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ORIGINAL ARTICLE

Frailty as a predictor of vertebral fractures in osteoporosis: A clinical perspective

Zeynep Şahiner, MD[1], Merve Güner, MD[2], Özgür Selim Uysal, MD[3]

[1]Department of Geriatrics, Ankara Bilkent City Hospital, Ankara, Türkiye
[2]Department of Geriatrics, Erzurum City Hospital, Erzurum, Türkiye
[3]Department of Orthopedics and Traumatology, Private Yüzüncü Yıl Hospital, Ankara, Türkiye

ABSTRACT

Objectives: This study aims to assess the correlation between vertebral compression fractures (VCFs) and frailty and to identify the possible link between the number of VCFs and frailty intensity in patients with osteoporosis (OP).

Patients and methods: Between January 2025 and February 2025, a total of 204 patients (143 males, 61 females; mean age: 71.8±5.5 years; range, 65 to 89 years) over 65 years who received treatment for OP in the inpatient setting were included. The patients were divided into two groups according to their Clinical Frailty Scale (CFS) scores as the frail group (n=141, CFS ≥4) and the non-frail group (n=63, CFS <4). Demographic and clinical characteristics, geriatric syndromes, and fracture prevalence were recorded.

Results: The handgrip strength was significantly reduced in the frail group (19 kg *vs*. 21 kg, p=0.004), with a probable sarcopenia rate of 42% (p=0.034). The rate of participants with no fractures, a single fracture, and multiple fractures was 42%, 26%, and 22% in the non-frail group, compared to 57%, 73%, and 77% in the frail group, respectively (p=0.018). This difference was particularly evident in patients with multiple fractures (odds ratio [OR]=2.34, 95% confidence interval [CI]: 1.13-4.87, p=0.023).

Conclusion: Frailty is strongly associated with a higher incidence of VCFs and multiple fractures in older individuals with OP.

Keywords: Compression fracture, frailty, geriatric patients, osteoporosis.

The world's population is rapidly aging due to rising lifespans and declining birth rates.[1] This demographic shift has significantly increased the number of individuals requiring care.[2] Osteoporosis (OP), characterized by inadequate density of bones and microstructural degeneration, is a systemic bone disease that increases fragility of bones and fracture risk.[3] The most common type of fragile fracture is vertebral compression fractures (VCFs), which are often accompanied by clinical manifestations such as back pain and functional impairment.[4,5] These fractures are a potent and separate risk factor for subsequent OP fractures, posing a major health challenge for aging populations.[4,5] Although bone mineral density (BMD) analysis is considered the most reliable method for predicting OP fracture risk, comprehensive clinical evaluation remains essential.[6]

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Correspondence: Zeynep Şahiner, MD. Ankara Bilkent Şehir Hastanesi, Geriatri Bölümü, 06700 Çankaya, Ankara Türkiye.

E-mail: zynppyds@hotmail.com

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Frailty is a multidimensional clinical condition defined by a decline in physiological reserves and a higher susceptibility to stresses, particularly in elderly individuals. It symbolizes a state of decreased power, stamina, and physiological function that raises the risk of negative health repercussions such as fractures and falling, and incapacity, inpatient treatment, and mortality.[7] The concept of frailty is often intertwined with aging; however, this is not an unavoidable result. Instead, it is influenced by a combination of factors, including chronic diseases, malnutrition, physical

inactivity, cognitive decline, and social isolation.[8] Clinically, frailty can be assessed using various tools. These assessments typically evaluate criteria such unintended weight loss, tiredness, poor physical activity, slowness, and vulnerability.[9] More importantly, frailty is considered a dynamic condition, indicating that, with appropriate interventions, such as resistance and balance training, nutritional support, and management of underlying chronic conditions, it can be mitigated or even reversed.[10,11] Identifying and managing frailty is crucial in geriatric medicine, as it allows healthcare providers to implement preventive strategies, reduce the risk of complications, and enhance the standard of living in elderly people. In the setting of OP, frailty plays a critical role, as frail individuals often have diminished bone density, impaired balance, and reduced muscle strength, all of which contribute to a higher susceptibility to fractures, including CVFs.[12,13]

Previous studies have shown that frailty is linked to OP fractures and may worsen following such fractures.[14-16] However, the link between frailty and VCFs has received little attention. In the present study, we aimed to assess the correlation between VCFs and frailty and to identify the possible link between the number of VCFs and frailty intensity.

PATIENTS AND METHODS

Study design and study population

This single-center, cross-sectional study was conducted at Ankara Bilkent City Hospital, Department of Geriatrics between January 2025 and February 2025. Patients aged over 65 years who received treatment for OP in the inpatient setting were screened. Inclusion criteria were as follows: age ≥65 years; having a diagnosis of OP according to the BMD values (T-score ≤–2.5 at the lumbar spine, femoral neck, or total hip); undergoing comprehensive geriatric assessment including frailty evaluation using the Clinical Frailty Scale (CFS); and having thoracolumbar radiographs for VCF assessment. Exclusion criteria were as follows: age below 65 years; current smoking or having a history of heavy alcohol consumption or substance abuse that potentially affect bone metabolism and fracture risk; presence of secondary OP due to conditions such as chronic kidney disease, hyperparathyroidism, Cushing's syndrome, multiple myeloma, or long-term glucocorticoid use; having a history of high-energy trauma-related fractures (e.g., fractures from motor vehicle accidents) rather than fragility fractures; having a diagnosis of neurological disorders such as stroke with significant motor impairment that could independently contribute to falls and fractures; presence of malignancies with bone metastases that can affect bone integrity; having missing geriatric assessment or thoracolumbar radiographs; and having severe cognitive impairment that constraints understanding of the study questions. Finally, a total of 204 patients (143 males, 61 females; mean age: 71.8±5.5 years; range, 65 to 89 years). The patients were divided into two groups according to their CFS scores as the frail group (n=141, CFS ≥4) and the non-frail group (n=63, CFS <4). A written informed consent was obtained from each patient. The study protocol was approved by the Ankara Bilkent City Hospital Ethics Committee (date: 05.02.2025, no: TABED 2-25-924). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data collection

Data including demographic and clinical characteristics of the patients, comorbidities, smoking status, and biochemistry test results were recorded. Education status was classified as 0=0-5 years, 1=6-12 years, and 2≥12 years.

Comprehensive geriatric assessment

Evaluations other than the frailty evaluation of the comprehensive geriatric assessment, which is required for all patients over the age of 65, were performed. Functional status was assessed using the Lawton-Brody Instrumental Activities of Daily Living (IADL).[17] The IADL is calculated over eight points based on the patient's proficiency with the phone, buying things, making eating, housework, laundry, taking drugs, and managing funds. The Katz Activities of Daily Living (ADL) (i.e., continence, bathing, dressing, feeding, transferring, and going to the toilet) scale was also used.[18] The nutritional status of the patient was evaluated via Mini-Nutritional Assessment Short Form (MNA-SF). In the MNA-SF test, the patients' body mass index (BMI), weight loss in the past three months, presence of psychosocial stress or an acute sickness within the past three months, mobility issues, cognition impairment, and hunger were questioned. Normal scores were defined as greater than 11 points, and malnutrition was defined as ≤8 points.[19] The strength of the muscles was assessed using the Takei grip strength device. Three interpretations were obtained while sitting with the dominant hand elbow bent at ninety degrees, and hand in neutral. Low muscular strength was defined as handgrip strength (HGS)

<16 kg for women and <27 kg for men, while low muscle strength was evaluated as probable sarcopenia according to these cut-off values.[20] Polypharmacy was defined as the usage of at least five drugs at the same time.[21]

Osteoporosis and vertebral compression fracture evaluation

In all patients who met the diagnostic criteria of OP, the BMD was measured in the lumbar vertebrae (L1-L4); T score of ≤–2.5.[22] Spinal fractures were detected by radiography using the Genant's semi-quantitative approach (20% decrease in spinal height was considered as collapse).[23]

Assessment of frailty

Frailty was evaluated by the CFS which assigns a score between 1 and 9, where 1 represents being extremely fit, 2 represents being well, 3 represents managing well, 4 represents having very mild frailty, 5 represents having mild frailty, 6 represents having moderate frailty, 7 represents having severe frailty, 8 represents having very severe frailty, and 9 represents being terminally ill. This scale was administered by two physicians and validated by interobserver agreement. People were divided into two categories according to the stated definitions. There are two categories: non-frail/robust (CFS <4) and living with frailty (CFS ≥4).[24,25]

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 23.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median and interquartile range (IQR) or number and frequency, where applicable. The Mann-Whitney U test was used to analyze continuous data points, while the chi-square test was used to examine variables with categories. A logistic regression model with multiple dimensions was employed to assess independent variables related to frailty with odds ratio (ORs) and 95% confidence intervals (CIs). A p value of <0.05 was considered statistically significant.

RESULTS

There were 141 patients in the frail group and 63 patients in the non-frail group. There was no statistically significant difference between the sex distribution between the groups (p=0.501), while a statistically significant difference in the age was observed (p<0.001). Forty-six and 36 patients were married in the non-frail group and in the frail group, respectively (p=0.204). There were no statistically significant differences between the groups in terms of education status, BMI, and comorbidities (p=0.461, p=0.500, and p=0.284) (Table I).

Table II shows the geriatric syndromes according to the presence of frailty between the patient groups. The Katz and Lawton's ADL scores were similar in both groups (p=0.100 and p=0.972). However, the frail group had poorer HGS (19 kg *vs.* 21 kg, p=0.004), and probable sarcopenia was more frequent in the frail group (42% *vs.* 27%, p=0.034). The rate of polypharmacy, another common geriatric problem, was found to be similar in both groups (p=0.491). Vertebral compression fracture

TABLE I
Baseline characteristics of the study population according to the presence of frailty

	Non-frail (n=63)			Frail (n=141)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			69.6±3.4			72.8±5.9	<0.001
Sex							
Female	45	28.6		94	33.3		0.501
Marital status							
Married	34	46.0		89	36.4		0.204
Education (year)							0.461
0-5	28	45.2		77	54.6		
6-12	20	32.3		38	27.0		
>12	14	22.6		26	18.4		
BMI (kg/m^2)			28.6±5.6			29.2±5.4	0.500
Comorbidity	58	92.1		135	95.7		0.284

SD: Standard deviation; BMI: Body mass index.

TABLE II
Geriatric syndromes of the study population according to presence of frailty

	Non-frail (n=63)				Frail (n=141)				
	n	%	Median	IQR	n	%	Median	IQR	*p*
Katz ADL			6	1			6	1	0.100
IADL			8	2			8	1	0.972
Malnutrition	21	33.3			57	40.4			0.340
Handgrip strength (kg)			21.0	5.0			19.0	5.0	0.004
Probable sarcopenia	17	27.0			60	42.6			0.034
Number of medications			4.0	4.0			4.0	4.5	0.730
Polypharmacy	24	38.1			61	43.3			0.491
Vertebral fracture	30	47.6			96	68.1			0.005
Multiple level fracture	17	27.0			60	42.6			0.034

IQR: Interquartile range; ADL: Activities of daily living; IADL: Instrumental activities of daily living.

TABLE III
The distribution of the frailty according to number of fractures

	Non-Fx (n=78)			Single Fx (n=49)			Multiple Fx (n=77)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
CFS score			3.7±0.9*			4.2±1.2			4.2±1.1	0.019
Non-frail	33	42.3		13	26.5		17	22.1		0.018
Frail	45	57.7*		36	73.5		60	77.9		0.018

Fx: Fracture; SD: Standard deviation; CFS: Clinical Frailty Scale; * The group that the difference aroused.

was seen in 47.6% in the non-frail group and 68.1% in the frail group, and the percentage of fractures at more than Level 1 was found to be 27% in the non-frail group and 42.6% in the frail group. Both cases were evaluated as significant disparities between the groups (p=0.005 and p=0.034).

The distribution of frailty according to the number of fractures is shown in Table III. The mean CFS score was 3.7±0.9 in the group without fractures, 4.2±1.2 in those with a single fracture, and 4.2±1.1 in the group with more than one fracture (p=0.019).

TABLE IV
Multivariable logistic regression analysis of the factors affecting frailty status

	Odds ratio	95% CI	*p*
Age (year)	1.14	1.05-1.23	0.001
Sex			
Female	1.3	0.64-2.64	0.475
BMI (kg/m^2)	1.02	0.96-1.08	0.583
Comorbidity	1.72	0.46-6.40	0.421

CI: Confidence interval; BMI: Body mass index.

The rate of patients with multiple fractures was higher in the frail group than in the non-frail group (77.9% *vs.* 22.1%, p=0.018). According to the multivariate logistic regression analysis, multiple fractures were significantly correlated with frailty, independent from sex, BMI, comorbidity, and single fracture (OR=2.32, 95% CI: 1.108-4.879, p=0.026) (Table IV).

DISCUSSION

In the present study, we investigated the correlation between VCFs and frailty and identified the possible link between the number of VCFs and frailty intensity. Our study results showed a significant correlation between frailty and VCFs in older individuals with OP. These findings indicate that frail individuals have not only a higher prevalence of VCFs, but are also more likely to experience multiple fractures relative to their non-frail peers. This highlights the relevance of frailty assessment as a crucial factor in managing OP and fracture risk.

Frailty has become increasingly recognized as a key predictor of inadequate medical circumstances

in elderly including falls, disability, and fractures. While OP and frailty are both age-related conditions, their interplay remains complex and multifaceted. The results of our study align with previous research suggesting that frailty exacerbates fracture risk by contributing to diminished bone strength, muscle weakness, and impaired balance. Similarly, the Global Longitudinal Study of Osteoporosis in Women (GLOW) has shown that frailty, as assessed by various frailty indices, is highly related to an elevated incidence of OP fractures, impairment, and falls.[26,27] Our study adds to this body of evidence by specifically focusing on vertebral fractures and their relationship with frailty severity.

Notably, our findings suggest that a significant proportion of individuals without fractures and those with a single fracture still exhibit frailty. This observation supports the hypothesis that frailty may precede fractures rather than being solely a consequence of them. Several studies have highlighted that frailty increases the likelihood of OP fractures, reinforcing the notion that frailty itself should be regarded as the main factor in fracture prevention strategies.[28]

The bidirectional relationship between frailty and VCFs is also worth discussing. While frailty predisposes individuals to fractures, fractures may further accelerate the progression of frailty by reducing mobility, increasing chronic pain, and exacerbating muscle loss. This cyclical relationship suggests that early detection and treatment of frailty may be crucial in minimizing the fracture risk and its subsequent complications. Previous studies have reported a higher mortality risk among older women with vertebral fractures, often linked to weight loss and physical weakness. However, many of these studies lacked standardized frailty assessments, relying instead on indirect indicators such as physical function decline. Our study, by utilizing a validated frailty assessment tool, provides a more precise characterization of this relationship.[26,29] In addition, the current study conducted a full geriatric examination in all patients and adds data to the literature. In our study, we found a significant correlation between fractures and fragility, consistent with the literature.[30]

Another main finding of this study is the association within multiple vertebral fractures and increased frailty severity. Considering various uncertainties, such as age, sex, and BMI, we found that individuals with multiple fractures had greatly increased frailty scores compared to those with a single fracture. This supports the hypothesis that VCFs have a cumulative impact on frailty progression. These results align with findings from the GLOW cohort, where individuals with major OP fractures exhibited a significantly greater increase in frailty index over time compared to those without fractures.[31-34]

In the current study, frailty induced or originated from fractures of the vertebrae. The increased number of VCFs was strongly related to a greater frequency of frailty in the VCF population. After adjusting for age, sex and BMI, >1 VCFs were linked to a greater risk of frailty more than one fracture. This finding is comparable with the findings of previous research utilizing the GLOW database,[27] in which the rise in frailty index was considerably larger in older women who suffered from a severe more OP fractures than comparable controls. We, thus, propose that VCF has a cumulative impact in increasing the frequency of frailty and deteriorating impairments. Frail patients may, however, be more likely to suffer numerous compression fractures. Frailty raises the incidence of falling and consequent fractures, whereas fractures increase the possibility of diminished physical endurance and frailty, demonstrating that these two illnesses are complexly linked and negatively affect each other.[35-38]

In this context, the role of sarcopenia is also notable. We found a substantial link between probable sarcopenia and frailty, which is consistent with prior research indicating that reduced muscle strength is a significant indicator of OP fractures. Given the close interplay between muscle and bone health,[39] interventions aiming at preserving muscle function such as resistance training and nutritional support may be beneficial in reducing both frailty and fracture risk. Furthermore, the strength of grip a widely recognized measure of muscle strength, has been independently associated with fracture risk, emphasizing the need for routine examinations of muscular function in individuals over 65 with OP.[40]

Despite these strengths, our study has certain limitations. The cross-sectional design prevents causal conclusions regarding the relationship between frailty and VCFs. Additionally, we assessed probable sarcopenia using HGS, while more comprehensive assessments including muscle mass and physical performance measures would provide a more robust evaluation. Also, although practical, the use of thoracolumbar radiography may have led to underreporting of certain fractures, particularly in cases of asymptomatic or mild

compression fractures. Future studies employing MRI-based assessments are needed to yield more precise fracture identification.

In conclusion, our study results underscore the strong association between frailty and VCFs, highlighting the need for routine frailty screening in OP patients. Given the bidirectional relationship between frailty and fractures, integrated management strategies addressing both conditions are essential. Future longitudinal studies are needed to investigate the temporal link between frailty progression, fracture occurrence, and potential interventions that may minimize these risks.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Conceptual and designing, statistical expertise: Z.Ş., Ö.S.U.; Collection and assembly of data: M.G.; Analyzing and interpreting data, composing the article: Z.Ş., M.G.; The article's essential revision for significant intellectual content: Ö.S.U, Z.Ş., M.G. All authors reviewed and approved the final version of the manuscript.

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