

## Original article

## Associations between bone mineral density, trabecular bone score, and body mass index in postmenopausal females

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## ABSTRACT

**Objectives:** Bone mineral density (BMD), as a gold standard determinant of osteoporosis, assesses only one of many characteristics contributing to the bone. Trabecular bone score (TBS) is applied to evaluate the microarchitecture of trabecular bone. A high body mass index (BMI) has been reported to have a positive correlation with BMD. However, the relation between BMI and TBS has remained unclear. Therefore, the aim of this study is to shed light on the associations between BMI, T-score, and TBS in postmenopausal women without a diagnosed underlying disease.

**Methods:** In this cross-sectional study, 1054 postmenopausal women were randomly recruited from the Department of Radiology, Isfahan University of Medical Sciences. Demographic characteristics and medical history of all subjects were collected from documents. TBS measurements for L1-L4 vertebrae were retrospectively performed by the TBS insight software using the dual X-ray absorptiometry (DXA) from the same region of spine of the subjects. The analysis was done to detect the correlation between TBS and BMI.

**Results:** A statistically significant negative correlation was found between TBS and BMI in patients with osteoporosis and low bone mass. In patients with normal T-scores, BMI was not significantly correlated to TBS ( $P > 0.05$ ). Furthermore, there was a significant positive association between T-score and BMI.

**Conclusions:** Although a higher BMI had a protective effect against osteoporosis, higher BMI was associated with a lower TBS in patients with an abnormal T-score. However, BMI did not have a significant effect on TBS in patients with normal T-scores.

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## 1. Introduction

Osteoporosis is a prevalent bone disease in postmenopausal women characterized by microarchitectural changes of bone tissue and reduction of bone mass compared to normal values. This health issue leads to a wide variety of complications including pain, decreased activity and quality of life, and increased rates of bone fractures and mortality [1,2]. Although vigorous efforts have been made to optimally delineate those at increased risk of osteoporosis-related bone fractures, there is still a high uncertainty in the accuracy of the current tools as determinants of bone strength [1,2]. Since bone mineral density (BMD) assesses only one of many

characteristics contributing to bone strength and fracture risk, evaluating the microarchitecture of trabecular bone using trabecular bone score (TBS) can improve the accuracy and sensitivity of risk assessment of fragility fractures [3–5]. TBS is an indirect index of trabecular microarchitecture that reflects trabecular counts, connection, and space between trabeculae using noninvasive and free radiation methods [5,6].

Previous studies have shown positive correlations between body mass index (BMI) and BMD as a gold standard determinant of osteoporosis [7–9]. Also, it has been reported that TBS is directly affected by abdominal weight accumulation [10]. To date, however, limited data exist on the association between TBS and BMI. This study, therefore, aims to shed light on the association between TBS and BMI in postmenopausal women without a diagnosed underlying disease.

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## 2. Methods

This cross-sectional study was performed on all postmenopausal women who were referred to the Department of Radiology at Askariye Hospital, Isfahan, Iran, from October 2018 to October 2019. Demographic characteristics and medical history of all subjects were collected from medical documents of the hospital. Being menopausal was the inclusion criterion. This study was approved by the ethical review board of the Department of Radiology, Isfahan University of Medical Sciences (IR.MUI.ME-D.REC.1398.305) and a waived need for informed consent. Menopause was defined as the permanent cessation of menstrual periods after 12 months of amenorrhea and in the absence of any pathological etiology. Exclusion criteria included hormonal diseases, orthopedic diseases, cancers, secondary causes of osteoporosis such as hyperparathyroidism, and consumption of vitamin D, and other medications or agents that could affect bone metabolisms.

The height and weight of the subjects were measured using a wall-mounted stadiometer and an electronic scale, respectively. BMI was then calculated by a BMI calculator using height (meter) and weight (kilogram) parameters. BMI was categorized as underweight (< 20), normal (20–25), overweight (25–30), and obese (> 30).

Patients were categorized into 3 groups according to age, including 45–60, 60–75, and older than 75 years, respectively.

TBS measurement for L1–L4 vertebrae was retrospectively performed at the Radiology Center of Askariye Hospital, Isfahan, Iran, through the TBS iNsight software (version 3.0.2.0; Medimaps, Merignac, France) using the dual X-ray absorptiometry (DXA) of the same region of the spine. In this study, all measurements were performed by the same operators and devices at the same center and the same calibrated device (Hologic Discovery wi 86,189). Based on the findings reported in a recent meta-analysis by McCloskey et al [11], TBS was divided into 3 levels including normal ( $TBS \geq 1.350$ ), partially degraded ( $1.350 > TBS > 1.200$ ), and degraded ( $TBS \leq 1.200$ ). Furthermore, T-scores were divided into 3° including normal (T-score  $\geq -1$ ), low bone mass ( $-1 > T\text{-score} > -2.5$ ), and osteoporosis (T-score  $\leq -2.5$ ).

Statistical analyses were performed using SPSS software version 24 (IBM, Chicago, IL). After assessing the normal distribution of numeric variables using Kolmogorov-Smirnov test, linear regression test was used to evaluate correlations between numeric variables. Comparisons of numeric variables between groups were carried out using one-way analysis of variance (ANOVA) and *post hoc* test. Data are reported as mean  $\pm$  standard deviation. Statistical analyses were performed according to age groups of patients, T-score, and BMI status. P-values less than 0.05 were considered as the significant threshold.

## 3. Results

In this study, 43 subjects were excluded due to incomplete data, and final subjects consisted of 1054 postmenopausal females with a mean age of  $60.43 \pm 7.85$  years (range, 45–88 years).

A total of 563 (53.4%) and 428 (40.6%) patients were aged 45–60 and 60–75 years, respectively. Sixty-three patients (6%) were older than 75 years.

The mean BMI of females was  $29.40 \pm 4.71$  kg/m<sup>2</sup>. Of 1054 participants, 6 (0.6%) were underweight, 173 (16.4%) had normal BMI, 407 (38.6%) were overweight, and 468 (44.4%) were obese (Table 1).

The mean of TBS was  $1.31 \pm 0.11$ . Normal TBS was detected in 384 (36.4%) of participants. A total of 528 (50.1%) and 142 (13.5%) of participants had partially degraded microarchitecture and

**Table 1**  
Demographic data.

Age, yr, mean (SD)	60.43 (7.85)
TBS category, mean (SD), n (%)	
Degraded	1.14 (0.14), 142 (13.5%)
Partially degraded	1.28 (0.04), 528 (50.1%)
Normal	1.42 (0.06), 384 (36.4%)
BMD T-score, mean (SD), n (%)	
Osteoporosis	−3.30 (0.74), 268 (25.4%)
Low bone mass	−1.75 (0.40), 475 (45.1%)
Normal	0.0 (0.82), 311 (29.5%)
BMI, mean (SD), n (%)	
Underweight	17.83 (0.60), 6 (0.6%)
Normal	22.99 (1.50), 173 (16.4%)
Overweight	27.50 (1.43), 407 (38.6%)
Obese	33.59 (3.13), 468 (44.4%)
Height, cm, mean (SD)	154.41 (6.73)
Weight, kg, mean (SD)	70.09 (11.79)

TBS, trabecular bone score; BMD, bone mineral density; BMI, body mass index; SD, standard deviation.

degraded microarchitecture, respectively.

Using lumbar T-score, normal T-score, low bone mass, osteoporosis was observed in 311 (29.5%), 475 (45.1%), and 268 (25.4%) of participants, respectively.

A negative correlation was detected between TBS and age ( $r = -0.29$ ,  $P < 0.001$ ). A negative correlation was detected between TBS and BMI among patients younger than 75 years of age in those with osteoporosis and low bone mass ( $P < 0.001$ ) (Table 2). In patients with normal T-scores, however, TBS and BMI were not correlated in any of the age groups ( $P > 0.05$ ) (Table 2).

A positive significant correlation was detected between TBS and height ( $r = 0.161$ ,  $P < 0.001$ ). However, TBS and weight were not significantly correlated ( $P > 0.05$ ).

TBS significantly correlated with lumbar T-score ( $r = 0.46$ ,  $P < 0.001$ ). The correlation between BMI and TBS was investigated in subjects with osteoporosis, low bone mass, and normal T-score. TBS and BMI significantly correlated in individuals with osteoporosis ( $r = -0.31$ ,  $P < 0.001$ ) and low bone mass ( $r = -0.37$ ,  $P < 0.001$ ). However, no significant correlation was detected between TBS and BMI among subjects with normal T-scores ( $P > 0.05$ ) (Table 3 and Fig. 1).

In this study, the mean of lumbar spine T-score was  $-1.99 \pm 1.31$ . A significant positive association was detected between T-score and BMI ( $r = +0.32$  and  $P < 0.01$ ). Moreover, there were statistically significant differences in T-scores between individuals with BMI values of less than 25, between 25 and 30, and more than 30 ( $P < 0.001$ ).

**Table 2**

BMI and TBS in patients with osteoporosis, low bone mass, and normal T-score and different age groups.

BMD T-score	BMI	TBS	P-value	r
45–60 years (n = 563)				
Osteoporosis (n = 97)	27.47 (5.23)	1.27 (0.07)	< 0.001	−0.37
Low bone mass (n = 258)	29.44 (4.55)	1.33 (0.08)	< 0.001	−0.36
Normal (n = 208)	30.69 (4.30)	1.40 (0.15)	> 0.05	−
60–75 years (n = 428)				
Osteoporosis (n = 146)	27.27 (4.25)	1.23 (0.07)	< 0.001	−0.35
Low bone mass (190)	30.17 (4.34)	1.28 (0.08)	< 0.001	−0.38
Normal (n = 92)	31.35 (4.64)	1.34 (0.10)	> 0.05	−
> 75 years (n = 63)				
Osteoporosis (n = 25)	25.68 (5.48)	1.21 (0.07)	> 0.05	−
Low bone mass (n = 27)	29.66 (4.32)	1.26 (0.10)	< 0.05	−0.48
Normal (n = 11)	28.61 (2.65)	1.35 (0.08)	> 0.05	−

Values are presented as mean (standard deviation).

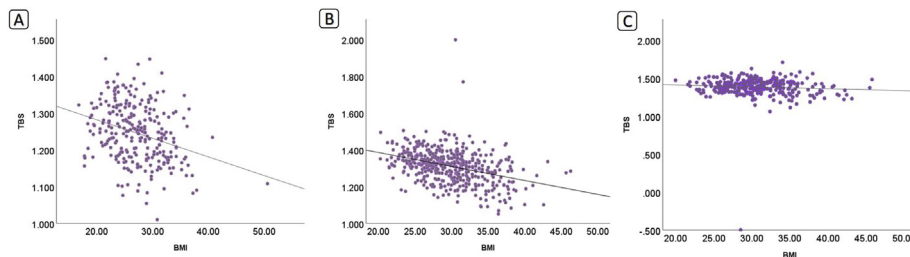
BMI, body mass index; TBS, trabecular bone score; BMD, bone mineral density.

**Table 3**

TBS in different categories of BMI in participants with osteoporosis, low bone mass, and normal T-score.

BMD T-score	BMI < 25 (n = 179)	25 ≤ BMI ≤ 30 (n = 407)	BMI > 30 (n = 468)	P-value
Osteoporosis	1.26 (0.07)	1.24 (0.07)	1.21 (0.07)	<0.001
Low bone mass	1.35 (0.06)	1.32 (0.07)	1.28 (0.10)	<0.001
Normal	1.39 (0.07)	1.38 (0.19)	1.38 (0.09)	>0.05

Values are presented as mean (standard deviation). TBS, trabecular bone score; BMI, body mass index; BMD, bone mineral density.

**Fig. 1.** The correlation between BMI and TBS in patients with osteoporosis (A), osteopenia (B), and normal (C) T-scores. BMI, body mass index; TBS, trabecular bone score. Equations as follows.  $y = 1.38 - 5.06E-3 * x$  (A),  $y = 1.54 - 7.62E-3 * x$  (B),  $y = 1.46 - 2.54E-3 * x$  (C).

#### 4. Discussion

In this study, correlations between BMI, T-scores, and TBS were investigated in Iranian postmenopausal women. Our findings showed a significant positive correlation between BMI and T-scores. Furthermore, a negative correlation was found between TBS and BMI in participants younger than 75 years with osteoporosis and low bone mass. However, there was no significant association between BMI and TBS in subjects with normal T-scores. The inconsistent correlations between BMI, TBS, and T-scores may in part be clarified by different mechanisms of effects of BMI on the microarchitecture of trabecular bone and BMD. Moreover, despite some studies on the correlation between BMI and T-scores or between BMI and TBS separately, there are limited number of works investigating these correlations simultaneously.

In a similar study, Kim et al [12] reported a significant negative correlation between TBS and BMI in patients with low bone mass and osteoporosis. They also found a negative correlation between weight and TBS, which is not consistent with our findings. However, Kim et al [12] reported a positive correlation between height and TBS, which is in line with our results. Since the results of this study showed no correlation between weight and TBS, it seems that the negative correlation between TBS and BMI is related to height. Based on these results, taller subjects have higher TBS and lower BMI.

Similar to our results, a negative correlation between TBS and BMI was also reported by Rajaei et al [13] in a study on 548 Iranian patients, indicating lower TBS in patients with higher BMI. Such a negative correlation was also reported in a study on 1999 postmenopausal females aged between 41 and 94 years ( $r = -0.34$ ,  $P < 0.001$ ) [14].

In another study on 53 post-menopausal healthy females, a negative correlation was observed between TBS and BMI ( $r = -0.33$ ,  $P = 0.01$ ) [15], as was also reported by Bonaccorsi et al ( $r = -0.12$ ,  $P = 0.03$ ) [16].

In a similar study, Looker et al [7] investigated TBS, BMD, and body size variables in the US population. They assessed lumbar spine BMD and TBS using DXA and TBS iNsite software in 7682 US adults. Consistent with our findings, they reported a significant positive correlation between T-score and all body size variables, and significant negative correlations between TBS and body size variables. They also found a correlation between TBS and BMI

( $r = -0.33$ ), which is different from those reported in previous studies (range =  $-0.13$  to  $-0.19$ ) [17–21]. One possible reason for this inconsistency could be the use of different versions of iNsite software, which results in differences in the correlations reported in previous studies. Another explanation for such a difference may be the use of different DXA instruments as their TBS data were collected using different instruments in 2005–2008. In contrast to our study, they excluded a major at-risk group for osteoporosis, ie, institutionalized subjects, from their sampling. As a result, their findings can only be used for the non-institutionalized US population.

In another study, Mazzetti et al [8] evaluated correlations between BMD, TBS, and BMI in 2730 Canadian subjects. Consistent with our results, they showed a significant negative correlation between TBS and BMI ( $r = -0.33$ ) and a significant positive correlation between BMD and BMI ( $r = 0.26$ ). Similar to the study of Looker et al, data were collected from different centers in 2005–2007, which may cause differences in reported correlations. In addition, there is an important difference between the exclusion criteria of our study and those used in their study. Indeed, they did not exclude subjects with hormonal diseases, orthopedic diseases, cancers, diseases affecting bones, and consumption of vitamin D and other medications or agents that could affect bone metabolisms. Compared to our study, however, their study had some superiorities including a larger sample size and investigation of both men and women. Unlike our study, they also compared TBS measurements derived from Hologic densitometer images with those derived from General Electric Lunar densitometers.

Romagnoli et al [22] assessed associations between BMI, TBS, and BMD in 87 Italian overweight/obese men. Our results are in line with their reported findings as they showed a significant positive correlation between BMD and BMI, and a significant negative correlation between TBS and BMI. It is of note that there are some important differences between their inclusion and exclusion criteria and those considered in our study, as they assessed their variables only in male and overweight/obese subjects. In addition, they excluded subjects with some comorbidities that were partly different from diseases excluded from our study.

Different correlations detected here between BMI, T-score, and TBS can be explained by the fact that BMI is not an adequate indicator of the distribution of fat tissue and cannot differentiate it from muscle weight.

Therefore, it is strongly suggested to investigate correlations between TBS, BMD, and other indexes of obesity, metabolic syndrome, and anthropometric factors in a larger sample of subjects.

Our study had some limitations including a small sample size, especially patients older than 75 years, a limited number of variables associated with obesity, and lack of evaluation of the effect of race on the studied correlations. Also, there are some potential confounders, including physical activity diet, or smoking, which has not been considered in this study.

## 5. Conclusions

Overall, a significant positive correlation was found between BMI and T-scores. Also, a significant negative correlation was detected between BMI and TBS in post-menopausal females younger than 75 years with osteoporosis and low bone mass. This suggests that a higher BMI has protective effects on osteoporosis, but is associated with a lower TBS in these categories of females. However, TBS values need further large population-based studies to provide more convincing data on the exact correlations between TBS, T-score, and body size variables in postmenopausal women.

## Conflicts of interest

No potential conflict of interest relevant to this article was reported.

## CRedit author statement

**Azin Shayganfar:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Mehrdad Farrokhi:** Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Sanaz Shayganfar:** Writing - original draft, Writing - review & editing. **Shadi Ebrahimian:** Data curation, Formal analysis, Writing - original draft, Writing - review & editing.

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