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Relationship between different body composition and bone mineral density in Qinhuangdao city

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SUMMARY

OBJECTIVE: This study aimed to explore the correlation between different body components and bone mineral density in healthy adults.

METHODS: A total of 306 non-manual subjects, 161 males and 145 females, were selected from the physical examination center of our hospital from June to September 2019. They were divided into control group, overweight group, and obese group according to body mass index. The muscle mass and fat mass, body fat content, trunk fat mass, upper limb and thigh fat mass, bone density of femoral neck and lumbar vertebra, and bone mineral salt content of the whole body were measured by dual-energy X-ray absorptiometry.

RESULTS: Body mass index, systolic blood pressure, diastolic blood pressure, femoral neck bone mineral density, bone mineral salt content, fat mass, muscle mass, upper limb fat mass, thigh fat mass, and trunk fat mass in the overweight group and obese group were all higher than those in the control group ($P<0.05$). The fat mass, muscle mass, upper limb fat mass, and trunk fat mass were positively correlated with the femoral neck bone mineral density, total lumbar vertebra bone mineral density, and bone mineral salt content ($P<0.05$). In addition, thigh fat mass was positively correlated with femoral neck bone mineral density and total lumbar spine bone mineral density, whereas body fat content was negatively correlated with bone mineral salt content.

CONCLUSION: Body composition was related to bone mineral density and bone mineral salt content, and the correlation between different body composition indexes, and bone mineral density, and bone mineral salt content was different.

KEYWORDS: Bone density. Muscles. Body composition.

INTRODUCTION

The human body is composed of water, protein, fat, and inorganic salts and their composition ratio is an essential health indicator. Thus, an unbalanced body composition ratio is an important cause of the development of many diseases. The measurement and analysis of body composition can provide an understanding of the general health and nutrition level of individuals, and to some extent, can also reflect factors such as gender, age, genetics, geographical location, growth, and development. It can also provide valuable information for the diagnosis and treatment of many diseases[1].

Osteoporosis is a systemic skeletal disorder characterized by osteopenia and deterioration of bone microarchitecture, leading to increased bone fragility and fracture risk[2]. The diagnosis of osteoporosis relies on clinical examination, bone mineral density (BMD) assessment, and dual-energy X-ray absorptiometry (DEXA). The measurement of BMD combined with identification of clinical risk factors is currently the gold standard for the diagnosis of osteoporosis[3].

This study aimed to investigate the correlation between body composition, bone mineral content (BMC), and BMD by performing physical examination in a healthy population using DEXA to provide a basis for the comprehensive assessment of body composition and a theoretical basis for the prevention and treatment of osteoporosis.

METHODS

Subjects

The data of 306 subjects who underwent physical examination at the Health Examination Center of the First Hospital of Qinhuangdao between June to September 2019 were retrospectively analyzed, and they all voluntarily underwent DEXA for body composition measurement and analysis. The subjects included 161 males and 145 females (excluding pregnant or lactating women). The study was approved by the Ethics Committee of the First Hospital of Qinhuangdao, and all subjects signed an informed consent form.

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Inclusion criteria

Inclusion criteria were as follows: (1) age 21–65 years; (2) non-manual worker; (3) no history of alcoholism or excessive smoking; (4) no severe liver and kidney disease or chronic obstructive pulmonary disease; (5) no cancer requiring treatment in the past 5 years; (6) no recent history of continuous bed rest for more than 3 months; (7) not taken drugs affecting bone metabolism and body composition (glucocorticoids, estrogen, thyroid hormone, parathyroid hormone, calcitonin, or bisphosphonates); and (8) not taken calcium, vitamin D supplements, or any drugs affecting calcium and vitamin D metabolism.

Grouping

The subjects were divided into three groups according to their body mass index (BMI): subjects with a BMI between 18.5 and 24 kg/m^2 were included in the normal control group (n=107); those with a BMI between 24 and 28 kg/m^2 were included in the overweight group (n=120); and those with a BMI greater than 28 kg/m^2 were included in the obese group (n=79), in accordance with the criteria issued by the National Health and Family Planning Commission of China[4].

Measurements

The measurements were taken using a Discovery QDR 4500 DEXA from Hologic. The instrument was calibrated before the examination to reduce the error. All the subjects were placed in the supine position and the body composition of the patients, including their total body muscle mass and fat mass, body fat content, trunk fat mass, upper limb and thigh fat mass, femoral neck and lumbar spine BMD, and total body BMC, were measured using a bone densitometer.

Statistical analysis

SPSS 13.0 statistical software was used in this study, and the measurement data were expressed as ± s. Analysis of variance (ANOVA) was used for the comparison of the three groups (a Student-Newman-Keuls (S-N-K) test was also used for comparison between the groups). Mono-factor analysis was performed using the Pearson correlation. $P<0.05$ was considered a statistically significant difference.

RESULTS

General information

A total of 306 subjects were included in this study, of which 161 were males and 145 were females. There were 56 males and 51 females in the normal control group with a mean age of 48.67 ± 7.49 years, 63 males and 57 females in the overweight group with a mean age of 48.91 ± 8.46 years, and 42 males and 37 females in the obese group with a mean age of 47.15 ± 9.91 years. The differences were not statistically significant in age, fasting blood glucose, total cholesterol, and low-density lipoprotein cholesterol among the three groups (see Table 1).

A comparison of body composition and levels of bone mineral density and bone mineral content

Compared with the control group, BMI, systolic blood pressure, diastolic blood pressure, femoral neck BMD, BMC, fat mass, muscle mass, upper limb fat mass, thigh fat mass, and trunk fat mass were all higher in the overweight and obese groups ($p<0.05$). Moreover, BMI, body fat content, fat mass, muscle mass, thigh fat mass, trunk fat mass, total lumbar spine BMD, and BMC were higher in the obese group than in the overweight group ($p<0.05$) (see Table 1).

The correlation of body composition with bone mineral density and bone mineral content at different sites

Fat mass, muscle mass, upper limb fat mass, and trunk fat mass were positively correlated with femoral neck BMD, total lumbar spine BMD, and BMC ($p<0.05$). Thigh fat mass was positively correlated with femoral neck BMD and total lumbar spine BMD, but not with BMC. In addition, body fat content was negatively correlated with BMC, but not with femoral neck BMD and total lumbar spine BMD (see Table 2).

DISCUSSION

In this study, we identified differences in body composition among obese, overweight, and normal-weight healthy subjects, and found correlations between different body composition indexes with BMD and BMC.

Body mass, BMI, and body composition are all important determinants of BMC and the occurrence of osteoporosis[5]. Most studies have concluded that BMD is positively correlated with BMI and that obesity can reduce the risk of osteoporosis, but some studies have shown that obese individuals are more likely to develop osteoporosis[6]. Fat mass has a positive role in peak bone mass acquisition in young male adults, but it accounts for only 1.8% of total body BMD change. In the presence of excess adipose tissue, low-grade inflammation is associated with a greater number of inflammatory cytokines, which negatively affects bone metabolism[7]. Therefore, it is uncertain whether adipose tissue plays

Table 1. Comparison of body composition and levels of bone mineral density and bone mineral content in different groups ($\bar{x}$±s).

Variables	Control group	Overweight group	Obese group	F	P
N (M/F)	107(56/51)	120(63/57)	79(42/37)	–	–
Age (years)	48.67±7.49	48.91±8.46	47.15±9.91	1.338	0.276
BMI (kg/cm^2)	22.05±1.55	25.89±1.12*	31.49±3.66*#	406.896	0.000
Systolic blood pressure (mmHg)	123.15±15.13	134.05±18.14*	134.56±18.03*	14.142	0.000
Diastolic blood pressure (mmHg)	76.70±12.61	84.53±12.56*	84.88±11.32*	13.950	0.000
Fasting plasma glucose (mmol/L)	5.73±0.70	6.16±1.74	5.98±1.18	2.948	0.054
Total cholesterol (mmol/L)	4.87±1.01	4.89±0.92	4.59±0.96	2.228	0.110
Low-density lipoprotein cholesterol (mmol/L)	2.84±0.88	2.91±0.81	2.70±0.96	1.244	0.290
Femoral neck BMD	0.74±0.12	0.77±0.11*	0.86±0.11*#	20.928	0.000
Total lumbar spine BMD	1.11±0.12	0.99±0.13	1.06±0.14*#	6.848	0.001
BMC (kg)	2.14±0.36	2.35±0.36*	2.48±0.33*#	18.498	0.000
Body fat content (%)	23.90±5.03	25.44±5.16	27.19±4.62*	3.713	0.039
Fat mass (kg)	15.82±3.72	18.66±3.36*	24.30±4.56*#	97.250	0.000
Muscle mass (kg)	43.53±7.33	52.96±7.37*	62.90±9.48*#	120.713	0.000
Upper limb fat mass (kg)	1.76±0.62	1.95±0.47*	2.75±0.73*#	56.064	0.000
Thigh fat mass (kg)	5.32±1.66	5.61±1.54	7.17±2.05*#	24.321	0.000
Trunk fat mass (kg)	7.53±2.14	9.63±1.94*	12.87±2.69*#	114.724	0.000

*P<0.05 compared with control group; #P<0.05 compared with overweight group.

Table 2. Correlation of body composition with bone mineral density and bone mineral content at different sites.

Variables	Femoral neck BMD		Total lumbar spine BMD		BMC	
	r	p	r	p	r	p
Body fat content (%)	-0.099	0.089	-0.052	0.374	-0.299	<0.001
Fat mass (kg)	0.297	<0.001	0.188	0.001	0.230	<0.001
Muscle mass (kg)	0.476	<0.001	0.279	<0.001	0.652	<0.001
Upper limb fat mass (kg)	0.252	<0.001	0.180	0.002	0.119	0.041
Thigh fat mass (kg)	0.208	<0.001	0.187	0.001	0.063	0.280
Trunk fat mass (kg)	0.280	<0.001	0.124	0.033	0.272	<0.001

a role in BMD. Our study showed that the level of femoral neck BMD and BMC was higher in the overweight and obese groups than in the control group (p<0.05). In addition, some studies have shown that blood lipid, blood glucose, and blood pressure have varying degrees of influence on BMD[8,9], but in this study, BMD and BMC have no correlation with blood glucose, blood pressure, and blood lipid, which may be related to the small sample size.

Iwaniec et al.[10] suggested that increased muscle mass and function may increase the positive effects of BMI on bone health. Bone cells can sense the increased mechanical load in obese patients and adapt to this change by increasing the BMD. Fracture risk in obese patients can be prevented by the increased bone load and the prevalence of hip fracture decreases with an increase in BMI in both men and women. Weight gain partially counteracts age-related bone loss. Higher body weight can increase bone tissue load, stimulate bone formation, and reduce bone resorption, which facilitates the increase in BMD and BMC and delays the occurrence of osteoporosis[11]. However, when the BMC is too high, it leads to increased bone stiffness, increased bone fragility, and a relative decrease in bone flexibility, making it prone to fracture. The results of our study found that with the increase of BMI, fat mass and muscle mass tended to increase, especially the trunk fat mass. In addition, the femoral neck BMD increased in people with a high BMI, but the total lumbar spine BMD did not follow this pattern.

Muscle strength has been reported to be an indicator of muscle mass and function in people of either sex and any age, and muscle strength also correlates with BMC and BMD[12]. Makovey et al.[13] found that the correlation between muscle mass and BMD was stronger than fat mass and BMD in both sexes. Fat mass and muscle mass and their distribution in the body were differentially associated with regional BMD and differed with age. For example, prior to menopause, left upper arm BMD in women was associated with muscle mass, whereas after menopause it was associated with fat mass[14]. Cheng et al.[15] concluded that muscle mass was the main factor affecting the lumbar spine, femoral neck, and total body BMD in all age groups, whereas fat mass was associated only with older men and postmenopausal women. After eliminating the effects of age, gender, and BMI, BMD was correlated with muscle mass but not with fat mass, and upper limb BMD was negatively correlated with the upper limb body fat rate[16].

Bone mineral content was correlated with total body fat in women (regardless of age) and young men, but not in older men. The proportion of lean soft tissue to total bone in the skeleton decreases with age in women but remains stable in men[17]. A study[12] showed that BMC/BMD decreased by 30% between the ages of 20 and 80 years in females, whereas it decreased by only 16% in males from the same age group, with their muscle mass decreasing by 18 and 17%, respectively. A longitudinal study including overweight and normal-weight children aged 9–11 years showed that changes in bone strength were associated with muscle mass, but not with fat mass[18]. The association between body fat content and bone mass was weak or did not exist[19]. Our results showed that fat mass, muscle mass, upper limb fat mass, and trunk fat mass were positively correlated with femoral neck BMD, total lumbar spine BMD, and BMC ($p<0.05$). Thigh fat mass was positively correlated with femoral neck BMD and total lumbar spine BMD, but not with BMC. In addition, body fat content was negatively correlated with BMC but not with femoral neck BMD or total lumbar spine BMD.

The decrease in the amount of activity in men as they age is more likely to lead to lower BMD[20], but effective exercise in youth can increase bone mass and help reduce bone loss due to aging. After exercise, such as weight-bearing aerobics and strength and resistance exercises, BMD loss is significantly reduced in the elderly, although both BMD and muscle strength decrease[20]. Howe et al.[21] concluded that exercise has a relatively small effect on BMD in postmenopausal women. However, another study[22] indicated that a 9-month high-impact jumping intervention can significantly increase leg BMC and bone mass and improve bone stiffness.

In summary, body composition is associated with BMD and BMC, but the increase in BMD and BMC is more closely related to muscle mass than fat mass. Exercise should be advocated as a way of preventing osteoporosis since such an improvement in lifestyle can reduce fat content and increase muscle content. Nevertheless, there are some limitations to this study, including the small number of subjects, the limitation to only one city, Qinhuangdao, and the lack of follow-up data. More studies are therefore needed to confirm the relationship between body composition and BMD to provide a firm basis for the prevention and treatment of osteoporosis.

ETHICS APPROVAL

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Qinhuangdao First Hospital (2019C009).

AUTHORS' CONTRIBUTIONS

YJZ, XJJ: Conception and design of the work. These authors have contributed equally to this study. **XL, WA:** Data collection. **YJZ, XJJ, WLZ:** Supervision. **JQL, WLZ:** Analysis and interpretation of the data. **YJZ, XJJ:** Statistical analysis. **YJZ, XJJ:** Drafting the manuscript. **YJZ, XJJ, WLZ:** Critical revision of the manuscript. All authors: Approval of the final manuscript.

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