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Association of Abdominal Fat Percentage, Body Mass Index, and Bone Mineral Density in Male Osteoporosis Patients

Erkek Osteoporoz Hastalarında Abdominal Yağ Yüzdesi, Vücut Kitle İndeksi ve Kemik Mineral Dansitesi İlişkisi

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Abstract

Objective: We aimed to investigate the relationship between bone mineral density (BMD), body mass index (BMI), and abdominal fat percentage in men with osteopenia and osteoporosis.

Materials and Methods: This single-center cross-sectional study included 156 men aged 50-75 years (86 with osteopenia, 70 with osteoporosis). Demographic, anthropometric, and laboratory data were collected. BMD and abdominal fat percentage were measured using dual-energy X-ray absorptiometry. Group comparisons were performed with the independent samples t-test or Mann-Whitney U test. Correlations were assessed with Spearman's coefficient, and subgroup analyses were conducted according to BMI categories.

Results: Men with osteoporosis had significantly lower height, weight, BMI, and abdominal fat percentage compared with those with osteopenia. Laboratory values were similar between groups. Abdominal fat percentage was weakly but positively associated with lumbar T-score and femur total BMD. BMI correlated positively with BMD at all skeletal sites. C-reactive protein was inversely associated with femur total BMD and positively with abdominal fat. In BMI-stratified analyses, abdominal fat percentage was positively correlated with femoral neck (r=0.275; p=0.042) and femur total BMD (r=0.374; p=0.005) only in normal-weight men, but not in overweight or obese men.

Conclusion: These findings suggest a biphasic relationship between adiposity and bone health, depending on BMI. Moderate abdominal fat may be associated with higher BMD in normal-weight men, whereas in overweight and obese individuals, inflammatory pathways may attenuate or abolish this benefit.

Keywords: Male osteoporosis, osteopenia, abdominal fat, body mass index, bone mineral density

Öz

Amaç: Erkek osteopeni ve osteoporoz hastalarında kemik mineral dansitesi (KMD), vücut kitle indeksi (VKİ) ve abdominal yağ yüzdesi arasındaki ilişkiyi araştırmaktır.

Gereç ve Yöntem: Tek merkezli kesitsel çalışmaya 50-75 yaş arası toplam 156 erkek hasta dahil edildi (86 osteopeni, 70 osteoporoz). Demografik, antropometrik ve laboratuvar verileri kaydedildi. KMD ve abdominal yağ yüzdesi çift enerjili X-ışını absorbsiyometrisi ile ölçüldü. Gruplar t-testi veya Mann-Whitney U testi ile karşılaştırıldı. Spearman korelasyonu ve VKİ kategorilerine göre alt grup analizleri yapıldı.

Bulgular: Osteoporoz grubunda boy, kilo, VKİ ve abdominal yağ yüzdesi osteopeni grubuna göre anlamlı olarak daha düşüktü. Laboratuvar parametreleri benzer bulundu. Abdominal yağ yüzdesi lomber T-skoru ve femur total KMD ile zayıf fakat pozitif ilişkiliydi. VKİ tüm iskelet bölgelerinde KMD ile pozitif koreleydi. C-reaktif protein femur total KMD ile ters, abdominal yağ yüzdesi ile pozitif ilişkiliydi. VKİ'ye göre stratifikasyonda abdominal yağ yüzdesi yalnızca normal kilolu erkeklerde femur boynu (r=0.275; p=0.042) ve femur total KMD (r=0.374; p=0.005) ile pozitif ilişkili bulundu; fazla kilolu veya obezlerde ilişki gözlenmedi.

Sonuç: Bulgular, yağ dokusu ile kemik sağlığı arasında VKİ'ye bağlı çift fazlı bir ilişki olduğunu göstermektedir. Orta düzeyde abdominal yağ, normal kilolu erkeklerde daha yüksek KMD ile ilişkili olabilirken, fazla kilolu ve obezlerde enflamatuvar mekanizmalar bu faydayı azaltabilir veya ortadan kaldırabilir.

Anahtar kelimeler: Erkek osteoporozu, osteopeni, abdominal yağ, vücut kitle indeksi, kemik mineral dansitesi

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Introduction

Osteoporosis and obesity are major public health problems that substantially contribute to morbidity and mortality worldwide (1). Traditionally, obesity was considered protective against osteoporosis by increasing mechanical loading and thereby preserving bone mineral density (BMD) (2,3). However, recent studies indicate that obesity may increase the risk of osteoporotic fractures depending on fat distribution (4,5). These inconsistencies may be due to reliance on general measures such as body mass index (BMI) or total body fat percentage, which do not capture the physiological differences between fat depots (6).

In men, osteoporosis remains a major health issue, largely due to underdiagnosis and undertreatment compared with women (7). In addition to age-related primary osteoporosis, secondary causes such as glucocorticoid use, alcohol consumption, hypogonadism, and diabetes mellitus are common in men (8). Declining testosterone levels play a critical role in the acceleration of bone loss, while increased adiposity contributes to hormonal imbalance by enhancing the aromatization of testosterone into estrogen (9).

Abdominal adiposity, particularly visceral fat, is a metabolically active depot that promotes low-grade inflammation, insulin resistance, and dysregulated secretion of adipokines and proinflammatory cytokines, thereby impairing bone remodeling and enhancing osteoclast activity (10,11). Indeed, the relationship between abdominal fat and BMD has been shown to vary by BMI category, with a positive association in normal-weight men and a negative association in overweight or obese men (12).

Although magnetic resonance imaging and computed tomography (CT) are considered gold standards for assessing fat distribution, their use is limited by cost, scan time, and radiation exposure in CT (13). In contrast, dual-energy X-ray absorptiometry (DXA), originally developed to evaluate BMD, is widely used because it can reliably assess both bone and body composition with low radiation exposure and short scan times (14,15).

Previous studies investigating the relationship between obesity and bone health in men have reported conflicting results (16-18). Therefore, this cross-sectional study aimed to investigate the association between BMD, BMI, and abdominal fat percentage in male patients with osteoporosis.

Materials and Methods

Data Source and Ethics

This single-center, cross-sectional study was conducted at the AIBU İzzet Baysal Physical Therapy and Rehabilitation Training and Research Hospital. Medical records of male patients with low bone mass who were evaluated between March 1, 2023, and March 1, 2025, were retrospectively reviewed. The study complied with the principles of the Declaration of Helsinki and received approval from the Institutional Review Board of Bolu Abant İzzet Baysal University (approval no: 2025/192, date: May 06, 2025). Written informed consent was obtained from all participants prior to enrollment.

Study Population

A total of 156 male patients aged 50-75 years with a confirmed diagnosis of osteopenia or osteoporosis were retrospectively included. Patients with a history of malignancy, inflammatory or infectious disease, diabetes mellitus (due to its potential to independently and profoundly affect adiposity and bone metabolism) (19,20), or corticosteroid use were excluded. In addition, participants with missing BMD measurements at the lumbar or femoral sites, metallic implants at measurement sites, advanced skeletal deformities, or missing or erroneous BMD data were not included in the analysis.

Patients were diagnosed according to the lowest T-score value obtained at the lumbar spine (L1-L4), femoral neck, or femur total regions. A T-score between -1.0 and -2.5 standard deviations (SD) was classified as osteopenia, and ≤-2.5 SD as osteoporosis (21).

Data Collection

Demographic and clinical characteristics, including age, height, weight, BMI, comorbidities, and medications, were extracted from patient files. Laboratory data obtained at the time of DXA scanning were recorded, including hemoglobin, leukocyte and platelet counts, C-reactive protein (CRP), calcium, parathyroid hormone (PTH), and vitamin D levels.

Anthropometric Measurements

Height and weight were measured manually during routine clinical assessment, and BMI was calculated as weight in kilograms divided by height in meters squared (kg/m²). BMI categories were defined according to World Health Organization classification as underweight (BMI <18.5), normal weight (BMI ≥18.5 and <25.0), overweight (BMI ≥25.0 and <30.0), and obese (BMI ≥30.0) (22).

DXA Scans

DXA scans were performed using an Osteosys Primus device (OsteoSys, South Korea) in accordance with standard acquisition protocols. Areal BMD values were obtained for the lumbar spine and femur. Additionally, abdominal fat percentage was assessed directly from the lumbar spine scan image using the manufacturer's automated region-of-interest (ROI) analysis. While this approach provides a practical surrogate of abdominal adiposity, it does not allow differentiation between visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT). Calibration of the DXA machine was routinely performed using a standard phantom according to manufacturer recommendations.

Statistical Analysis

All analyses were performed using IBM SPSS Statistics version 22 (IBM Corp., Armonk, NY, USA) and JMP Pro 18 Student Edition

(SAS Institute Inc., Cary, NC, USA). Continuous variables were expressed as mean ± SD for normally distributed data or median with interquartile range for non-normally distributed data, as assessed by the Shapiro-Wilk test. Categorical variables were presented as numbers and percentages. Group comparisons were conducted using the independent samples t-test or Mann-Whitney U test for two groups.

Correlations between variables (e.g., abdominal fat percentage, BMI, CRP, and BMD parameters) were analyzed using Spearman's correlation coefficient. A two-tailed p-value <0.05 was considered statistically significant. Correlation strength was interpreted as follows: r≤0.29, weak; r=0.30-0.49, moderate; r≥0.50, strong.

Results

A total of 156 male patients were included, comprising 86 with osteopenia and 70 with osteoporosis. There was no significant difference in age between groups [66.5 (61.3-72.0) vs. 67.0 (62.3-74.0) years; p=0.621]. Patients with osteoporosis had significantly lower height (166±7.4 cm vs. 170±7.0 cm; p=0.004), weight [70.0 (62.0-79.8) vs. 78.0 (72.3-85.8) kg; p<0.001], and BMI [25.7 (23.5-29.1) vs. 26.8 (25.0-29.39) kg/m²; p=0.014] compared with the osteopenia group (Table 1). The abdominal fat percentage was slightly but significantly lower in the osteoporosis group [28.9 (19.1-35.0) % vs. 30.9 (25.9-36.1) %; p=0.040]. The prevalence of BMI <25 kg/m² was higher in the osteoporosis group (47.1% vs. 25.6%), whereas obesity (BMI >30 kg/m²) was more frequent in the osteopenia group (24.4% vs. 17.1%).

Table 1. Demographic, biochemical, and densitometric characteristics of male patients with osteopenia and osteoporosis

Variable	Osteopenia (n=86)	Osteoporosis (n=70)	p-value
Demographics			
Age (years)	66.5 (61.3-72)	67 (62.3-74)	0.621
Height (cm)	170±7.0	166±7.4	**0.004**
Body weight (kg)	78 (72.3-85.8)	70 (62-79.8)	**<0.001**
BMI (kg/m²)	26.8 (25-29.3)	25.7 (23.5-29.1)	**0.014**
Weight status			
BMI <25	22 (25.6%)	33 (47.1%)	**0.020**
BMI 25-29.9	43 (50%)	25 (35.7%)	
BMI ≥30	21 (24.4%)	12 (17.1%)	
Hematological indices			
White blood cell count (10³/µL)	6.7 (5.8-7.7)	6.7 (5.5-8.5)	0.692
Neutrophil count (10³/µL)	3.8 (3.1-4.4)	3.8 (3-5)	0.708
Monocyte count (10³/µL)	0.6 (0.5-0.7)	0.6 (0.5-0.7)	0.845
Lymphocyte count (10³/µL)	2 (1.7-2.5)	2 (1.6-2.6)	0.685
Hemoglobin (g/dL)	14.7 (13.9-15.5)	14.4 (13.4-15.3)	0.088
Platelet count (10³/µL)	209 (182.3-245)	218.5 (191.5-255)	0.505
Laboratory values			
Serum calcium (mg/dL)	9.3 (8.8-9.5)	9.3 (8.9-9.6)	0.844
Serum vitamin D (ng/mL)	21.1 (13.9-27.4)	23.4 (19-30.2)	0.068
Parathyroid hormone (pg/mL)	53.6 (41.2-70.2)	61 (46.4-82.9)	0.082
C-reactive protein (mg/L)	2 (2-4.3)	2.5 (2-5)	0.090
DXA measurements			
Lumbar spine T-score	0.1 (-1.1-1.2)	-0.85 (-1.6-0.2)	**0.002**
Lumbar total BMD (g/cm²)	1.185 (1.059-1.317)	1.069 (0.975-1.187)	**<0.001**
Femoral neck T-score	-1.9 (-2.2- -1.5)	-2.9 (-3.3- -2.6)	**<0.001**
Femoral neck BMD (g/cm²)	0.879 (0.850-0.933)	0.760 (0.715-0.794)	**<0.001**
Femur total T-score	-1.5 (-1.8- -1.2)	-2.6 (-3.0- -2.2)	**<0.001**
Femur total BMD (g/cm²)	0.982 (0.932-1.052)	0.845 (0.771-0.911)	**<0.001**
Abdominal fat percentage (%)	30.9 (25.9-36.1)	28.9 (19.1-35)	**0.040**

Values are presented as mean ± standard deviation (SD) or median (interquartile range) as appropriate, based on data distribution. Group comparisons were performed using independent samples t-test or Mann-Whitney U test. DXA: Dual-energy X-ray absorptiometry, BMD: Bone mineral density, BMI: Body mass index

Laboratory parameters, including calcium, vitamin D, PTH, CRP and hematological indices, showed no significant differences between the groups (all p>0.05).

Correlation analysis revealed a weak but significant positive association between abdominal fat percentage and lumbar T-score (r=0.168; p=0.036) and femur total BMD (r=0.202; p=0.011). BMI was also positively correlated with BMD at all skeletal sites (r-values between 0.174 and 0.308; all p<0.05). CRP was inversely associated with femur total BMD (r=-0.163; p=0.040) and weakly correlated with abdominal fat percentage (r=0.173; p=0.031). When stratified by BMI categories, no correlation was observed between abdominal fat percentage and BMD in overweight or obese individuals. However, among normal-weight participants, abdominal fat percentage was positively correlated with femoral neck BMD (r=0.275; p=0.042) and femur total BMD (r=0.374; p=0.005).

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Discussion

In this cross-sectional study of 156 men with low bone mass, we found that those with osteoporosis had significantly lower height, weight, BMI, and abdominal fat percentage compared with men with osteopenia. Abdominal fat percentage was positively associated with lumbar and femur total BMD. This relationship was evident only in men with normal BMI, where femoral neck BMD showed a weak correlation and femur total BMD a moderate correlation. In contrast, overweight and obese men did not demonstrate such associations. CRP was inversely related to femur total BMD. These findings highlight the complex, context-dependent interplay between body composition, inflammation, and skeletal health.

The observation that men with osteoporosis had lower weight, BMI, and abdominal fat percentage than those with osteopenia is consistent with previous studies linking low body weight and fat mass to reduced bone strength and increased fracture risk (23,24). The higher prevalence of normal weight (BMI <25) in the osteoporosis group and obesity (BMI >30) in the osteopenia group further supports the notion that higher BMI may exert a protective effect against bone loss. This may potentially delay the progression to osteoporosis. Mechanical loading from body weight stimulates adaptive bone remodeling, whereas reduced weight diminishes this osteogenic stimulus. Several epidemiological studies also reported that higher BMI is protective against hip fractures in men (25), although this benefit may not extend to obese individuals (26). Our data support this biphasic model: Insufficient adiposity is detrimental, but excessive adiposity does not confer additional skeletal benefit.

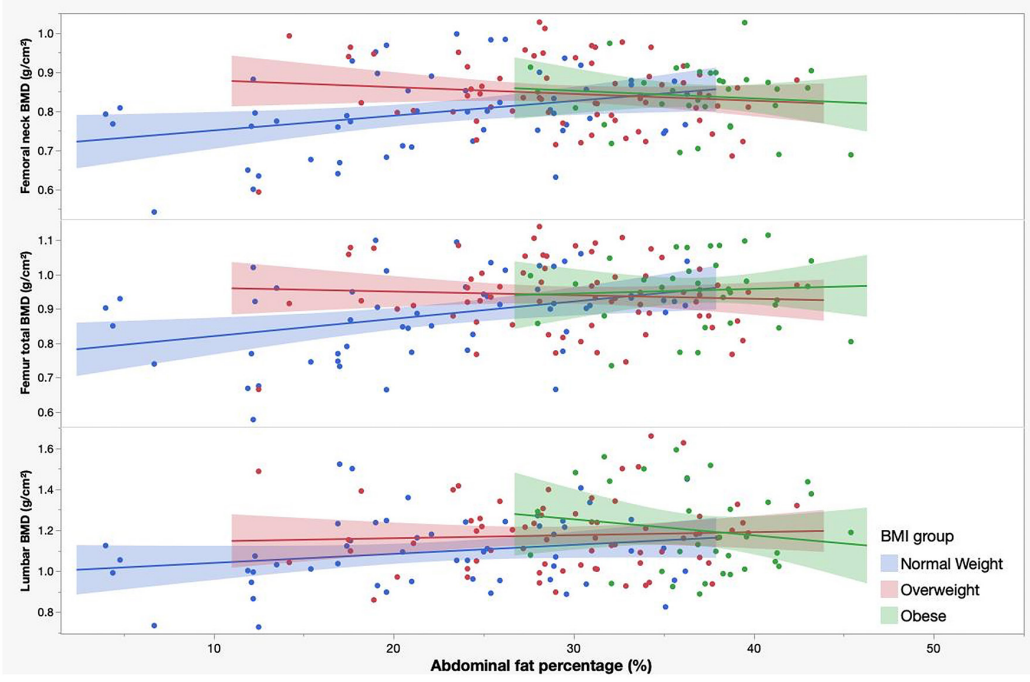

Figure 1. Interaction plots with 95% confidence intervals between abdominal fat percentage and body mass index (BMI) groups on bone mineral density (BMD) at lumbar and femoral sites in males

The positive association between abdominal fat percentage and BMD in normal-weight men, but not in overweight or obese men, suggests a threshold effect of adiposity on bone. This finding is consistent with Bland et al. (12), who observed positive correlations between adiposity and BMD in normal-weight men but negative associations in obese men at the whole body and lumbar spine. Importantly, and in agreement with our results, they found no significant relationship between adiposity and BMD at femoral sites in any BMI group. Our BMI-stratified observations are further supported by Zhu et al. (27), who reported similar variations across weight categories. The negative relationship we observed in obese men parallels the findings of Katzmarzyk et al. (16), who described an inverse VAT-BMD association in overweight and obese individuals, although their study did not include normal-weight participants—a gap addressed by our analysis.

Several mechanisms may underlie this biphasic relationship. In men with normal BMI, the dominant protective factor for bone appears to be mechanical loading from overall body weight, which enhances bone remodeling. Moderate adiposity may also contribute indirectly by providing estrogen through aromatization of androgens and by secreting adipokines such as leptin that support osteoblast activity (28,29). In contrast, in overweight and obese individuals, these benefits may be outweighed by metabolic and inflammatory consequences specific to abdominal adiposity. VAT is particularly metabolically active and secretes pro-inflammatory cytokines such as tumor necrosis factor-α and interleukin-6, which stimulate osteoclastogenesis and bone resorption (30). This distinction suggests that while BMI reflects a primarily mechanical influence on bone, abdominal fat represents a metabolically driven pathway that can shift from supportive to detrimental as fat mass increases. Our finding that CRP correlated negatively with femoral BMD supports this inflammatory mechanism and aligns with prior evidence linking obesity-related inflammation to bone loss (31).

Age also showed significant associations with BMD in our cohort, consistent with established patterns in male skeletal aging. Older age has been linked to lower hip BMD but paradoxically higher spine BMD, likely reflecting spinal osteophyte formation and other age-related changes (32). CRP was inversely associated with femur total BMD and modestly correlated with abdominal fat percentage, supporting the concept that obesity-induced inflammation contributes to bone fragility. Chronic low-grade inflammation increases osteoclast activity while impairing osteoblast function, leading to net bone loss (33). Prior studies also demonstrated that elevated CRP predicts lower hip and spine BMD in men (34).

Taken together, these findings suggest that moderate adiposity is associated with higher BMD in normal-weight men, whereas this positive association plateaus or becomes negative in overweight and obese individuals, potentially due to inflammatory and metabolic factors. Clinically, osteoporosis management in men should address not only weight optimization but also reduction of abdominal adiposity and preservation of lean mass. Lifestyle strategies such as resistance training and adequate protein intake are particularly important, as they counteract sarcopenic obesity, a condition characterized by concurrent muscle loss and fat accumulation that further compromises skeletal integrity (35).

Study Limitations

A strength of this study is the use of DXA-derived abdominal fat percentage, which provides a more direct and objective assessment of central adiposity compared with anthropometric measures such as waist circumference (36). However, an important limitation is the inability to distinguish between VAT and SAT. Recent evidence suggests that in obesity, both VAT and SAT may negatively affect bone health, potentially mitigating this limitation (12). Another limitation is the lack of physical activity data, as sedentary behavior—commonly associated with central obesity—is an important determinant of both VAT accumulation and bone loss (25). The positive association observed in normal-weight men may therefore partly reflect a healthier balance between mechanical loading and metabolic profile. Furthermore, data on supplementation and medication use (e.g., calcium, vitamin D, antiresorptives) and dietary intake (specifically of calcium and protein) were not available, which could have confounded associations. Finally, the cross-sectional design precludes causal inference. Longitudinal studies are needed to determine whether central adiposity contributes to, or merely reflects, bone loss in men.

Conclusion

In summary, men with osteoporosis had lower BMI and abdominal fat percentage compared with those with osteopenia, and abdominal fat percentage was positively associated with BMD only in normal-weight individuals. These findings support a biphasic relationship between adiposity and bone, where moderate fat levels may be associated with higher BMD, but excessive adiposity confers no benefit and may even be detrimental through inflammatory pathways. Given the cross-sectional design, these associations (particularly in normal-weight men) should be interpreted with caution, and confirmation in longitudinal studies is warranted. Nonetheless, the results suggest that clinical strategies should focus on maintaining adequate but not excessive body fat, reducing abdominal adiposity, and preserving muscle mass to optimize skeletal health in men.

Ethics

Ethics Committee Approval: The study complied with the principles of the Declaration of Helsinki and received approval from the Institutional Review Board of Bolu Abant İzzet Baysal University (approval no: 2025/192, date: May 06, 2025).

Informed Consent: Written informed consent was obtained from all participants prior to enrollment.

Footnotes

Authorship Contributions

Concept: T.A., Y.E., Design: T.A., Y.E., Data Collection or Processing: Y.E., E.Ö., Analysis or Interpretation: T.A., Literature Search: Y.E., Writing: Y.E., T.A.

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