ORIGINAL ARTICLE

A study on bone mass density using dual energy X-ray absorptiometry: Does high body mass index have protective effect on bone density in obese patients?

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Background: Osteoporosis is known as reduction of bone density, which is diagnosed using dual-energy X-ray absorptiometry. Although some studies have shown high body mass index (BMI) as a protective factor for osteoporosis and fracture risks, some other studies demonstrated obesity as a risk factor for osteoporosis. The aim of this study is to evaluate the relationship between BMI and bone mineral density (BMD) in premenopausal and postmenopausal females. Furthermore, we determined the correlation between BMI and fracture risk in postmenopausal females. **Materials and Methods:** In this study, we evaluated the relationship between the age and BMI with 10-year probability fracture risk (estimated using fracture risk assessment tool) and BMD in the L1–L4 spine and femoral neck. Data were collected from BMD center, Askariye Hospital, Isfahan, Iran, from May 2016 to July 2017. **Results:** The study consisted of 1361 individuals, including 305 premenopausal females and 1056 postmenopausal females. The results showed a statistically significant increase of BMD ($P < 0.001$) and a decrease of fracture risk ($\beta = -0.158$, $R^2 = 0.518$) with an increase of BMI in postmenopausal females. Moreover, lumbar spine and femoral neck BMD were significantly higher in individuals with BMI ≥30 than in those with BMI <25 in both premenopausal and postmenopausal females ($P < 0.001$). In addition, older postmenopausal females indicated significantly lower L1–L4 BMD ($r = -0.280$, $P < 0.05$) and femoral neck BMD ($r = -0.358$, $P < 0.05$). **Conclusion:** The results showed a positive correlation between BMI and BMD of the spine and femoral neck which did not differ by menopausal status. However, there was a correlation between BMI and fracture risk in postmenopausal females.

Key words: Body height, body mass index, body weight, bone density

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INTRODUCTION

Osteoporosis is characterized by low bone mass, causing reduced bone strength and increased risk of fracture. Although imaging modalities have been shown to be capable of detecting osteoporotic patients, the gold standard method for the diagnosis of osteoporosis is still measurement of bone mineral density (BMD) using dual-energy X-ray absorptiometry (DXA). The value of T-score ≤−2.5 at the hip, spine, or forearm is defined as osteoporosis.[1-3] Low bone mass can result in fragility fractures which was estimated 9 million in the world in 2000.[4] Osteoporotic fractures, especially hip fracture, cause increased morbidity. It has been estimated that by the year 2050, more than 50% of osteoporotic fractures will be observed in Asia.[5] The risk of a 10-year probability of fractures between the ages of 40 and 90 years can be estimated using a diagnostic tool called fracture risk assessment tool (FRAX), which is affected by clinical risk factors and BMD at the femoral neck.[6] BMD is affected by several factors including smoking, excessive alcohol use, glucocorticoids use, chronic diseases, and low body weight.[7] Low weight or

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low body mass index (BMI) is an important risk factor for future fractures, whereas high BMI appears to be protective against fractures.[8] The positive correlation between BMI and BMD is reported in many studies,[9-11] whereas some others suggest the negative effect of obesity on BMD.[12,13] Most of these studies have been performed on a specific gender and age.[14,15] Different results in studies may be due to an exclusive pattern of lifestyle, obesity and fat distribution in males, premenopausal females, and postmenopausal females. There are few studies reporting the relationship between anthropometric measurements and bone density in groups of females and males.[16] Since obesity is associated with increased prevalence of diabetes mellitus, hypertension, hyperlipidemia, and cardiovascular diseases,[17] it is important to determine the definite relation between BMI and BMD to give patients advanced lifestyle suggestions according to their age so that the morbidity and mortality caused by osteoporosis and obesity can be reduced.

The aim of this study is to evaluate the relationship between BMI and BMD in premenopausal and postmenopausal females and to detect the correlation between BMI and fracture risk in postmenopausal females.

MATERIALS AND METHODS

This cross-sectional study consisted of 1380 patients, including all premenopausal females and postmenopausal females who were referred to the referral Bone Mineral Density center, Askariye Hospital, Isfahan, Iran, from May 2016 to July 2017. The approval of the study was received from the Internal Review Board of the Isfahan radiology department, and an informed consent form was signed by each participant. Exclusion criteria were chronic use of medications affecting bone metabolism including glucocorticoids, antiepileptic medications, etc., chronic medical conditions including rheumatoid arthritis, thyroid, and parathyroid disorders, renal failure, malignancies, etc., family history of osteoporosis, and history of smoking or alcohol use. For each participant, a prepared questionnaire for the Hologic densitometry device was filled out to obtain information including gender, age, height, weight, and menopausal status, history of chronic diseases, drug use, and BMI. In postmenopausal females, DXA values including BMD, T-score of L1–L4 and the femoral neck, and FRAX of the hip and other regions were collected based on the final report of the radiologist. Moreover, Z-score and BMD of L1–L4 and femoral neck were collected from the radiologist report for premenopausal females.

Anthropometric measurements, including height and weight, were performed on patients wearing light clothes and no shoes. BMI was calculated using the weight (kg)/height^2 (m) formula. A calibrated beam scale and a measuring tape were used to measure height and weight. BMD was measured using a daily calibrated DXA device (Hologic Discovery wi #86189). BMD, T-score and Z-scorer of the lumbar vertebrae and femoral neck were obtained. FRAX was obtained using the FRAX website https://www.sheffield.ac.uk/FRAX/tool.jsp.[18,19]

The patients were divided into three groups according to the standard categorization of BMI by World health organization criteria as normal ($18.5 \leq BMI \leq 24.9$), overweight ($25 \leq BMI \leq 29.9$), and obese ($BMI \geq 30$).[20] The number of participants with BMI < 18.5 kg/m^2 was not enough to be analyzed separately and thus, they were not entered into the analysis.

BMDs of the lumbar spine (L1–L4) and femoral neck were measured according to standard protocols using a daily calibrated DXA. T-score and Z-score were obtained based on normal values of an age- and gender-matched Iranian group. Postmenopausal females were osteoporotic if T-score was ≤−2.5 and had osteopenia if $-2.5 < T\text{-score} < -1$. Z-score was used for BMD reporting in premenopausal females. Z-score ≤ −2.0 and Z-score > −2 were defined as "below the expected range for age" and "within the expected range for age," respectively.[21]

The statistical tests used in this study were Pearson's correlation, one-way analysis of variance, linear regression, and two-way ANOVA. The analysis was carried out in the two groups of premenopausal females and postmenopausal females, separately. Dependent variables included BMDs and T-score in the lumbar spine and femoral neck. BMI and age were independent variables. The relationship between age, BMI, and BMD with the FRAX of the hip and other major osteoporotic fractures in postmenopausal females was analyzed using the mentioned tests. Differences were considered statistically significant when $P < 0.05$. SPSS version 24 for Windows (SPSS Inc., Chicago, IL, USA) was used to perform the analysis.

RESULTS

The study population consisted of 1361 premenopausal and postmenopausal females. The age of the participants ranged between the age of 20 and 88 years with the mean and the standard deviation (SD) of 56.44 ± 10.39 years. The participants were classified into two categories based on their menopausal status, including 1056 postmenopausal females (77.6%) and 305 premenopausal females (22.4%). The mean ± SD of femoral neck BMD and L1–L4 BMD were 0.88 ± 0.14 and 0.72 ± 0.13, respectively.

A significant increase of femoral neck BMD with an increase of BMI was detected in both premenopausal and

postmenopausal females ($P < 0.05$) [Table 1]. Moreover, in premenopausal females, L1–L4 BMD was significantly higher in obese individuals than those with normal and overweight BMI (no significant difference was detected among overweight and normal individuals). However, in postmenopausal females, an increase of BMI caused an increase of BMD in all groups of BMI [Table 1]. In comparison to BMI and BMD between postmenopausal and premenopausal females, a significant interaction was detected in L1–L4 BMD. Postmenopausal females were more likely to be affected by BMI than premenopausal females [Table 1].

Postmenopausal females

The postmenopausal females had a mean ± SD of 29.38 ± 4.45 kg/m^2 for BMI and 60.35 ± 7.85 years for age. Of all the postmenopausal females, 15.3%, 42.7%, and 42.0% were in normal, overweight and obese groups, respectively.

Lumbar spine

A negative correlation was observed for the relationship between age and L1–L4 BMD ($r = -0.280$, $P < 0.05$). The analysis showed a positive correlation between lumbar spine T-score and BMI ($r = 0.324$, $P < 0.01$) [Table 2]. Those who had higher BMI had significantly higher T-score. The same results were observed by comparing BMD in different BMI categories ($P < 0.05$) [Table 1]. The overall frequency of osteoporosis and osteopenia in postmenopausal females was 25.1% and 44.8%, respectively. Moreover, 55.9% of the postmenopausal females with normal lumbar spine T-score were obese [Table 2]. It was a higher percentage than what was observed in overweight females (36.3%) and females with normal BMI (7.7%) [Table 2].

Femoral neck

A negative correlation was detected between age and femoral neck BMD ($P < 0.05$, $r = -0.358$). The relationship between femoral neck T-score and BMI was the same as that for the lumbar spine in menopausal females [Table 2]. Among patients with osteoporosis, 20.6% were obese which was lower than the percentage observed in normal BMI (30.0%) and overweight (49.4%) osteoporotic participants. Moreover, 56.6% of females with normal T-score had BMI ≥30 [Table 2]. The lowest percentage of normal femoral T-score was observed in normal BMI females (6.7%) [Table 2].

Fracture risk assessment tool

Using linear regression for analyzing the relationship between femoral neck BMD, BMI, and FRAX, a statistical negative relation was observed between BMD, BMI, and the FRAX of hip and other regions [Table 3]. Furthermore, an increase of age led to an increase of the FRAX. The results showed a significant increase of BMD ($P < 0.001$) and a decrease of fracture risk ($\beta = -0.158$, $R^2 = 0.518$) with an increase of BMI in postmenopausal females.

Premenopausal females

The premenopausal females had a mean ± SD of 28.47 ± 4.57 kg/m^2 for BMI and 42.88 ± 5.64 years for age. Of all the premenopausal females, 21.3%, 43.6%, and 35.1% were in normal, overweight, and obese groups, respectively.

Lumbar spine

No significant decrease was observed in lumbar spine BMD with an increase of age in the premenopausal females ($P > 0.05$). However, Z-score significantly increased by increasing age ($P < 0.05$). The results indicated an increase of lumbar Z-score with an increase of BMI, which was not significant between BMI <25 and 25 ≤ BMI <30. Moreover, in BMI ≥30, BMD, and Z-score were significantly higher than those with BMI <30 ($P < 0.01$).

Femoral neck

The correlation between the femoral neck Z-score with age was the same as that for the lumbar spine. A significant increase in Z-score with an increase of BMI was observed in the three groups of different BMIs ($P < 0.01$) [Table 2].

DISCUSSION

The results in this study showed the significant relationship between BMI and lumbar spine and femoral neck BMD. Lumbar spine and femoral neck BMD were significantly higher in obese individuals than in those with BMI <25. These relationships did not differ by menopausal status.

The positive correlation between BMI and BMD has been proven in many studies.[22-24] In a study conducted in Isfahan, Iran, on males, similar results were detected, and both obesity and high body weight significantly decreased the risk of osteoporosis.[25] This positive correlation between BMI and BMD was also shown in a report of 5995 males aged

Table 1: Mean±standard deviation of femoral neck and L1-L4 bone mineral density among pre- and post-menopausal females with different body mass index

BMD	Premenopausal female (*n*=305)			Postmenopausal female (*n*=1056)			*P*		
	Normal	Overweight	Obese	Normal	Overweight	Obese	BMI	Pre-post¶	BMI* pre-post¡
Femoral neck	0.76±0.13	0.81±0.11	0.85±0.13	0.65±0.19	0.69±0.12	0.74±0.12	<0.001	<0.001	0.655
L1-L4	0.95±0.14	0.94±0.12	1.00±0.12	0.78±0.14	0.84±0.14	0.90±0.12	<0.001	<0.001	0.005

¶Comparison of pre- and post-menopausal females; ¡ Interaction between BMI and menopausal status. Two-way ANOVA was used for statistical analysis. BMD=Bone mineral density; BMI=Body mass index; *Femoral neck: not significant. L1-L4: significant

Table 2: Measures of lumbar spine and femoral neck Z-score in premenopausal females and T-score and fracture risk assessment tool in postmenopausal females

	Normal, *n* (%)	Overweight, *n* (%)	Obese, *n* (%)	*P*
Premenopausal females	*n*=65	*n*=133	*n*=107	
L1-L4 Z-score	−0.55±1.21	−0.45±1.02	−0.01±1.13	<0.01
Below expected range for age	9 (45.0)	8 (40.0)	3 (15.0)	0.01
Within expected range for age	56 (19.6)	125 (43.9)	104 (36.5)	
Femoral neck Z score	−0.62±1.07	−0.13±0.83	0.39±1.03	<0.001
Below expected range for age	6 (85.7)	1 (14.3)	0 (0.0)	<0.001
Within expected range for age	59 (19.8)	132 (44.3)	107 (35.9)	
Postmenopausal females	*n*=162	*n*=451	*n*=443	
L1-L4 T-score	−2.35±1.28	−1.77±1.22	−1.23±1.22	<0.001
Osteoporotic	77 (29.1)	128 (48.3)	60 (22.6)	<0.001
Osteopenic	61 (12.8)	209 (43.7)	208 (43.5)	
Normal	24 (7.7)	114 (36.3)	175 (55.9)	
Femoral neck T-score	−1.98±1.03	−1.52±0.98	−1.01±1.05	<0.001
Osteoporotic	51 (30.0)	84 (49.4)	35 (20.6)	<0.001
Osteopenic	84 (17.5)	218 (45.3)	179 (37.2)	
Normal	27 (6.7)	149 (36.7)	229 (56.6)	
FRAX hip	1.78±2.58	1.09±1.71	0.75±1.69	<0.001
FRAX other	5.15±6.11	4.07±3.73	3.23±3.28	<0.001

FRAX=Fracture risk assessment tool

Table 3: Linear regression of 10 years probability of hip fracture and other major osteoporotic fractures with bone mineral density, age and body mass index in postmenopausal females

	FRAX hip		FRAX other	
	B	SE	*B*	SE
Femoral neck BMD	−3.350**	0.390	−0.697**	0.786
Age	0.125**	0.006	0.298**	0.011
BMI	−0.158**	0.061	−0.256*	0.122

*Correlation is significant at the 0.05 level; **Correlation is significant at the 0.01 level. FRAX=Fracture risk assessment tool; BMD=Bone mineral density; SE=Standard error

65 years and more.[26] The same results were reported in a study examining postmenopausal females, which confirmed the influence of BMI on BMD and a lower prevalence of osteoporosis in obese females.[27] In another study carried out by Salamat *et al*. on males ≥50 years and postmenopausal females, the risk of osteoporosis was significantly lower in participants with BMI <25 than in those with BMI ≥30, which is in concordance with our results.[16] However, in another study on postmenopausal Mexican-Mestizo females, a significantly higher BMD was observed in higher BMI. Moreover, overweight individuals were observed to have lower BMD than obese patients but higher BMD than those with normal BMD.[28]

In contrast to this study, there are many reports suggesting the negative correlation between obesity and BMD. In these reports, it was shown that obese premenopausal and postmenopausal females lost more BMD than normal and overweight individuals over years, leading to a higher rate of osteoporosis.[29-31] The same results were reported by other authors, suggesting that increasing of an adipose tissue is not a beneficial factor for high bone density.[14,32,33] The reason for the negative effect of BMI on bone density is the fat distribution pattern. Although higher BMI may cause higher BMD due to heavier loads on the skeleton,[34] it cannot characterize fat mass and distribution. However, the pattern of obesity and fat distribution may be effective on the rate of the osteoporosis. It appears that visceral fat, which is more stored in males, is associated with higher levels of pro-inflammatory cytokine, causing bone resorption. However, females having more subcutaneous fat are more protected against osteoporosis because of higher levels of estrogen, adiponectin, and leptin.[35]

In this study, among premenopausal females, the lumbar spine and femoral neck BMD were not affected by age. Moreover, among postmenopausal females, older females had a significantly lower lumbar spine and femoral neck BMD and T-score. The negative correlation between age and BMD was reported in other studies[36,37] and was shown to be directly related to postmenopausal estrogen deficiency.[32] These results may question age-related relationship with BMD in some special groups, including premenopausal females.

The study demonstrated that increasing BMI and femoral neck BMD could cause a reduction in the probability of the hip and other major osteoporotic fractures in postmenopausal females. Older individuals have a higher risk of fractures. The same results are found in other studies, showing an increased risk of fractures in lower BMDs.[38,39] Using FRAX can help physicians to find osteopenic patients who might benefit from medical therapies to reduce future fracture risks.

According to the results of this study, despite the harmful effects of obesity on the body, it can prevent low BMD for age. Therefore, the ideal weight to prevent osteoporosis and systemic diseases caused by obesity has remained unknown. Different results in different studies may be due to the specific study population, study design, small number of sample sizes, and methodological differences.

The strength of this study was the enrolment of a large number of individuals, including females in different menopausal status, which makes the results of this report more valid than previous ones. Considering the high number of participants who entered the study during a

1-year-period, the obtained results can be generalized. Our results showed that BMI was indicators of BMD in all the age groups and in different parts of the body skeleton. Age can help us to estimate the degree of osteoporosis in bone mass of postmenopausal females. Although this study provides a better understanding of the relationship between BMI and age as well as their impact on BMD in premenopausal females and postmenopausal females, it still has some limitations. The skeletal mass index including muscle strength and muscle mass was shown to be significantly related to osteoporosis and BMD in the lumbar spine and total hip.[40] This index was not measured in this study. Another limitation of this study was the absence of trabecular bone score (TBS) measurement. TBS is a quantitative index that measures the bone microarchitecture and reflects trabecular counts, connection, and space between trabeculae and provides information about bone independent of BMD.[41,42] Although there is a positive correlation between BMI and BMD, there are few studies reporting a negative correlation between TBS and BMI.[43,44] To explore the relationship between BMI, the fracture risk and TBS, further studies are required.

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Conflicts of interest

There are no conflicts of interest.

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