

Original Research Article

The effect of body mass index on bone mineral density in postmenopausal women

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ABSTRACT

Background: The aim of this study was to evaluate the association between BMI and BMD among postmenopausal women.

Methods: A total of 121 healthy female patients, aged 65.67±8.59 years, previously menopausal, were enrolled. Subjects were divided into five subgroups according to their BMI. History of fracture and BMD were recorded and compared between groups.

Results: Among the 121 subjects, 77 (63.6%) individuals had a normal BMD, 32 (26.4%) had osteopenia, and 12 (9.9%) were diagnosed with osteoporosis. Mean of waist circumference was 96.1±8.52cm. The prevalence of fractures was 29.8% in this study. A simple correlation analysis revealed that waist circumference was negatively related to lumbar spine BMD ($r = -0.374$, $p = 0.03$) and lumbar spine BMD T score ($r = -0.352$, $p = 0.002$) whereas body weight was positively related to BMD of lumbar spine BMD ($r = 0.41$, $p = 0.0001$) and lumbar spine BMD T score ($r = 0.31$, $p = 0.001$). Age and years since menopause (YSM) were negatively correlated with BMD and T score ($p = 0.001$, $p = 0.0001$, respectively).

Conclusions: Even though higher BMI seems to have positive impact on bone density thanks to hormonal and mechanical reasons, increased waist circumference is a sign of a metabolic syndrome and systemic inflammation which are known as having negative effect on bone density. Therefore, postmenopausal women specifically with abdominal obesity should be evaluated for osteoporosis.

Keywords: Body mass index, Bone mineral density, Obesity

INTRODUCTION

Menopausal transition represents a period of dynamic changes in reproduction and nonproductive tissues and is believed to play an important role in aging women's biology and health status.^{1,2}

In post-menopausal period, cardiovascular system disorders form the major risk for women, followed by

bone tissue loss and osteoporosis. Because of cessation of ovarian function and decrease in estrogen hormone level, bone loss accelerates with the age and the severity of osteoporosis increases.³⁻⁵ Osteoporosis is defined as a common systemic skeletal disease characterized by low bone mass and microarchitectural degradation of bone tissue, with a consequent increase in bone fragility. This manifest itself as fractures even with minimum trauma occurring at multiple sites, most often at the spine, hip, or

wrist.⁶ Fractures related with osteoporosis are associated with considerable morbidity due to kyphosis, chronic pain and pressure sores resulting from needed bed rest. These imply great morbidity and high cost for health services.⁷

Dual energy X-ray absorptiometry (DXA) is a simple, reliable, and reproducible tool used in the assessment of bone mineral density (BMD), and is the gold standard for the diagnosis of osteoporosis. A strong association between BMD scores and the probability of fragility fractures is well-documented.^{8,9} Based on the WHO definitions, a T-score >-1 is normal, while T-scores <-1 to >-2.5 indicate osteopenia, and T-scores <-2.5 are diagnostic for osteoporosis.¹⁰

According to the Turkish Osteoporosis Society, based on FRACTURK study's data, frequency of osteoporosis and low bone mass is estimated that around 50% among Turkish women over 50 years of age. Moreover, this study has shown us that more than 24,000 hip fractures occurred in women and men aged 50 years or more in 2010, 73% of which were in women. The majority of hip fractures in women occurred after the age of 75. Assuming no change in age and sex-specific incidence, it is expected that the number of hip fractures will increase to approximately 64,000 in 2035.¹¹

Also, obesity is another common medical problem which has an epidemic importance, and the number of patients with obesity is rapidly increasing in industrialized countries. Currently, 23.9% of women above 15 years old are obese and 30.1% are overweight in Turkey.¹² These figures are expected to increase in the future. Different studies have shown a protective role of obesity against osteoporosis, but recent evidence suggests that obesity, and thus fat mass, may prove to be risk factors for decreased bone density and fractures.^{13,14}

The purpose of this prospective study was to evaluate the association between the body mass index and bone mineral density among postmenopausal women.

METHODS

Authors studied 121 women aged ≥ 45 years whose BMD was measured at the Department of Physical Therapy at Rize 82nd year State Hospital between January 2014 and January 2015. The inclusion criteria were postmenopausal community ambulant women aged 47-80 years with cessation of menses for at least 12 months. Patients with history of surgical menopause, limited physical activity from a stroke or dementia, chronic diseases affecting bone structure (e.g., malignancy, anoxia nervosa, turner syndrome, rheumatic diseases, hyperparathyroidism, hyperthyroidism, Cushing's syndrome, inflammatory bowel disease, osteomalacia, renal failure, and diabetes mellitus), history of bariatric surgery interventions, chronic consumption of alcohol, tobacco, cigarettes, using medication which are known to

affect bone metabolism were excluded from the study. All participants signed their written consent before taking part in the study.

Data collection procedure

All subjects underwent complete medical history and clinical examination. Participants' ages, anthropometric characteristics, durations of menopause, numbers of children, and use of calcium supplements were recorded during the study.

Outcomes measurements

All subjects' height and weight measurements were taken by the same qualified research coordinator using a standardized weighing scale that was calibrated weekly. BMI was calculated as weight (in kilograms) divided by height (in meters) squared (kg/m^2). Subjects were divided into five subgroups according to their BMI; normal weighted ($18.5 \leq \text{BMI} < 24.9 \text{kg}/\text{m}^2$), overweight ($25 \leq \text{BMI} < 29.9 \text{kg}/\text{m}^2$), class I obese ($30 \leq \text{BMI} < 34.9 \text{kg}/\text{m}^2$), class II obese ($35 \leq \text{BMI} < 39.9 \text{kg}/\text{m}^2$), class III obese ($\text{BMI} \geq 40 \text{kg}/\text{m}^2$) according to WHO definition.¹⁵

The primary clinical outcome measure was the patients' lumbar spine BMD. BMD was assessed by dual energy X-ray absorptiometry at the lumbar spine, using a Lunar DPX-L, Madison, Wisconsin, USA. It is calibrated daily using a standard phantom provided by the manufacturer. Lumbar spine BMD was the mean of lumbar vertebrae 1-4. According to WHO (World Health Organization) criteria, patients who has a T-score lower than -2.5 is diagnosed with osteoporosis.

Statistical analysis

Sample size calculation was done by using an effect size of 33% and 80% power at 95% confidence interval and it is enough that study comprise 121 patients. All statistical analyses were performed with SPSS for the IBM Statistical Package Version 23.0. The data were expressed as mean SD. The parametric distribution of the data was confirmed by the Kolmogorov-Smirnov test. The continuous demographic variables of patients were compared using Student's t-test variables. Categorical variables were compared by chi-square test. Analysis of variance (ANOVA) was used to compare the BMD levels of groups. Pearson correlation analysis were used to evaluate the interrelationship between parameters. A p value of 0.05 was considered statistically significant.

RESULTS

A total of 121 patients were included in this study. The baseline clinical characteristics of patient groups are shown in Table 1. The average age of the recruited patients was 65.67 ± 8.59 years. The population was subdivided into five different groups depending on BMI; 6 (5%) individuals were normal weighted, 27 (22.3%)

individuals were overweight, 39 (32.2%) were class I obese, 29 (24%) were class II obese, 16.5 (20%) were class III obese. The average lumbar spine BMD was

1.08±0.19g/cm² and the average lumbar spine BMD T score was -0,572±1,42.

Table 1: Characteristics of the subjects (n=121).

Variables	Subgroups	Mean±SD	n	%
Age (year)	-	65.67±8.59	-	-
BMI (kg/cm ²)	-	33.69±5.96	-	-
BMI	Normal weighted	-	6	5
	Overweight	-	27	22.3
	Obese Class I	-	39	32.2
	Obese Class II	-	29	24
	Obese Class III	-	20	16.5
Waist (cm)	-	96.1±8.52	-	-
Systolic BP (mmHg)	-	141.7±11.21	-	-
Years since menopause	-	18.31±10.55	-	-
Lumbar spine BMD (g/cm ²)	-	1.08±0.19	-	-
Lumbar spine BMD T score	-	-0,572±1,42	-	-
BMD categories (%)	Normal	-	77	63.6
	Osteopenia	-	32	26.4
	Osteoporosis	-	12	9.9
Fracture	Yes	-	36	29.8
	No	-	85	70.2

BMI, body mass index; BMD, bone mineral density; BP, blood pressure. All values are expressed as n (%), or mean ± standard deviation

Table 2: Comparisons of normal weighted, overweight, class I, class II and class III obese postmenopausal women according to anthropometric and densitometric data.

Characteristics	Normal weighted	Overweight	Obese			p value
			Class I	Class II	Class III	
Age (years)	65.5±12	64±4.9	73±10.6	69±19.7	63±7.07	0.07
Waist (cm)	88.8±10	92.6±5.4	102±9.4	104±11.6	110±6.2	0.02*
YSM	22±2.8	34±0.7	26±13.4	16±16.9	10.5±7.7	0.10
Lumbar spine BMD (g/cm ²)	0.8±0.3	0.9±0.3	0.80±0.25	1.03±0.12	1.03±0.12	0.0001*
Lumbar spine BMD T score	-1.9±0.7	-0.6±1.48	-3.20±2.1	-1.3±0.98	-1.3±0.98	0.024*
Fracture	0	10 (%37)	13 (%33)	8 (%27.5)	5 (%25)	0.44

BMD, bone mineral density; YSM, years since menopause. All values are expressed as n (%), or mean±standard deviation. p<0.05*

Among the 121 subjects, 77 (63.6%) individuals had a normal BMD, 32 (26.4%) had osteopenia, and 12 (9.9%) were diagnosed with osteoporosis. Mean of waist circumference was 96.1±8.52cm. The prevalence of fractures was 29.8% in this study (Table 1).

Statistically significant differences were found between groups in waist circumference, lumbar spine BMD and T scores (p=0.02, p=0.0001, p=0.024, respectively) when compared with normal weighted, overweight, class I, class II and class III obese postmenopausal women according to anthropometric and densitometric data. According to ANOVA analysis which aims to point the

significance diversity between the BMI groups and arithmetic mean values of lumbar spine BMD and T-score, it is found to be statistically significant (p=0.0001, p=0.024, respectively) (Table 2). There were no statistically significant baseline differences in age, years since menopause between groups. The group with the highest fracture frequency was class 1 obese (37%), followed by class II obese group (27.5%) (Table 2). There was no relationship between BMI groups and fracture frequency (p=0.44).

A simple correlation analysis revealed that waist circumference was negatively related to lumbar spine

BMD ($r = -0.374$, $p = 0.03$) and lumbar spine BMD T score ($r = -0.352$, $p = 0.002$) whereas body weight was positively related to BMD of lumbar spine BMD ($r = 0.41$, $p = 0.0001$) and lumbar spine BMD T score ($r = 0.31$, $p = 0.001$) (Table 3). Age and years since menopause (YSM) were negatively correlated with BMD and T score ($p = 0.001$, $p = 0.0001$, respectively) (Table 3).

Table 3: Pearson’s coefficient (r) and significance level (p), between body mass index, age, waist and years since menopause with bone mineral density and T score in 121 postmenopausal women.

Characteristics	Lumbar spine BMD (g/cm ²)		Lumbar spine BMD T score	
	r	p	r	p
Age (years)	-0.245	0.007*	-0.305	0.001*
BMI (Kg/m ²)	0.41	0.0001*	0.31	0.001*
Waist (cm)	-0.374	0.03*	-0.352	0.002*
YSM	-0.284	0.002*	-0.319	0.0001*

BMI, body mass index; BMD: bone mineral density, YSM, years since menopause, $p < 0.05$ *

DISCUSSION

The prevalence of both obesity and osteoporosis have been rapidly increasing, which lead to increased morbidity and mortality for both genders.^{16,17} Several studies have investigated the relationship between obesity and osteoporosis; however, there still is not a consensus regarding this subject. The generally accepted opinion suggests that obesity has a protective effect against osteoporosis and weight loss leads to decreased BMD levels.^{13,18,19} Due to several research issues (differences in the randomization of the study groups, varying measurement methods, the volatile nature of body weight, retrospective nature of the studies, the difficulties in follow-ups of longitudinal studies), the topic is still disagreed upon.

The structure of the bone is influenced by many different factors such as age, gender, race, genetics, reproductivity, calcium intake, BMI and exercise.^{20,21} Among these, BMI is probably the most controversial. The increasing BMI has multifactorial effects on the bone metabolism. It is generally accepted that, increasing body weight mechanically reinforces bone production.²² Also, the adipose tissue is an important source of estrogen for the postmenopausal women. It is known that estrogen (the levels of which increases in the peripheral tissues in the case of obesity) inhibits osteoclasts, in other words, the bone resorption.^{23,24} The adipocytes also produce the leptin hormone, which regulates appetite and the body weight. It is suggested that leptin may decrease bone formation among obese women.²⁵ According to another suggested mechanism, obesity stimulates the bone-active hormone, amylin and preptin hormones from the pancreas beta cells, together with insulin and the insulin-like growth factor (which stimulate bone formation).²⁶ These

mechanisms indicate that obesity has a protective effect against osteoporosis. However, the net effects are still unclear.

Albala et al, have found that the bone mass in the lumbar spine and the femoral neck had increased among the postmenopausal obese women, compared to the women with normal weighted.²⁰ This finding is compatible with several other studies; however, it was recently suggested that obesity leads to inflammation and the pro-inflammatory markers stimulate osteoclastic activity to accelerate osteoporosis.^{13,18} Greco et al, have studied 398 males and females and they have found that morbidity obesity was not protective against osteoporosis.¹³ In present cross-sectional study that authors conducted among 121 postmenopausal women, authors have compared the BMD of the participants according to their BMI's. Authors found that the BMI was positively correlated with bone mineral density at the lumbar spine. Also, the overall prevalence of osteoporosis was found to be lower for the class III obese group. Both the BMD values and the T-scores of the lumbar spine improved with increasing body weight. Additionally, it was found that the waist circumference was negatively correlated with the lumbar spine BMD and T-score. Increasing waist circumference (which is an indicator of central obesity) was found to be positively associated with increased risk of osteoporosis, regardless of BMI. These indicate the complexity of obesity and its influence on the bone metabolism. Kim et al, have found that body weight was a protective factor against bone fractures; however, it was also found that the body fat percentage and the waist circumference were negatively correlated with BMD, which may lead to vertebral fractures.¹⁴ This study suggests that if obesity is defined by BMI and body weight, it can be considered a protective factor against bone mineral loss or vertebral fractures. However, if it is based on body fat percentage, it is a risk factor for osteoporosis.¹⁴ Different studies indicate that the waist circumference is associated with the bone mineral density of the radius bone, however, BMI was not found to be associated with BMD.^{27,28} Subsequently, the separate findings of Hsu et al, have supported the negative correlation between the body fat mass and the bone mass.^{29,30} Even if it would seem that a high BMI is a protective factor against osteoporosis, the systemic inflammation that results from increasing abdominal fat (despite the degree of obesity) leads to an increased risk of osteoporosis development.

The most important negative effect of osteoporosis is an increased risk of bone fractures.³¹ The fractures may lead to morbidities that severely limit the individual's independence, and even death. Thus, it is a clinical necessity to foresee these fractures and to determine possible precautions and treatments. In the literature, it was seen that for a long time, especially when BMD could not be measured, BMI calculations were one of the most commonly used clinical measurement method in determining fracture risks.³² Based on the data obtained

previous studies, it was considered that a high BMI had protective effects against bone fractures.³¹⁻³³ However, recent studies suggest that the BMI values are unreliable indicators of osteoporosis and fracture risks.¹⁹ Compston et al, have separately found that obesity was not protective against bone fractures among postmenopausal women, despite the high BMD values.^{19,24} In present study, authors have found that increasing degree of obesity decreased the risk of developing osteoporosis; however, there was not a significant improvement in fracture rates. The number of fractures was higher among the class III obese compared to the classes I and II. However, this finding was not statistically significant.

The risk of fracture among the obese can depend on several factors. As obesity is associated with an increased risk of falling due to postural instability and muscle weakness the obese are at greater risk for trauma and bone fractures, compared to the normal weighted individuals.^{19,24,34} Compston et al, have found that the obese women with fractures have better BMD values compared to non-obese women with fractures, and that they have similar clinical risk factors.¹⁹ Ong et al, have conducted a cross-sectional analysis with 4288 volunteers, and have determined that a high BMD is not a protective factor against fractures.³⁵ These findings suggest that BMD is not singularly sufficient to predict bone quality and strength. In other words, the high BMD levels that accompany obesity does not indicate a decreased risk for fractures.

Present study has some limitations. To demonstrate that body composition is related to bone mineral density, body fat mass should be analyzed as visceral fat and subcutaneous fat. There are possible errors to interpret the effect of fat tissue on low bone mineral density because fat tissue absorbs less radiation than lean tissue, so high percentage fat could yield a false low BMD.^{35,36} Although BMI is a quick, easy measure of body composition that is widely used, especially in assessing risk of osteoporosis, it may have limitations in its usefulness in predicting bone-related outcomes in obese women.³⁶ There are also limitations in using DXA machines to measure BMD among obese individuals as fat mass and fat distribution around the waist and hip can artificially increase BMD measurements.³⁷

Based on the results of our study, increased body weight is positively correlated with high BMD, whereas waist circumference is negatively correlated with BMD and might increase the risk of fractures. If obesity is only evaluated through the BMI of a person, it may cause us to overlook the complex relationship between osteoporosis and the fatty tissue. Obesity may improve the BMD values through hormonal and mechanical effects. However, especially abdominal obesity can lead to several disorders (such as insulin resistance, diabetes mellitus, metabolic syndrome, etc.) and can disrupt the bone metabolism through systemic inflammation.³⁸ Among the postmenopausal women, the osteoporosis and

fracture risk evaluations should include not only the BMD, but also the waist circumference, the fatty mass, hunger plasma glucose levels, the serum concentrations of lipids and C-reactive protein. The determination of the risk of fracture should include the increased risk of micro/macro traumas that are associated with obesity, and the osteoporosis prevention and treatment plans should be revised accordingly.

Authors believe that the association between the body fat and bone masses may be investigated in further studies, that may include genetics and molecular biology. These studies will help the development of new therapeutic interventions, diagnoses and management strategies to improve osteoporosis and bone fracture-related morbidities.

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