Relationship Between Prepatellar Fat Thickness and Bone Mineral Density

Hatice Agir[1] and Ozlem Orhan[2]

[1]*Department of Physical Medicine and Rehabilitation, Sanliurfa Training and Research Hospital, Sanliurfa, Turkiye*
[2]*Department of Orthopaedics and Traumatology, Harran University Medicine Faculty, Sanliurfa, Turkiye*

ABSTRACT

Objective: To evaluate the relationship between bone mineral density (BMD) by measuring the prepatellar fat thickness with knee radiography and to gain a measurement method that has not been done before in the literature.

Study Design: Cross-sectional descriptive study.

Place and Duration of the Study: Department of Physical Medicine and Rehabilitation, Training and Research Hospital, Sanliurfa, Turkiye, between January and June 2020.

Methodology: Patients' age, body mass index (BMI) data, prepatellar fat thickness (mm), L1-L4 total, bone mineral density femoral neck, femur trochanter major, and femur total T scores were recorded. The relationships between these three groups (normal, osteopenia, osteoporosis) and between prepatellar fat tissue measurement were evaluated. One-way analysis of variance (ANOVA) and Post Hoc Tukey tests were used in the analysis.

Results: A statistically significant difference was found in terms of trochanter major T score measurements ($X^2 = 20.435$; $p < 0.001$) and BMI ($X^2 = 66.535$; $p < 0.001$) measurements of prepatellar fat thickness measurement. A statistically significant difference was found between the three groups in terms of prepatellar fat thickness measurement, L1-4 T-score, femoral neck, and femur total values ($p < 0.001$).

Conclusion: Prepatellar fat thickness in postmenopausal Turkish women was positively correlated with BMD; BMD increases as the prepatellar fat thickness increases. This explains that perapatellar fat thickness creates a mechanical load on the bones and causes an increase in BMD.

Key Words: *Osteoporosis, Fat thickness, Bone mineral density.*

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INTRODUCTION

Osteoporosis (OP) is a systemic skeletal disease characterised by decreased bone mass and deterioration in the microarchitecture of bone tissue, resulting in increased bone fragility and increased fracture risk.[1] OP is the most common bone disease and has become a significant public health problem. Its frequency increases with age; the prevalence was 5-13% in individuals aged 60-70 years old, while 11-50% in those over 80 years. In 2010 alone, 5.5 million women and 22 million men, and roughly 3.5 million frailty fractures were reported in European Union countries. This resulted in a cost over 37 billion Euros, which is expected to increase by 25% in 2025. The total estimated cost of osteoporosis in the UK in 2018 was £2.5 billion.[2-4]

Correspondence to: Dr. Hatice Agir, Department of Physical Medicine and Rehabilitation, Sanliurfa Training and Research Hospital, Sanliurfa, Turkiye
E-mail: haticeagir10@hotmail.com

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Many mechanical, biochemical, genetic factors, comorbidities, drugs, and lifestyle play a role in the pathogenesis of OP; recently, more attention has been given to the interaction between bone and adipose tissue. More body weight or body fat mass is known to have a positive effect on bone mineral density (BMD).[5] This positive relationship is thought to be explained by the stresses caused by mechanical loading and the metabolic response from bone-related hormones secreted by adipocytes. Hormones such as leptin, adiponectin, and sex hormones secreted by adipocytes are protective against OP due to their stimulating effects on the proliferation and differentiation of osteoblasts. It has been reported that the elderly with high serum leptin concentrations have higher rates of fragility and muscle weakness in later years. Recent studies have also revealed a negative relationship between body fat mass and bone. However, some studies suggest that the positive relationship between body fat mass and bone reverses when body weight is considered.[6]

Recently, it has started to be investigated which body component is more critical in OP as an alternative to maintain body weight against OP. For example, Bani *et al*. reported that waist circumference, waist-to-hip ratio (WHR), and belly fat were positively associated with BMD. In addition, some studies examine

the relationship between waist, hip, and triceps fat thickness and BMD.[6]

To the best of the authors' knowledge, no study in the English-language literature has explored the association between prepatellar subcutaneous adipose tissue (SAT) and BMD. Therefore, this study aimed to investigate the possible relationship between prepatellar SAT thickness and BMD.

METHODOLOGY

In this retrospective study, lateral knee direct radiography (X-ray) and dual-energy X-ray absorptiometry (DXA) results of 325 patients aged 50-80 years who applied to the Department of Physical Therapy and Rehabilitation at the Sanliurfa Training and Research Hospital between January and June 2020 were examined. Patients with a history of acute trauma around the knee, previous knee surgery, history of malignancy, septic arthritis, and rheumatologic disease were excluded. In addition, the study did not include patients with secondary osteoporosis and male patients. A total of 250 female patients with primary osteoporosis in the postmenopausal period were included in the study.

Patients' age, body mass index (BMI), prepatellar fat thickness (mm) measured from X-ray knee lateral radiograph, T-score in BMD (L1-4, femoral neck, femur trochanter major, and femur total) were recorded. The data of the patients were recorded retrospectively, and the data of the cases in the hospital were recorded. According to the WHO classification,[6] BMI is 18.4 and below thin, 18.5-24.9 normal, 25-29.9 obese 1, 30-39.9 obese 2, and more than 40 obese 3. The patients were classified as normal, osteopenia, and OP according to the WHO's DXA T-score result. A T-score of <-1 in BMD measurements is classified as normal, between -1.0 and -2.5 as osteopenic and >-2.5 as osteoporosis.[7] The relationship between these three groups (normal, osteopenia, and osteoporosis) determined in BMD measurement and between BMI and prepatellar fat thickness measurement was evaluated.

Lateral knee radiographs of the patients taken for any reason in the last three months were examined. Prepatellar fat thickness was measured on the lateral radiograph with the knee flexed at 30°.[8] The distance between the line drawn perpendicular to the anterior of the patella and the vertical line drawn on the skin surface in the lateral knee X-ray was recorded in millimeters (mm) (Figure 1). Its distance between two parallel lines was drawn on anterior surface of patella and skin. Both authors calculated all measurements in the Fonet PACS software program. Prepatellar fat measurement on direct radiography was measured electronically by the same observers independently of each other.

This research was conducted by the ethical standards of the institute and in line with the 1964 Helsinki Declaration its later amendments. The study was approved by the Ethical Review Board (ERB) of the Harran University, Faculty of Medicine, Clinical Research Ethics Committee, Sanliurfa, Turkiye (Approval No. HRU/21.17.06 Dated on 04.10.2021). In addition, all individual participants signed a general research consent form, approved by the institutional review board, allowing inclusion in retrospective reviews.

Data were recorded for reliability analysis. The Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) v. 21.0 software program was used to construct the databases and to perform the statistical analysis. Quantitative data were expressed as mean ± standard deviation (SD) in the tables. Categorical data were presented with n (numbers) and percentages (%). The skewness coefficient was calculated to determine whether prepatellar fat thickness data distribution was normal. Levene's homogeneity test was applied to determine whether parametric/nonparametric tests would be used. According to the results obtained, one-way analysis of variance (ANOVA) and Post Hoc Tukey tests were used to analyse the homogeneously distributed L1-4 T-score, femoral neck T-score, and femoral total T-score. Since homogeneity was not achieved in trochanter major and BMI subgrouping, the Kruskal-Wallis and Post Hoc (Dunnett T3) tests were used to analyse these data. Normality of variables was assessed by the Kolmogorov-Smirnov test. This study's statistical significance level was accepted as $p < 0.05$ with a 95% confidence interval (CI). The Pearson correlation coefficient (PCC) was used to evaluate the reliability of the radiographic evaluation between different observers and for the same observer. Internal consistency was assessed using Cronbach's alpha reliability coefficient.

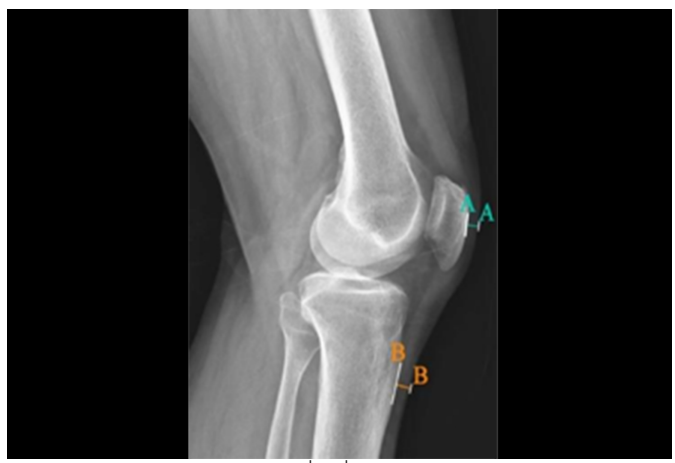

Figure 1: Prepatellar thickness (|AA|).

RESULTS

Demographic data of the postmenopausal female patients aged 50-80 years included in the study are given in Table I. The mean age of the patients was 66.69 ± 7.02 years, and the BMI was 32.70 ± 5.86 kg/m^2. The mean prepatellar fat thickness was 14.17 ± 6.87 mm (3.6-38.8).

There was a statistically significant difference between the amount of prepatellar fat thickness and trochanter major T-score ($X^2 = 20.435$; $p < 0.001$) and BMI ($X^2 = 66.535$; $p < 0.001$, Table II). While this difference is in favour of trochanter major between prepatellar fat thickness and normal values, it is in favour of patients with a BMI over 40 kg/m^2.

Table I: The demographic and clinical characteristics of patients (n = 250).

	n	%	Mean ± SD (min-max)
Age (year)			66.69 ± 7.02 (51-80)
Body mass index (kg/m^2)			32.70 ± 5.86 (19.2-50.5)
Prepatellar fat thickness (mm)			14.17 ± 6.87 (3.6-38.8)
BMI classification			
18.5-24.9	20	8	
25-29.9	63	25.2	
30-34.9	86	34.4	
35-39.9	50	20.0	
>40	31	12.4	

Table II: The relationship of prepatellar fat thickness with trochanter major T-score and BMI.

	Category	n	Mean Rank	SD	x²	p-value
Trochanter major T-score	Normal	111	139.7	2	20.435	<0.001*
	Osteopenia	115	124.1			
	Osteoporosis	24	66.3			
BMI	18.5-24.9	20	78.2	4	66.535	<0.001*
	25-29.9	63	81.7			
	30-34.9	86	127.2			
	35-39.9	50	154.9			
	>40	31	192.5			

Kruskal-Wallis H test.

Table III: Relationship between prepatellar fat thickness and trochanter major, L1-4, femoral neck, femoral total T-score.

	Prepatellar fat thickness (mm) mean ± SD	p-value
L1-4 T-score		
Normal	18.38 ± 7.68	p <0.001*
Osteopenia	14.42 ± 6.20	
Osteoporosis	11.15 ± 5.94	
Femur neck T-score		
Normal	15.84 ± 6.94	p <0.001*
Osteopenia	13.28 ± 6.66	
Osteoporosis	10.25 ± 5.17	
Femur total T-score		
Normal	15.87 ± 6.81	p <0.001*
Osteopenia	13.10 ± 6.75	
Osteoporosis	11.03 ± 5.70	
Trochanter major		
Normal	13.58 ± 5.66	p >0.05
Osteopenia	12.15 ± 6.24	
Osteoporosis	11.73 ± 4.70	

**ANOVA test *p <0.001.*

A statistically significant difference was found between the three groups in prepatellar fat thickness measurement, L1-4 T-score, femoral neck, and femur total values (p <0.001). Prepatellar fat thickness was found to be higher in the group with a normal L1-4 T-score (18.38 mm) than in the osteopenic (14.22 mm), and osteoporotic group (11.56 mm). Prepatellar fat thickness was found to be higher in the femoral neck T-score normal group (15.84 mm) compared to the osteopenic (X = 132.85) and osteoporotic groups (X = 102.52). In addition, the prepatellar fat thickness was found to be higher in the femoral total T-score group (15.87 mm) compared to the osteopenic (13.10 mm) and osteoporotic group (11.03 mm). There was no significant correlation between prepatellar fat thickness and trochanter major T-score (p >0.05, Table III).

The Pearson correlation coefficient (PCC) (0.985) was used to evaluate the reliability of the radiographic evaluation between different observers and for the same observer. In addition, internal consistency was evaluated using Cronbach's alpha (0.977) reliability coefficient. As a result, the reliability between the two observers in the measurements was excellent.

DISCUSSION

Few studies evaluated the relationship between regional adiposity, subcutaneous fat thickness, and BMD. These studies used measurements of waist, hip, and triceps fat thickness. There were controversial results regarding the relationship between fat mass and BMD.[9,10]

This study is the first in the literature to show that increased prepatellar fat thickness is protective in bone density. Bone density can be estimated by measuring the prepatellar fat thickness on the lateral knee X-ray taken with the correct technique, which is non-invasive, easily accessible, simple, and inexpensive.

Low BMI is a risk factor for osteoporotic fractures, and therefore obesity may be protective against fractures. However, it has been reported that obesity may be associated with an increased risk of fractures in some skeletal regions.[11] Although BMI has an important place in the classification and definition of obesity, its use alone is insufficient. While SAT may collect in the central region in some patients, it may be observed as less or more than expected according to BMI around the hip joint or the knee.[8,12-14]

Although studies have shown the relationship between BMD and waist, hip, and triceps fat thickness, the effect mechanism is not clearly understood.[10,15] Kilicarslan *et al.* reported a significant relationship between body weight, BMI, waist circumference, hip circumference, fat mass, fat percentage, lean mass, total muscle mass, and BMD.[16] In this study, there was a significant difference in the trochanter major T score in those with a BMI over 40 kg/m^2.

Prepatellar fat thickness measurement was defined by Wagner in 2018 and is quite up-to-date in the literature.[8] Watts *et al.* found that prepatellar fat thickness before a total knee replacement was significant regarding post-operative infection risk. They showed that the prepatellar and pretubercular SAT thickness distance in these patients was statistically significantly higher in patients who underwent reoperation.[13] Yoo *et al.* showed that the periarticular adipose tissue index, which they defined for total knee arthroplasty (TKA), is a ratio that can be used to evaluate the risk of wound complications in their study on 376 patients.[12]

The literature found no relationship between waist, waist-hip ratio (WHR), abdominal fat tissue mass measured, and BMD by DXA.[4,15] On the contrary, as measured by DXA, Nguyen *et al.* showed that abdominal fat contributes to the risk of hip fracture in older women. However, this relationship depended on a person's weight or BMD value of the femoral neck.[17] Ensrud *et al.* reported that hip circumference predicted hip fracture in older women. The same study emphasised that obesity originates from SAT and visceral adipose tissue (VAT) and that these tissues may affect bone health differently.[18] In this study, the authors measured the prepatellar fat thickness with direct radiography, an easily accessible and shorter examination. The authors found that prepatellar fat thickness was significantly higher in patients with normal L1-4, femoral neck, and femoral total T-scores.

While SAT may collect in the waist region in some people, it may be observed less or more than expected around the hip joint or the knee in some individuals.[8,12-14] In a study among healthy adults, SAT was positively correlated with BMD in various skeletal regions; however, this correlation was reported as insignificant when body weight was considered. Another study reported that SAT was negatively correlated with BMD in prediabetic overweight children.[19] This study found a negative correlation between prepatellar fat thickness, which the authors used as SAT and BMD; the BMD value decreased as the prepatellar fat thickness increased.

The literature has reported that increased prepatellar fat thickness is associated with infection, re-operation, and wound complications after TKA.[12-14] In addition, Sezgin *et al*. reported that periarticular adipose tissue distribution could be used for early failure in total hip arthroplasty.[20] Regional fat thickness has different results in different departments, independent of other risks. This study showed that regional fat distribution, such as prepatellar fat thickness, affects osteoporosis independent of BMI.

However, Gilsanz *et al*. found that SAT had a beneficial effect on strength independent of cortical bone structure and leg length, and thigh musculature. Still, no results were reported regarding adjustment for body weight. In prediabetic overweight children, SAT was negatively correlated with BMC after controlling for demographic and anthropometric characteristics.[21] In this study, SAT and VAT, were found to be independent predictors of bone mass rather than total body fat mass.

Given the limited availability of health resources combined with significant innovations in the management of OP, economic considerations have played an important role in decision-making.[22] In a cohort of 50,000 postmenopausal women aged 50-74 years with a prior osteoporotic fracture, an estimated direct incremental cost of €27.83 per woman per year for screening was reported.[23] This study reveals a significant relationship between newly defined fat thickness measurement and DXA, which is accepted as the gold standard in diagnosing OP. Today, DXA is the gold standard for diagnosing OP. However, DXA is a relatively more expensive diagnostic method that requires a visit to a referral centre and costs an average of US$98 in 2010.[24,25] Considering that the diagnosis and treatment costs of OP are high, the direct x-ray film required for prepatellar fat thickness measurement is easily accessible, inexpensive, and important for the prediction of BMD for branch physicians dealing with musculoskeletal diseases.

In this study, prepatellar fat thickness in postmenopausal Turkish women was positively correlated with BMD; BMD increases as the prepatellar fat thickness increases. This explains that perapatellar fat thickness creates a mechanical load on the bones and causes an increase in BMD. In addition, prepatellar fat thickness is also important in predicting BMI. Prepatellar fat thickness can be measured using routine lateral knee radiography; it is a method that does not risk patient safety, can be easily measured with simple computer software, and does not require any extra cost. Although DXA is the gold standard in diagnosing OP, the authors wanted to emphasise that easily accessible knee radiography can be an alternative in determining the OP risk group.

The newly defined prepatellar fat tissue thickness in the literature is an anatomically important structure. In this study, the authors wanted to evaluate its relationship with BMD. Prepatellar SAT thickness measured radiographically from the lateral knee radiograph can be considered as a parameter that does not cause additional cost or risk in predicting OP, and can be easily calculated. Furthermore, it can give highly reliable and reproducible results.

The limitations of this study are that it was a single-centric study, and care should be taken when generalising it to the population. In addition, the study was planned retrospectively and only included postmenopausal female patients. The other factors such as diet, physical activity, smoking, alcohol habits, drug use, chronic obesity, and nutritional status affecting osteosarcopenia were not questioned. There is a need for prospective, multicentre studies with the participation of both genders in the future.

CONCLUSION

Bone quality increases as prepatellar fat thickness increases in postmenopausal women. Although DXA is the gold standard in the diagnosis of osteoporosis, the authors believe that knee radiography, an easily accessible, fast, and reliable test, can also be used to determine the risk group.

ETHICAL APPROVAL:
The study was approved by the Clinical Research Ethics Committee of the Harran University, Sanliurfa, Turkiye (Approval No. HRU/21.17.06 Dated on 04.10.2021). This research was conducted by the ethical standards of the institute and in line with the 1964 Helsinki Declaration and its later amendments.

PATIENTS' CONSENT:
All individual participants signed a general research consent form, approved by the Institutional Review Board, allowing inclusion in retrospective reviews.

COMPETING INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
HA, OO: Conception, study design, and manuscript revision.
HA: Data acquisition and drafting of the manuscript.
OO: Data analysis and interpretation.
Both authors approved the final version of the manuscript to be published.

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