									
FM	0.361***	0.234***	0.261***	0.458***	0.468***	0.373***	0.264***	0.303***	0.236***
%BF	0.207***	0.081	0.102*	0.304***	0.308***	0.246***	0.153**	0.190**	0.133**
FMI	*0*.306***	0.177***	0.193***	0.399***	0.407***	0.321***	0.213***	0.264***	0.193***
LM	0.444***	0.423***	0.443***	0.489***	0.504***	0.406***	0.362***	0.362***	0.278***
LBMI	0.382***	0.366***	0.340***	0.414***	0.423***	0.334***	0.287***	0.325***	0.203***
Normal (18.5–23.9 kg/m^2)									
FM	0.053	0.052	0.029	0.232***	0.220*	0.211*	0.188*	0.131	0.030
%BF	−0.022	−0.035	−0.082	0.108	0.110	0.094	0.097	0.062	−0.025
FMI	0.023	0.024	−0.042	0.177*	0.159	0.163	0.137	0.095	0.001
LM	0.185*	0.192*	0.298**	0.282**	0.258**	0.263**	0.217*	0.171*	0.117*
LBMI	0.147	0.161	0.150	0.199*	0.136	0.192*	0.132	0.114	0.073
Normal (18.5–24.9 kg/m^2)									
FM	0.180*	0.093	0.117	0.306***	0.309***	0.273***	0.199**	0.182*	0.098
%BF	0.063	−0.011	−0.015	0.164*	0.165*	0.150*	0.088	0.086	0.027
FMI	0.132	0.052	0.047	0.247***	0.241***	0.222***	0.140*	0.150*	0.065
LM	0.264*	0.245***	0.350***	0.334***	0.340***	0.285***	0.279***	0.239**	0.162*
LBMI	0.191**	0.191**	0.197**	0.226**	0.197**	0.193**	0.167*	0.159**	0.102

FM fat mass, *%BF* percent body fat, *LM* lean mass *FMI* Fat body mass index, *LBMI* lean body mass index, *TB* total body, *FN* femoral neck, *TF* total femur

* Statistical significance ($P < 0.05$); ** Statistical significance ($P < 0.01$); *** Statistical significance ($P < 0.001$)

Table 3 Age-adjusted partial correlation between body composition-related parameters and BMD

	TB	Arm	Leg	Trunk	Pelvis	Spine	FN	TF	L1–L4
Overweight (24–27.9 kg/m^2)									
FM	0.092	0.007	0.034	0.140*	0.163*	0.104	0.040	0.009	0.067
%BF	−0.066	−0.164*	−0.120*	−0.033	−0.015	−0.039	−0.080	−0.097	−0.036
FMI	−0.012	−0.106	−0.076	0.025	0.052	0.003	−0.056	−0.069	0.006
LM	0.321***	0.356***	0.326***	0.363***	0.369***	0.308***	0.274***	0.245***	0.224**
LBMI	0.166*	0.252***	0.171	0.179**	0.189**	0.145*	0.122	0.135*	0.118*
Overweight (25–29.9 kg/m^2)									
FM	0.064	0.068	−0.002	0.134*	0.173**	0.063	−0.007	0.042	0.032
%BF	−0.141*	−0.279***	−0.203**	−0.106	−0.081	−0.129*	−0.163*	−0.109	−0.111
FMI	−0.072	−0.209**	−0.147*	−0.027	0.013	−0.073**	−0.138*	−0.072	−0.084
LM	0.357***	0.386***	0.358***	0.416***	0.432***	0.338***	0.281***	0.266***	0.246***
LBMI	0.209**	0.279***	0.209**	0.222**	0.247***	0.173**	0.133*	0.131*	0.095
Obese (≥28 kg/m^2)									
FM	0.148	0.013	0.073	0.192*	0.196*	0.156	0.073	0.087	0.288**
%BF	−0.105*	−0.227**	−0.191*	−0.038	−0.069	−0.019	−0.132	−0.087	0.089
FMI	−0.014	−0.145	−0.101	0.013	−0.001	0.016	−0.069	−0.024	0.154
LM	0.411***	0.395***	0.436***	0.375***	0.445***	0.269**	0.301***	0.286**	0.284*
LBMI	0.254**	0.289**	0.293***	0.147	0.213*	0.088	0.204*	0.201*	0.094
Obese (≥30 kg/m^2)									
FM	0.101	−0.002	0.042	0.049	0.018	0.060	−0.097	−0.121	0.245
%BF	−0.202	−0.259*	−0.276*	−0.160	−0.215	−0.101	−0.250*	−0.337**	0.075
FMI	−0.112	−0.207	−0.214	−0.142	−0.168	−0.112	−0.187	−0.248*	0.091
LM	0.487***	0.434**	0.526***	0.326*	0.378**	0.251	0.247	0.360**	0.235
LBMI	0.261*	0.235**	0.241***	0.084	0.173	0.008	0.210	0.325*	0.027

FM fat mass, *%BF* percent body fat, *LM* lean mass, *FMI* Fat body mass index, *LBMI* Lean body mass index, *TB* total body, *FN* femoral neck, *TF* total femur

* Statistical significance ($P < 0.05$); ** Statistical significance ($P < 0.01$); *** Statistical significance ($P < 0.001$)

($r = 0.235$–0.526; $P < 0.01$) by WHO and WGOC criteria. %BF appeared negatively significant with total body, arm and leg BMD ($r =$ negative 0.105–0.227; $P < 0.05$) by WGOC criteria, however, %BF and FMI appeared negatively significant with BMD at arm, leg, FN and TF ($r =$ negative 0.248–0.337; $P < 0.05$) by WHO criteria.

Multiple regression analysis

Tables 4 and 6 showed determination coefficients and regression coefficients for FM and LM. In normal weight, there was 16.5–42.1 % of BMD variability at almost sites according to WGOC criteria, 16.8–35.7 % according to WHO criteria. In overweight, there was 10.4–20.9 % of BMD variability at almost sites according to WGOC criteria, 12.1–29.5 % according to WHO criteria. In obesity, there was 14.3–36.7 % of BMD variability at almost sites in obesity according to WGOC criteria, 15.0–44.7 % according to WHO criteria.

Lean mass (LM) showed statistically positively significant relations with BMD at almost sites (all $P < 0.05$) in all groups. Only in normal weight and overweight by WGOC criteria, FM appeared positively significant with BMD at almost sites.

Tables 5 and 6 showed determination coefficients and regression coefficients for %BF and FMI. In overweight, there was 9.5–23.6 % of BMD variability at almost sites in overweight according to WGOC criteria, and 11.3–30.8 % according to WHO criteria. In obesity, there was 19.0–36.7 % of BMD variability at almost sites according to WGOC criteria and 16.5–44.1 % according to WHO criteria. %BF and FMI appeared insignificant related to BMD in normal groups. %BF and FMI appeared statistically negatively significant relations with BMD at almost sites in overweight and obesity. However, they were inconsistent in same site.

Discussion

The present results of our research showed that the percentage of obesity in adult men was different by two criteria for obesity: that of normal weight, overweight and obesity

Table 4 Determination coefficients for FM, LM to BMD

	Normal				Overweight				Obese			
	(18.5–23.9 kg/m^2)		(18.5–24.9 kg/m^2)		(24–27.9 kg/m^2)		(25–29.9 kg/m^2)		(≥28 kg/m^2)		(≥30 kg/m^2)	
	R^2	SE of estimate	R^2	SE of estimate	R^2	SE of estimate	R^2	SE of estimate	R^2	SE of estimate	R^2	SE of estimate
TB	0.203	0.082	0.198	0.088	0.108	0.087	0.135	0.083	0.235	0.076	0.361	0.069
Arm	0.282	0.075	0.216	0.081	0.209	0.078	0.295	0.074	0.352	0.076	0.359	0.075
Leg	0.258	0.105	0.206	0.112	0.124	0.109	0.166	0.103	0.302	0.095	0.447	0.081
Trunk	0.315	0.079	0.290	0.086	0.157	0.084	0.189	0.079	0.165	0.078	0.150	0.081
Pelvis	0.394	0.099	0.357	0.105	0.176	0.105	0.210	0.101	0.254	0.098	0.254	0.107
Spine	0.165	0.122	0.168	0.130	0.141	0.131	0.136	0.125	0.079	0.126	0.178	0.134
FN	0.421	0.109	0.300	0.125	0.104	0.125	0.150	0.111	0.331	0.098	0.369	0.099
TF	0.329	0.124	0.244	0.136	0.067	0.127	0.092	0.119	0.209	0.108	0.301	0.099
L1–L4	0.091	0.147	0.050	0.162	0.106	0.157	0.121	0.148	0.143	0.141	0.168	0.149

BMD bone mineral density, *TB* total body, *FN* femoral neck, *TF* total femur Dependent variables as BMD; independent variables as FM, LM and age

Table 5 Determination coefficients for %BF, FMI to BMD

	Normal				Overweight				Obese			
	(18.5–23.9 kg/m^2)		(18.5–24.9 kg/m^2)		(24–27.9 kg/m^2)		(25–29.9 kg/m^2)		(≥ 28 kg/m^2)		(≥ 30 kg/m^2)	
	R^2	SE of estimate	R^2	SE of estimate	R^2	SE of estimate	R^2	SE of estimate	R^2	SE of estimate	R^2	SE of estimate
TB	0.175	0.083	0.211	0.086	0.149	0.085	0.147	0.082	0.241	0.076	0.360	0.070
Arm	0.255	0.077	0.221	0.081	0.236	0.077	0.308	0.074	0.367	0.076	0.441	0.074
Leg	0.237	0.106	0.238	0.110	0.160	0.107	0.184	0.104	0.313	0.095	0.476	0.080
Trunk	0.293	0.080	0.304	0.085	0.196	0.082	0.191	0.079	0.160	0.079	0.165	0.081
Pelvis	0.380	0.100	0.371	0.104	0.198	0.104	0.216	0.100	0.259	0.099	0.259	0.108
Spine	0.138	0.124	0.176	0.130	0.155	0.130	0.142	0.125	0.085	0.127	0.122	0.136
FN	0.419	0.109	0.316	0.123	0.149	0.122	0.171	0.109	0.315	0.098	0.369	0.099
TF	0.339	0.124	0.252	0.135	0.095	0.125	0.113	0.118	0.190	0.110	0.326	0.098
L1–L4	0.091	0.147	0.065	0.160	0.117	0.158	0.113	0.149	0.137	0.142	0.111	0.151

BMD bone mineral density, *TB* total body, *FN* fermoral neck, *TF* total femur Dependent variables as BMD; independent variables as %BF, FMI, weight and age

were 27.2, 44.8 and 28 % according to WGOC criteria, and 40.2, 48.2 and 11.6 % according to WHO criteria. The numbers of overweight were more than other groups. The results suggested the percentages of overweight and obesity were high, as Hou et al. [25] reported recently the prevalence of combined overweight and obesity was significantly increased in Chinese men. The body composition-related parameters (FM, %BF, FMI, LM and LBMI) and BMD at total body and regional sites gradually significantly increased among normal weight, overweight and obesity.

When the subjects were divided into normal weight, overweight and obesity, the body composition-related parameters appeared different effect on BMD. Not only by WHO BMI but also by WGOC BMI for obesity, LM and LBMI could always help to determinant of BMD at total body and regional sites in adult men, which means that LM and LBMI were strongest predictors of BMD. The results suggested that the future intervention studies to prevent loss of bone mass should focus on strategies to increase or maintain LM and LBMI. Many reports showed continent opinion [26].

According to WGOC criteria, FM appeared significantly positive with BMD at trunk, pelvis, spine, femur and L1–L4 but no significant with BMD at arm and leg. %BF appeared significantly negative with BMD in total body, arm and leg in overweight and obesity, but FMI showed no significance with BMD. According to WHO criteria, the relationships of %BF and FMI with BMD at trunk, pelvis, and femur were positive in normal weight, however, which appeared significantly negative with BMD at total body and arm, leg, femur in overweight and obesity. FM showed no significance.

Table 6 Regression coefficients (Beta) and *P* values for FM, LM to BMD in model one and for %BF, FMI to BMD in model two

	TB		Arm		Leg		Trunk		Pelvis		Spine		FN		TF		L1–L4	
	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*
Normal (18.5–23.9 kg/m^2)																		
M1:FM	0.048	0.544	0.044	0.551	0.054	0.469	0.236	0.007	0.208	0.003	0.236	0.004	0.169	0.012	0.125	0.078	0.029	0.128
LM	0.188	0.031	0.186	0.025	0.301	<0.001	0.311	<0.001	0.265	0.001	0.355	<0.001	0.355	<0.001	0.160	0.046	0.125	0.175
M2:%BF	−0.020	0.800	−0.031	0.688	−0.135	0.088	0.028	0.362	0.031	0.430	0.001	0.998	0.025	0.721	0.012	0.868	−0.024	0.772
FMI	0.021	0.787	0.021	0.784	−0.138	0.091	0.055	0.693	0.039	0.597	0.031	0.714	0.027	0.701	0.019	0.803	0.001	0.998
Normal (18.5–24.9 kg/m^2)																		
M1:FM	0.170	0.008	0.085	0.191	0.113	0.073	0.287	<0.001	0.277	<0.001	0.275	<0.001	0.180	0.003	0.168	0.007	0.099	0.153
LM	0.291	0.003	0.259	<0.001	0.349	<0.001	0.362	<0.001	0.352	<0.001	0.306	<0.001	0.284	<0.001	0.252	<0.001	0.233	0.001
M2: % BF	−0.053	0.429	−0.097	0.143	−0.134	0.043	0.010	871	0.010	0.871	0.038	0.578	−0.030	0.627	−0.017	0.798	−0.060	0.390
FMI	−0.036	0.616	−0.079	0.261	0.015	0.959	0.031	0.643	0.021	0.745	0.059	0.395	−0.034	0.604	0.003	0.961	−0.056	0.448
Overweight (24–27.9 kg/m^2)																		
M1:FM	0.099	0.118	0.008	0.898	0.046	0.470	0.149	0.017	0.174	0.005	0.125	0.047	0.052	0.414	0.020	0.764	0.064	0.318
LM	0.329	<0.001	0.375	<0.001	0.352	<0.001	0.414	<0.001	0.398	<0.001	0.342	<0.001	0.322	<0.001	0.258	<0.001	0.245	0.001
M2: % BF	−0.139	0.027	−0.238	<0.001	−0.198	0.002	−0.139	0.028	−0.104	0.084	−0.112	0.083	0.093	0.686	−0.029	0.903	−0.106	0.106
FMI	0.065	0.782	0.082	0.713	−0.057	0.804	0.021	0.927	−0.090	0.144	−0.112	0.090	−0.179	0.005	−0.158	0.017	−0.098	0.144
Overweight (25–29.9 kg/m^2)																		
M1:FM	0.034	0.557	−0.104	0.062	−0.046	0.439	0.090	0.131	0.137	0.018	0.026	0.670	−0.038	0.536	0.009	0.883	0.005	0.993
LM	0.367	<0.001	0.395	<0.001	0.407	<0.001	0.464	<0.001	0.432	<0.001	0.372	<0.001	0.301	<0.001	0.303	<0.001	0.268	<0.001
M2: % BF	−0.054	0.783	−0.320	<0.001	−0.080	0.667	−0.180	0.004	−0.131	0.023	−0.056	0.769	0.126	0.503	0.063	0.745	0.069	0.772
FMI	−0.180	0.003	−0.113	0.524	−0.281	<0.001	−0.093	0.628	0.047	0.803	−0.195	0.004	−0.284	<0.001	−0.181	0.004	−0.172	0.011
Obese (≥28 kg/m^2)																		
M1:FM	0.069	0.360	−0.050	0.475	−0.023	0.749	0.133	0.088	0.116	0.117	0.113	0.177	−0.002	0.983	0.036	0.646	0.247	0.003
LM	0.485	<0.001	0.410	<0.001	0.550	<0.001	0.407	<0.001	0.504	<0.001	0.318	0.001	0.305	<0.001	0.314	0.001	0.284	0.003
M2: % BF	−0.212	0.005	−0.284	<0.001	−0.326	<0.001	−0.112	0.153	0.064	0.455	−0.085	0.351	−0.174	0.027	−0.143	0.094	−0.141	0.110
FMI	−0.082	0.765	−0.036	0.676	−0.055	0.519	−0.144	0.072	−0.203	0.008	−0.110	0.199	−0.050	0.848	0.018	0.837	0.010	0.916
Obese (≥30 kg/m^2)																		
M1:FM	0.052	0.632	−0.053	0.621	−0.014	0.887	0.026	0.834	−0.020	0.864	0.050	0.570	−0.077	0.474	−0.154	0.169	0.034	0.554
LM	0.601	<0.001	0.608	<0.001	0.668	<0.001	0.387	<0.001	0.504	<0.001	0.117	0.160	0.250	0.064	0.549	<0.001	0.123	0.176
M2: % BF	−0.327	0.004	−0.001	0.997	−0.039	0.912	0.091	0.668	−0.044	0.917	0.160	0.242	−0.158	0.165	−0.330	0.010	0.127	0.356
FMI	−0.078	0.845	−0.330	0.008	−0.442	<0.001	−0.261	0.041	−0.342	0.005	−0.216	0.114	−0.222	0.061	0.208	0.124	−0.127	0.357

BMD bone mineral density, *TB* total body, *FN* femoral neck, *TF* total femur Dependent variables as BMD; independent variables as FM, LM and age in model one

Dependent variables as BMD; independent variables as %BF, FMI, weight and age in model two

Therefore, %BF and FMI were adverse to overweight and obesity in adult Chinese men. It was consistent with the finding that the risks of osteoporosis, non-spine fractures were significantly higher for subjects with a higher percentage body fat in a study of a large cohort of Chinese subjects [27]. Other researches provided further evidence that FM may have no beneficial effect on bone [28–31].

So as to research the correlation of FM and LM to BMD, the regression model was established. The results showed LM was a determinant to BMD and FM was significantly positive to BMD in normal weight and overweight by WGOC criteria and only in normal weight by WHO criteria. Because there was inconsistent in fat-related parameters and BMD, we explored the effect of %BF and FMI on BMD. The results showed that %BF and FMI were not related to BMD in normal weight, and which were adverse to total body and regional BMD in overweight and obesity. Comparing with two criteria, we found the differences in fat-related parameters and BMD according to WHO criteria were more obvious than that according to WGOC criteria. We also found that %BF and FMI were useful to research the relationship between osteoporosis and obesity at the same time.

The outcomes based on the WHO and WGOC categories were interesting. Among northern Chinese men, Both LM and LBMI were strong predictors of BMD, but fat-related parameters showed significant differences: positively associations in normal, and negatively associations in overweight and obesity. It suggested that any of body composition was vital to conserve normal weight, and it was quite necessary to control overweight and obesity, especially %BF and FMI, and to increase and maintain LM and LBMI at the same time. The strength of this paper was that it was based on WHO and WGOC BMI categories, and based on adopted lean-related parameters such as LM and LBMI, and fat-related parameters such as FM, %BF and FMI. But it was under-estimated optimal cut-off values of parameters. Perhaps it would be a target to discuss relationship between obesity and osteoporosis and prevent osteoporosis and related fracture.

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