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**ORIGINAL ARTICLE**

# Impact of age and body mass index on dual-energy X-ray absorptiometry scan results in postmenopausal women

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## ABSTRACT

**Aim** To analyse the impact of age and body mass index (BMI) on dual-energy X-ray absorptiometry (DXA) scan results in postmenopausal women.

**Methods** The study included 100 postmenopausal women who underwent the DXA procedure, out of which 50 had a normal BMI and 50 were overweight/obese. Data that were examined included age, BMI, T-score of the lumbar region and the femoral neck, as well as bone mineral density (BMD). Correlation results were presented as Pearson's correlation coefficient (r).

**Results** The T2-score and BMD2 were significantly lower in older patients compared to younger ones (p=0.008 and p=0.007, respectively). *Post hoc* test results showed that the T2-score and BMD2 were significantly lower in patients ≥71 years of age compared to patients ≤59 years of age (p=0.006 and p=0.005, respectively). Also, T1- and T2-scores, as well as BMD1 and BMD2, were significantly higher in overweight/obese patients (p<0.001 and p=0.003; p<0.001 and p=0.002, respectively). The correlation between BMI and the T1-score was moderate (r=0.429), between BMI and the T2-score weak (r=0.348), between BMI and BMD1 moderate (r=0.431), and between BMI and BMD2 weak (r=0.344).

**Conclusion** Our study showed that both age and BMI are important factors affecting DXA procedures and should be taken into account with each postmenopausal woman individually in everyday practice.

**Keywords:** body weight, densitometry, postmenopause

## INTRODUCTION

Accurate body composition assessment is essential for evaluating health status and disease risk across diverse populations. Dual-energy X-ray absorptiometry (DXA) has emerged as a precise tool for quantifying fat mass, lean mass, and bone mineral density (BMD), offering crucial insights for clinical decision-making and research (1). However, interpreting DXA scans is complex and influenced by various factors, including the age and body mass index (BMI). This index, calculated from an individual's height and weight, serves as a widely used proxy for body fatness and significantly impacts DXA measurements, highlighting variations in fat distribution and lean mass composition with increasing BMI (2). These variations underscore the importance of considering BMI when interpreting DXA scans, especially in clinical settings where accurate body composition assessment informs management strategies for obesity-related conditions and overall health (3).

Bones naturally become thin with age. The level of calcium and other minerals decreases as people age, resulting in lower bone weight and density, and thus increased fragility. Greater bone thickness is a protective factor related to osteoporosis development (4). Several prospective studies have indicated that underweight (BMI ≤18.5) women lose more bone density and have a higher risk of osteoporotic fractures compared to those of average weight (5–7). While BMI impacts osteoporosis development, BMD could be the primary risk factor for osteoporosis and fractures. This hypothesis was tested and the results suggested that BMD rather than BMI mediates fracture risk (8).

Other radiological procedures could be applied to postmenopausal women for these purposes, such as vertebral fracture assessment, trabecular bone score, and quantitative computed tomography, but DXA is still a standard procedure and has a fundamental place in routine analyses (9).

Unfortunately, this problem has not been sufficiently well examined in Bosnia and Herzegovina (B&H), although there is no objective obstacle to it, because DXA is a routine procedure in clinical centres in B&H, and the most frequent patients are women, many of whom are postmenopausal.

The aim of this study was to analyse the impact of age and BMI on DXA scan results in postmenopausal women.

The authors decided to conduct this study in order to deepen the understanding of how these factors affect the interpretation of DXA scans in clinical and research settings, especially when it comes to quantifying BMD. The obtained data will serve

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healthcare professionals to refine their approach to assessing body composition and improve patients' care, thereby enhancing outcome of obesity and metabolic health management.

## PATIENTS AND METHODS

### Patients and study design

For this prospective study, patients were recruited when they came to the Clinic for Nuclear Medicine, Clinical Centre of the University of Sarajevo, for the DXA procedure in the period between December 2023 and March 2024.

Inclusion criteria were: postmenopausal women (women who had not had a period for over a year) with a recommendation to have the DXA procedure done due to a suspected diagnosis of osteopenia or osteoporosis.

Exclusion criteria were: male patients, menstruating women, pregnant or lactating women, postmenopausal women but with no recommendation for the DXA procedure due to a suspected diagnosis of osteopenia or osteoporosis.

When the necessary parameters (confidence level 95%, margin of error 5%, and population proportion 50%) were entered into the calculator that estimates the sample size, the number of patients to be included in the study was 100, therefore, 100 postmenopausal women who had undergone the DXA procedure were included, out of which 50 were overweight/obese and 50 had a normal BMI.

The patients were classified into three groups based on their age (for the purpose of the statistical analysis because the age range was from 47 to 84 years): group 1 ≤59, group 2 60-70, and group 3 ≥71 years of age.

The patients were also classified into two groups based on their BMI: group 1 – overweight/obese (BMI ≥25) and group 2– normal weight (BMI ≤24.9).

All patients signed an informed consent form.

The study was approved by the Ethics Committee of the Clinical Centre of the University of Sarajevo.

### Methods

The DXA procedures were done using Lunar DPX (GE Healthcare, the United States of America).

The examined data included the patients' age, BMI, the T-score of the lumbar region (T1), the T-score of the femoral neck (T2), BMD of the lumbar region (BMD1), and BMD of the femoral neck (BMD2).

The T-score is the difference between a patient's BMD and the BMD of a healthy young adult. A lower T-score represents a greater risk of bone fracture. The T-score results were interpreted as follows: >-1.0 = normal, -1.0 to -2.5 = osteopenia, <-2.5 = osteoporosis.

### Statistical analysis

Results were presented as descriptive statistics. The normality of the data distribution was tested by the Kolmogorov-Smirnov test. The data distribution was normal and parametric tests were used to prove the differences between the variables: ANOVA, independent samples t-test, and *post hoc* Tukey. Test results were considered significant at $p<0.05$. Correlation results were presented as Pearson's correlation coefficient (r): <0.19 very weak correlation, 0.20-0.39 weak correlation, 0.40-0.59 moderate correlation, 0.60- 0.79 strong correlation, 0.80-1.00 very strong correlation.

## RESULTS

A total of 100 postmenopausal women were included. They were classified into three groups based on the age range (47-84 years): ≤59 with 20, 60-70 with 55, and ≥71 years of age with 25 women. The mean age was 65.69±7.566 years. The women were also classified into two groups based on their BMI: 50 were overweight/obese (BMI ≥25) and 50 had normal weight (BMI ≤24.9). The lowest BMI of 20.2, and the highest one of 38.1, with the mean BMI of 29.15 ± 3.231, were found. Values of T1-score ranged from -5.0 to 2.4, with the mean of -1.640 ± 1.391; for T2-score: from -3.7 to 1.3 (-1.513 ± 0.887); for BMD1: from 0.583 to 1.473 (0.983 ± 0.167); and for BMD2: from 0.529 to 1.219 (0.828 ± 0.123) (Table 1).

**Table 1. Descriptive statistics of T-scores and bone mineral density (BMD) in the entire sample**

| Values | T1-score | T2-score | BMD1 | BMD2 |
|---|---|---|---|---|
| Mean | -1.640 | -1.513 | 0.983 | 0.828 |
| Median | -1.800 | -1.600 | 0.965 | 0.815 |
| Standard deviation | 1.391 | 0.887 | 0.167 | 0.123 |
| Range | 7.4 | 5.0 | 0.890 | 0.690 |
| Minimum | -5.0 | -3.7 | 0.583 | 0.529 |
| Maximum | 2.4 | 1.3 | 1.473 | 1.219 |

T1, T-score of the lumbar region; T2, T-score of the femoral neck; BMD1, bone mineral density of the lumbar region; BMD2, bone mineral density of the femoral neck

According to T-scores, most patients had osteopenia: T1-score in 44 (44%) and T2-score in 67 (67%) women; normal BMD: T1-score in 32 (32%) and T2-score in 25 (25%) women. Osteoporosis was presented with T1-score in 24 (24%) and T2-score in eight (8%) women. The most common occurrence of osteopenia compared to normal BMD and osteoporosis was seen in patients 60-70 and ≥71 years of age: T1-score in 26 (47.3%) and T2-score in 39 (70.9%), and T1-score in 11 (44%) and T2-score in 16 (64%) women, respectively; in overweight/obese women: T1-score in 24 (48%) and T2-score in 33 (66%) women. In women of normal weight, osteopenia was the most common: T1-score in 20 (40%) and T2-score in 34 (68%) women. Osteoporosis was presented with T1-score in 18 (36%) and T2-score in nine (18%) women; normal BMD: T1-score in 12 (24%) and T2-score in seven (14%) women. Most patients ≤59 years of age had normal BMD: T1-score in nine (45%) and T2-score in 12 (60%) women (Table 2).

The T2-score and BMD2 were significantly lower in older women ($p=0.008$ and $p=0.007$, respectively). Results of *post hoc* test showed that the T2-score and BMD2 were significantly lower in patients ≥71 years of age compared to patients ≤59 years of age ($p=0.006$ and $p=0.005$, respectively) (Table 3).

Differences in tested parameters between the patients of two BMI groups showed that T1- and T2-scores ($p<0.001$ and $p=0.003$, respectively), as well as BMD1 and BMD2 ($p<0.001$ and $p=0.002$, respectively), were significantly higher in overweight/obese women (Table 4).

All correlations were positive: moderate between BMI and the T1-score ($r=0.429$), weak between BMI and the T2-score ($r=0.348$), moderate between BMI and BMD1 ($r=0.431$), and weak between BMI and BMD2 ($r=0.344$) (Figure 1).

**Table 2. Distribution of women with normal bone mineral density (BMD), osteopenia, and osteoporosis according to T-scores, age and body mass index (BMI)**

| Group | T1-score | | | T2-score | | |
|---|---|---|---|---|---|---|
| | >-1.0 | -1.0 to -2.5 | <-2.5 | >-1.0 | -1.0 to -2.5 | <-2.5 |
| **All patients** | 32 | 44 | 24 | 25 | 67 | 8 |
| **Age group** (years) | | | | | | |
| ≤59 | 9 | 7 | 4 | 12 | 8 | 0 |
| 60-70 | 15 | 26 | 14 | 13 | 39 | 3 |
| ≥71 | 8 | 11 | 6 | 5 | 16 | 4 |
| **BMI group** | | | | | | |
| Overweight/obese (BMI ≥25) | 20 | 24 | 6 | 17 | 33 | 0 |
| Normal weight (BMI ≤24.9) | 12 | 20 | 18 | 7 | 34 | 9 |

T1, T-score of the lumbar region; T2, T-score of the femoral neck; T-score >-1.0 = normal BMD; T-score -1.0 to -2.5 = osteopenia; T-score <-2.5 = osteoporosis

**Table 3. Differences in tested parameters among three age groups of women**

| Parameter | **Age group** (years) | p |
|---|---|---|
| T1-score | ≤59 | |
| | 60-70 | 0.670 |
| | ≥71 | |
| T2-score | ≤59 | |
| | 60-70 | 0.008 |
| | ≥71 | |
| BMD1 | ≤59 | |
| | 60-70 | 0.684 |
| | ≥71 | |
| BMD2 | ≤59 | |
| | 60-70 | 0.007 |
| | ≥71 | |
| ***post hoc*** | | |
| T2-score | ≤59 – 60-70 | 0.129 |
| | ≤59 – ≥71 | 0.006 |
| | 60-70 – ≥71 | 0.162 |
| BMD2 | ≤59 – 60-70 | 0.108 |
| | ≤59 – ≥71 | 0.005 |
| | 60-70 – ≥71 | 0.166 |

T1, T-score of the lumbar region; T2, T-score of the femoral neck; BMD1, bone mineral density of the lumbar region; BMD2, bone mineral density of the femoral neck

## DISCUSSION

In our study, the T-score and BMD of the femoral neck were significantly lower in patients ≥71 years of age compared to patients ≤59 years of age, confirming that the age was a risk factor for the development of osteopenia and osteoporosis. Several studies have suggested that increased age is an independent risk factor for BMD loss in postmenopausal women (10–12). This could play a vital role in early diagnosis of osteoporosis. There are many physiological changes in older people supporting previous findings: low calcium absorption, vitamin D deficiency, as well as bone and muscle loss or cognition and coordination difficulties causing falls (13,14). Alterations in bones are very common with ageing because there is a decrease in trabecular thickness and cortical bone porosity, as well as an increase in marrow adiposity. These changes are predominately caused by an increased osteoclast activity in postmenopausal women (15). It is important to mention that apoptosis of osteoblasts and osteocytes is independent of estrogen-mediated effects. Bone remodelling could be triggered by reactive oxygen species (ROS), deoxyribonucleic acid (DNA) damage, as well as telomere and heterochromatin dysfunction (16).

In our study, T-scores and BMD of both the lumbar region and the femoral neck were significantly higher in overweight/obese women. Osteoporosis and obesity were previously thought to be unassociated (17), but there are several genetic and environmental components that both conditions share (18).

**Table 4. Differences in tested parameters between two body mass index (BMI) groups of women**

| Parameter | BMI group | Mean (±SD) | p |
|---|---|---|---|
| T1-score | Overweight/obese (BMI ≥25) | -1.162 (±1.284) | <0.001 |
| | Normal weight (BMI ≤24.9) | -2.118 (±1.339) | |
| T2-score | Overweight/obese (BMI ≥25) | -1.250 (±0.823) | 0.003 |
| | Normal weight (BMI ≤24.9) | -1.776 (±0.878) | |
| BMD1 | Overweight/obese (BMI ≥25) | 1.041 (±0.154) | <0.001 |
| | Normal weight (BMI ≤24.9) | 0.926 (±0.161) | |
| BMD2 | Overweight/obese (BMI ≥25) | 0.864 (±0.114) | 0.002 |
| | Normal weight (BMI ≤24.9) | 0.792 (±0.123) | |

SD, standard deviation; T1, T-score of the lumbar region; T2, T-score of the femoral neck; BMD1, bone mineral density of the lumbar region; BMD2, bone mineral density of the femoral neck

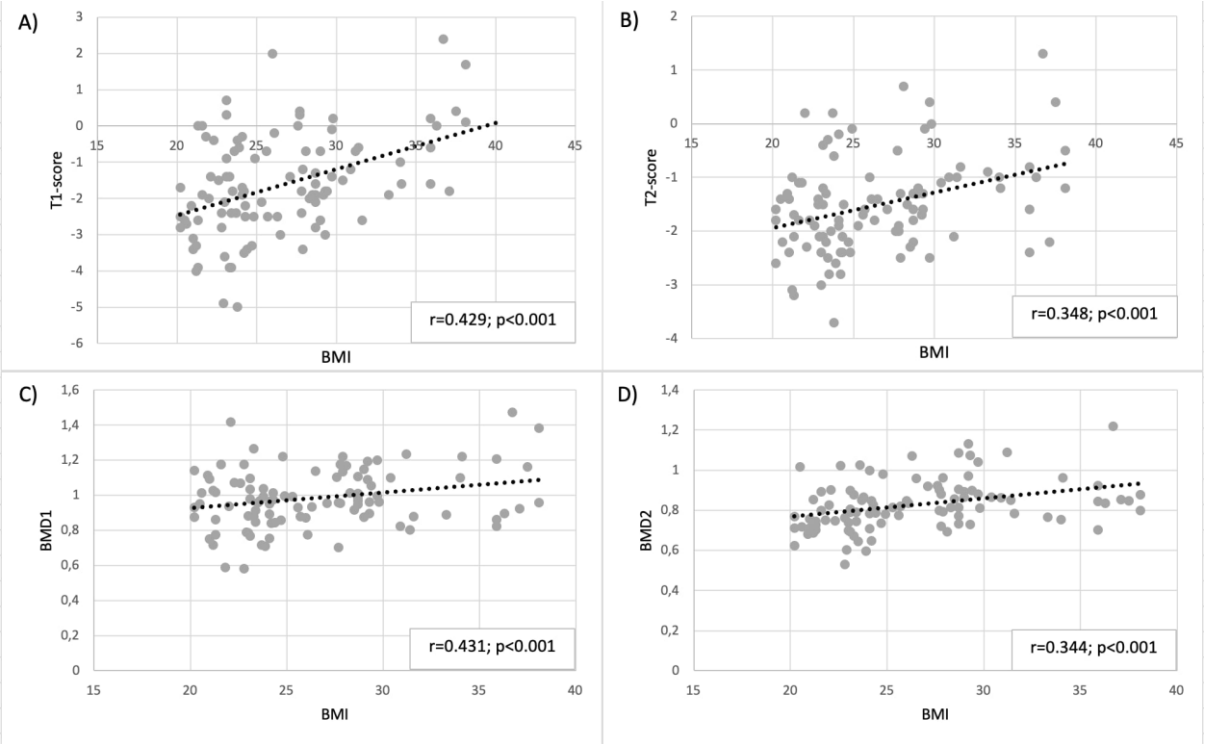


**Figure 1. Correlations between: A) body mass index (BMI) and the T1-score; B) BMI and the T2-score; C) BMI and BMD1; and D) BMI and BMD2**

T1, T-score of the lumbar region; T2, T-score of the femoral neck; BMD1, bone mineral density of the lumbar region; BMD2, bone mineral density of the femoral neck

One of the most significant indicators of obesity is body fat mass, which is proposed to be protective for bones. However, having too much fat mass may not shield one from osteoporosis (19). Numerous hypotheses justify the reported physiological correlations between fat and bone, despite the absence of a clear consensus (20). The most important hypothesis indicates that the same precursor stem cell promotes the differentiation of adipocytes and osteoblasts, as well as the release of hormones from adipocytes that influence bone formation (21). In postmenopausal women with osteoporosis, results showed that the lower the BMI, the greater the BMD loss (6). Overweight patients had significantly higher BMD compared to those of normal weight (7). On the other hand, in one study (22), fragility was correlated with increased body fat mass. The relationship between BMI and BMD was not a simple linear relationship, and there was a saturation point (23). Therefore, people with low BMI should take preventive measures against osteoporosis, but those with high BMI are not amnestied of the risk of osteoporosis (24). Furthermore, no significant correlation between BMI and BMD of the lumbar region was found, while a significant positive correlation was found between BMI and BMD of the femoral neck (25). In our study, positive correlations were found between BMI and BMD of both the lumbar region and the femoral neck (moderate and weak, respectively). Contradicting results of these studies could be explained by variations in the chosen variables, the sample structure, or the experimental methodology.

To conclude, our study showed that both age and BMI are important factors affecting DXA procedures and should be taken into account with each postmenopausal woman individually in everyday practice. Because studies have shown conflicting results, this area will remain captivating for researchers.

## AUTHOR CONTRIBUTIONS

Conceptualization, H.Ć.; Data curation, H.Ć. and N.S.; Formal Analysis, H.Ć.; Investigation, H.Ć. and N.S.; Methodology, H.Ć., Š.C., S.A., A.S. and E.T.; Writing – original draft, N.S. and N.O.Ć.; Writing – review & editing, N.O.Ć.; Supervision, Š.C., S.A., A.S. and E.T. All authors have read and agreed to the published version of the manuscript.

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## TRANSPARENCY DECLARATION

Conflict of interests: None to declare.

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