

DOI: 10.4274/tod.galenos.2025.70594

Turk J Osteoporos 2026;32(2):117-23



The Relationship Between Postural Balance, Posture and Postural Awareness in Patients Diagnosed with Osteoporosis

Osteoporoz Tanılı Hastalarda Postüral Denge, Duruş ve Postüral Farkındalık Arasındaki İlişki

© Muhammet Şahin Elbastı¹, © Kardelen Çelebi², © Songül Bağlan Yentür²

¹University of Health Sciences Türkiye, Elazığ Fethi Sekin City Hospital, Department of Physical Medicine and Rehabilitation, Elazığ, Türkiye

²Firat University Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Elazığ, Türkiye

Abstract

Objective: Osteoporosis, characterized by low bone mass and microarchitectural deterioration, leads to increased fracture risk. Beyond skeletal fragility, it is associated with postural deformities, balance impairments, and potentially diminished postural awareness, which are critical factors for fall prevention. This study aims to investigate the relationship between postural balance, posture, and postural awareness in postmenopausal women diagnosed with osteoporosis compared to those with osteopenia.

Materials and Methods: A cross-sectional study was conducted with 32 postmenopausal women (osteoporosis, n=16; osteopenia, n=16). Participants were assessed using the timed up and go (TUG) test for functional mobility, the Berg balance scale (BBS) for balance, the New York posture scale (NYPS) for postural alignment, and the postural awareness scale (PAS) for body awareness. Bone mineral density was determined by lumbar spine T-scores. Statistical analyses included the Mann-Whitney U test for group comparisons and Spearman's correlation to examine relationships between variables.

Results: The osteoporosis group demonstrated significantly lower postural awareness (PAS), poorer balance (BBS), longer TUG times, and more postural deviations (NYPS) compared to the osteopenia group ($p<0.05$), despite similar age and body mass index. Lumbar T-scores were significantly correlated with better PAS, BBS, and NYPS scores ($p<0.01$), and negatively correlated with TUG times ($p<0.01$), with stronger correlations observed in the osteoporosis group. A significant proportion of the osteoporosis group was classified as having low awareness, high fall risk, and poor posture.

Conclusion: Osteoporosis is associated with significantly impaired postural awareness, poorer postural alignment, and reduced balance compared to osteopenia. The strong correlations between bone mineral density and functional parameters underscore the interconnection between skeletal and neuromuscular health. These findings highlight the necessity of integrating functional assessments and targeted interventions, such as balance training and postural awareness education, into standard osteoporosis management to reduce fall risk and improve quality of life.

Keywords: Osteoporosis, postural balance, posture, awareness, osteopenia, fall risk

Öz

Amaç: Kemik kütleinin azalması ve mikro-mimari bozulma ile karakterize osteoporoz, kırık riskini artırır. Osteoporoz; postüral deformiteler, denge bozuklukları ve düşmeyi önlemede kritik olan postüral farkındalıkta azalma ile ilişkili olabilir. Bu çalışmanın amacı, osteoporoz tanılı postmenopozal kadınlarda postüral denge, postür ve postüral farkındalığın osteopenili kadınlara göre farklılığını ve bu değişkenler arasındaki ilişkileri incelemektir.

Gereç ve Yöntem: Kesitsel çalışmaya 32 postmenopozal kadın dahil edildi (osteoporoz n=16; osteopeni n=16). Fonksiyonel mobilite timed up and go (TUG) testi ile, denge Berg denge skalası (BDS) ile, postür New York postür skalası (NYPS) ile ve postüral farkındalık postüral farkındalık skalası (PFS) ile değerlendirildi. Kemik mineral yoğunluğu lomber omurga T-skoru ile belirlendi. Gruplar arası karşılaştırmalarda Mann-Whitney U testi, değişkenler arası ilişkilerde Spearman korelasyon analizi kullanıldı.

Corresponding Author/Sorumlu Yazar: Muhammet Şahin Elbastı, MD, University of Health Sciences Türkiye, Elazığ Fethi Sekin City Hospital, Department of Physical Medicine and Rehabilitation, Elazığ, Türkiye

E-mail: m.sahin23@hotmail.com **ORCID ID:** orcid.org/0000-0002-2100-5455

Received/Geliş Tarihi: 05.10.2025 **Accepted/Kabul Tarihi:** 10.12.2025 **Epub:** 27.02.2026 **Publication Date/Yayınlanma Tarihi:** 05.08.2026

Cite this article as/Atf: Elbastı MŞ, Çelebi K, Bağlan Yentür S. The relationship between postural balance, posture and postural awareness in patients diagnosed with osteoporosis. Turk J Osteoporos. 2026;32(2):117-23



Bulgular: Gruplar yaş ve vücut kitle indeksi açısından benzerdi. Osteoporoz grubu osteopeni grubuna göre anlamlı derecede daha düşük postürül farkındalık (PFS), daha kötü denge (BDS), daha uzun TUG süreleri ve daha fazla postürül sapma (NYPS) gösterdi ($p<0,05$). Lomber T-skoru; PAS, BBS ve NYPS ile pozitif ($p<0,01$), TUG süresi ile negatif yönde anlamlı korelasyon gösterdi ($p<0,01$) ve bu ilişkiler osteoporoz grubunda daha güçlüydü. Osteoporoz grubunun önemli bir kısmı düşük farkındalık, yüksek düşme riski ve kötü postür sınıflamasındaydı.

Sonuç: Osteoporoz, osteopeniye kıyasla postürül farkındalıkta belirgin azalma, postürül hizalanmada bozulma ve dengede zayıflama ile ilişkilidir. Kemik mineral yoğunluğu ile fonksiyonel parametreler arasındaki güçlü ilişkiler, iskelet ve nöromusküler sağlık arasındaki bağlantıyı desteklemektedir. Düşme riskini azaltmak ve yaşam kalitesini artırmak için fonksiyonel değerlendirmelerin ve denge eğitimi ile postürül farkındalık eğitimi içeren hedef müdahalelerin standart osteoporoz yönetimine entegre edilmesi önerilir.

Anahtar kelimeler: Osteoporoz, postürül denge, postür, farkındalık, osteopeni, düşme riski

Introduction

Osteoporosis is a chronic and progressive disease characterised by low bone mass and deterioration of the bone's microarchitecture, resulting in brittle bones (1). Osteoporosis is considered a silent disease because it usually does not cause symptoms until the first fracture occurs (2). Bone density decreases with age, and the incidence of fractures increases (3). Osteoporosis is one of the musculoskeletal problems commonly seen in women during menopause (4). One of the most significant changes observed in the musculoskeletal system due to ageing and osteoporosis is postural deformities. Postural changes in osteoporotic cases can lead to complications such as falls, balance problems, and vertebral fractures (5).

Decreased bone mass, vertebral fractures, and spinal deformities can lead to loss of vertebral height. Granito et al. (6) noted an increase in thoracic kyphosis associated with low bone mineral density (BMD). The sagittal vertical axis, pelvic tilt, lumbar lordosis, and thoracic kyphosis were all found significantly different between osteoporotic patients and the control group (7). In addition to postural abnormalities, spinal deformities like thoracic and/or lumbar kyphosis can result in decreased spinal mobility and range of motion. Osteoporotic patients with spinal kyphosis use their hip or ankle joints more (8). However, a shift in the center of gravity and impaired balance control due to postural changes can make it more difficult for the person to stand and walk. Furthermore, because kyphosis changes the center of mass of the body, it results in a relatively unstable posture. These factors may affect control over the centre of mass position and the ability to compensate for balance changes (9). In osteoporosis patients, reduced muscle mass and deformities in the spinal structure can disrupt postural balance and increase posture disorders. In such cases, postural awareness is important for the individual to develop and maintain correct posture habits in their daily life (10).

Postural awareness is the ability to recognise changes in posture and body position that an individual makes in daily life. This awareness is crucial for maintaining healthy postural habits and preventing poor posture. Good posture ensures minimal stress on the joints (11), while poor posture leads to increased stress on the joints due to misalignment of body parts (12).

In the prevention and management of osteoporosis, it is important to determine the level of knowledge, particularly among postmenopausal women who are at risk for this disease

(13). Identifying individuals' knowledge and attitudes regarding osteoporosis may contribute to the development of public health programs aimed at effective prevention of osteoporosis (14). While the relationship between osteoporosis, progressive postural deformities such as kyphosis, and subsequent impairments in balance and fall risk is well-established in the literature, the impact of these physical changes on an individual's postural awareness remains a significant and under-investigated gap. Postural awareness is a critical component for maintaining healthy posture and executing compensatory strategies to prevent falls. This study, therefore, moves beyond the well-documented pathophysiology to investigate the specific relationship between objective postural balance, spinal alignment, and the level of postural awareness in individuals with osteoporosis. By quantitatively assessing this triad, our research aims to provide original insights that could inform the development of targeted rehabilitation programs, shifting the focus from strength and bone health alone to include the enhancement of body perception and proprioceptive feedback for better postural control and fracture prevention. Investigating the effects of osteoporosis on postural awareness and balance may contribute to the development of education and exercise programs aimed at increasing postural awareness. Therefore, the aim of this study is to investigate the relationship between postural balance, posture, and postural awareness in individuals with osteoporosis.

Materials and Methods

The study included postmenopausal women diagnosed with osteoporosis and osteopenia who were under follow-up at Elazığ Medical Hospital. The required sample size and power calculation for the study were calculated using the G*Power Ver.3.1.9.4 program. The sample volume representing the population was determined based on the conditions of $\alpha=0.05$ risk and $1-\alpha=0.80$ accuracy rate, using the results of the comparison of the mean Berg balance scale (BBS) scores in the study by Alshahrani and Reddy (15). Based on the results of the power analysis, the effect size was 1.09 and the actual power was 0.82, indicating that the sample size for the study required a minimum of 15 participants in each group.

This study had ethical approval from the Firat University Ethics Committee (approval number: 2024/15-32, date: 19.12.2024). The study was completed with 32 participants. At the beginning of the study, the participants' medical histories were

obtained through face-to-face interviews. Fracture history was obtained through a structured interview and, when available, verified by reviewing medical records and/or imaging reports. Informed consent forms were obtained from the participants who volunteered to participate in the study. Information on the duration of osteoporosis diagnosis, age, occupation, body mass index, duration of menopause, history of vertebral or non-vertebral fractures, and comorbidities was obtained and recorded. Dynamic and functional balance was measured using the timed up and go (TUG) test and the BBS. Postural awareness was measured using the postural awareness scale (PAS). Posture was assessed using the New York posture scale.

Women in the postmenopausal period, patients diagnosed with osteoporosis or osteopenia according to World Health Organization criteria, and patients who could stand independently were included in the study. Patients with any ongoing orthopaedic or neurological disease, lower extremity pain that prevented standing and bearing weight, any other systemic chronic disease that could affect posture or balance, cognitive dysfunction, and a history of vertebral surgery were excluded from the study. In addition, participants using medications known to impair balance (e.g., sedatives/hypnotics or other centrally acting agents) were excluded.

Balance Assessment

Dynamic balance and functional mobility were evaluated using the TUG. The person was instructed to get up from a seated position, walk three meters at a normal and safe pace, turn around, walk back, and then sit down once more. The time was noted in seconds (s). The patient started the test with their arms resting on the chair's armrests and their feet flat on the ground. To finish the task, patients were instructed to walk at a pace that felt safe to them. For people with mobility impairments or the elderly, 10-20 seconds is acceptable, while less than 10 seconds is regarded as normal mobility (16).

The patient's performance was observed and scored on a scale of 0-4 for each of the 14 instructions in the BBS, a measure of balance. If the patient cannot complete the task at all, they receive a score of 0, and if they can finish it on their own, they receive a score of 4. A score of 0-20 indicates impaired balance, 21-40 indicates acceptable balance, and 41-56 indicates good balance. The maximum score is 56. The scale takes ten to twenty minutes to complete (17).

Postural Awareness Evaluation

Postural awareness, a German measure created by Cramer et al. (18), was assessed using the PAS. Twelve items make up the PAS, and each one is scored on a Likert-style scale that goes from 1 (not applicable to me at all) to 7 (completely applicable to me). The structure of the PAS scale is two-factor. Need for attention regulation with postural awareness is the second factor, and ease/familiarity with postural awareness is the first. Each of the twelve items on the scale has a score ranging from 1 (not applicable to me at all) to 7 (completely applicable to me). The PAS scale has reverse scoring for items 1, 2, 3, 4, 5, and 12.

Item 12 has been omitted from the Turkish adaptation of the PAS. The Turkish adaptation of the PAS consists of 11 items. A minimum of 11 and a maximum of 77 points can be obtained on the scale (19).

Posture Assessment

Thirteen distinct sections of the body were assessed for potential posture changes using the New York Posture Scale. Five points are awarded for proper posture, three points for moderately impaired posture, and one point for severely impaired posture. The final test score falls between 13 and 65. Good posture is indicated by a high score. The New York posture assessment scale is used to measure changes in posture from the lateral (neck, chest, shoulders, upper back, torso, abdomen, waist) and posterior (head, shoulders, back, hips, feet, and heels) perspectives (20).

Statistical Analysis

The data obtained in the study were analysed using the SPSS for Windows 22.0 (Statistical Package for the Social Sciences) program. The data was analyzed using descriptive statistical techniques, including number, percentage, median, minimum, and maximum values. The data did not exhibit a normal distribution, according to the Shapiro-Wilk normality test, which was used to assess whether continuous variables did. As a result, the chi-square test was employed for categorical data analysis and the Mann-Whitney U test for intergroup comparisons. Whereas categorical data are displayed as numbers and percentages [n (%)], continuous variables are displayed as medians (25th-75th percentile); minimum-maximum. The relationship between the variables was assessed using Spearman's rank correlation coefficient. All tests were conducted bilaterally (two-tailed), with a significance level of $p < 0.05$.

Results

The comparative results of the demographic, clinical, and functional characteristics of the osteoporosis and osteopenia groups are summarized in Table 1. None of the participants had a history of vertebral or non-vertebral fracture. While no significant difference was found between the groups in age, body mass index, and duration of menopause, lumbar spine T-scores were found to be significantly lower in the osteoporosis group. Furthermore, postural awareness levels, balance, and mobility performance were found to be significantly weaker in individuals in this group compared to the osteopenia group.

The categorical distributions of participants were compared according to postural awareness levels, fall risk, postural alignment, and balance levels (Table 2). A significant proportion of individuals in the osteoporosis group had low awareness levels, high fall risk, and poor posture, while most of these parameters were better in the osteopenia group. Significant differences were also observed between the groups in terms of balance level.

The relationships between functional and clinical parameters were analysed separately for each group (Table 3). In both groups,

Table 1. Comparison of demographic, clinical, and functional parameters between osteoporosis and osteopenia groups

Parameters median (percentile 25-75); (min-max)	Osteoporosis group (n=18)	Osteopenia group (n=18)	p*
Age/years	63.00 (56.00-66.00); (53.00-75.00)	62.00 (53.00-68.00); (52.00-75.00)	0.563
BMI/kg/cm ²	30.60 (29.80-32.39); (26.10-34.90)	29.47 (27.30-30.80); (25.60-37.10)	0.181
Osteoporosis diagnosis time/years	3.00 (2.00-4.00); (1.00-7.00)		
Duration of menopause/years	10.00 (5.00-13.00); (2.00-20.00)	10.00 (3.00-13.00); (2.00-20.00)	0.650
Lumbar spine (L1-L4) T-score	-2.63 (-2.90- -2.50); (-3.75- -2.50)	-1.93 (-2.10- -1.70); (-2.30- -1.40)	<0.001
OAS	31.00 (29.00-32.00); (22.00-45.00)	42.50 (36.00-49.00); (32.00-52.00)	<0.001
TUG test/seconds	15.00 (14.00-17.00); (12.00-22.00)	11.00 (10.00-12.00); (10.00- 16.00)	<0.001
NYPRC	40.50 (39.00-45.00); (37.00-51.00)	51.00 (47.00-53.00); (40.00- 61.00)	<0.001
BBS	41.50 (36.00-45.00); (34.00-46.00)	48.00 (47.00-50.00); (40.00-55.00)	<0.001

PAS: Posture awareness scale, TUG: Timed up and go, NYPRC: New York posture rating chart, BBS: Berg balance scale, *: Mann-Whitney U test, BMI: Body mass index, OAS: Osteoporosis awareness scale

Table 2. Distribution of postural awareness, fall risk, postural alignment, and balance subgroups between osteoporosis and osteopenia groups

Parameters		Osteoporosis group (n=18)	Osteopenia group (n=18)	χ ²	p**
PAS	Low postural awareness	7 (38.9%)	0 (0%)	9.926	0.007
	Moderate postural awareness	11 (61.1%)	16 (88.9%)		
	High postural awareness	0 (0%)	2 (11.1%)		
TUG	Low/acceptable risk (≤13.5 s)	4 (22.2%)	17 (94.4%)	19.314	<0.001
	High fall risk (>13.5 s)	14 (77.8%)	1 (5.6%)		
NYPRC	Moderate posture	5 (27.8%)	0 (0%)	14.761	0.001
	Good posture	7 (38.9%)	1 (5.6%)		
	Very good posture	6 (33.3%)	17 (94.4%)		
BBS	Acceptable balance	7 (38.9%)	1 (5.6%)	5.786	0.016
	Good balance	11 (61.1%)	17 (94.4%)		

PAS: Posture awareness scale, TUG: Timed up and go, NYPRC: New York posture rating chart, BBS: Berg balance scale, χ²: Chi-square value, **: Chi-square test

positive and significant correlations were found between the T-score and awareness, posture, and balance scores. The TUG, however, demonstrated a negative and significant relationship with these parameters. These relationships were particularly stronger in the osteoporosis group.

Discussion

This study examined the relationship between posture, balance, and postural awareness levels in postmenopausal women diagnosed with osteoporosis. The findings indicate that osteoporosis is not limited to a decrease in BMD; it also affects important functional areas such as balance, posture, and body awareness.

This study concluded that individuals in the osteoporosis group had significantly lower levels of postural awareness. It implies that these women are navigating their world with an inaccurate

“internal postural map”. As thoracic kyphosis increases and the body’s center of gravity shifts, proprioceptive feedback from the spine and trunk muscles may become unreliable. The individual may thus lose the ability to sense their own slump, allowing minor, uncorrected postural errors to accumulate into fixed deformities. This places them in a precarious position as they are less likely to consciously engage protective strategies to maintain stability. This result suggests that changes in the spinal structure may negatively affect the body’s ability to perceive its position. In particular, the shift of the body’s centre of gravity forward, accompanied by an increase in thoracic kyphosis, may prevent individuals from receiving adequate proprioceptive feedback. As a result, individuals may not notice the deterioration in their posture, which may lead to more serious postural problems over time. Osteoporosis is associated with more pronounced postural

Table 3. Spearman correlations between functional and clinical parameters in osteoporosis and osteopenia

Parameters r (p)	Osteoporosis group (n=18)					Osteopenia group (n=18)				
	Lumbar spine (L1-L4) T-score	PAS	TUG test	NYPRC	BBS	Lumbar spine (L1-L4) T-score	OAS	TUG test	NYPRC	BBS
Lumbar spine (L1-L4) T-score	1 (.)	0.940 (<0.001)	-0.898 (<0.001)	0.941 (<0.001)	0.930 (<0.001)	1 (.)	0.876 (<0.001)	-0.932 (<0.001)	0.874 (<0.001)	0.875 (<0.001)
OAS	0.940 (<0.001)	1 (.)	-0.927 (<0.001)	0.964 (<0.001)	0.967 (<0.001)	0.876 (<0.001)	1 (.)	-0.734 (<0.001)	0.977 (<0.001)	0.986 (<0.001)
TUG test	-0.898 (<0.001)	-0.927 (<0.001)	1 (.)	-0.954 (<0.001)	0.976 (<0.001)	-0.932 (<0.001)	-0.734 (<0.001)	1 (.)	-0.763 (<0.001)	-0.734 (<0.001)
NYPRC	0.941 (<0.001)	0.964 (<0.001)	-0.954 (<0.001)	1 (.)	-0.969 (<0.001)	0.874 (<0.001)	0.977 (<0.001)	-0.763 (<0.001)	1 (.)	0.970 (<0.001)
BBS	0.930 (<0.001)	0.967 (<0.001)	-0.969 (<0.001)	0.976 (<0.001)	1 (.)	0.875 (<0.001)	0.986 (<0.001)	-0.734 (<0.001)	0.970 (<0.001)	1 (.)

PAS: Posture awareness scale, TUG: Timed up and go, NYPRC: New York posture rating chart, BBS: Berg balance scale, r: Spearman's correlation coefficient, p: Spearman correlation test

changes, such as increased thoracic kyphosis and reduced spinal length, which are less severe or absent in osteopenia. These structural changes further impair postural awareness and stability (9). In addition, the worsening of postural awareness in osteoporosis is linked to lower BMD, vertebral deformities, and muscle weakness, which are less pronounced in osteopenia (21,22). Women with osteoporosis exhibit significantly greater postural sway (both anteroposterior and mediolateral) than those with osteopenia or normal bone density, indicating worse postural control. The osteoporosis group consistently demonstrated the highest instability across all tested positions, while the osteopenia group had intermediate values between osteoporosis and healthy controls (23).

This study was concluded that individuals in the osteoporosis group had lower balance levels and higher risk of falling according to the results of BBS and TUG. These findings reveal that osteoporosis may negatively affect individuals' ability to safely perform daily living activities. This study corroborate that osteoporosis does not merely weaken the skeleton; it undermines the very system designed to protect it, creating a perfect storm for fracture. In particular, the negative effects of spinal deformities on static and dynamic balance are consistent with previous literature. People with osteoporosis consistently demonstrate poorer balance compared to those without osteoporosis. This includes greater postural sway, altered balance control strategies, and reduced ability to maintain stability, especially in challenging positions (8,24). Muscle weakness, increased spinal kyphosis, and vertebral fractures further compromise balance in osteoporosis, making postural control more difficult (5,24,25). In some studies, balance impairment is a stronger predictor of future fractures than BMD itself, highlighting its clinical importance (26). Studies found that individuals with osteoporosis have significantly worse balance than those with osteopenia, which is parallel to this study. Osteoporotic patients

demonstrate greater postural sway (both anteroposterior and mediolateral) and more pronounced instability in all tested positions compared to osteopenic and healthy individuals (22,27). Objective and behavioral balance tests reveal a higher proportion of abnormal results in osteoporosis, and vestibular dysfunction is more prevalent in this group (28).

The study indicates that individuals in the osteoporosis group have significant posture abnormalities. Osteoporosis leads to vertebral fractures and spinal deformities, which shift the body's center of gravity forward, increasing instability and the risk of falls. Muscle weakness, proprioceptive deficits, and pain further contribute to postural problems (29). The weakening of the vertebral structure not only affects bone health but also disrupts the functional integrity of posture, thereby reducing the individual's mobility and quality of life. Recent genetic and clinical studies confirm a causal association between low bone BMD in osteoporosis and increased postural instability. Lower BMD, especially at the femoral neck and lumbar spine, is significantly associated with greater postural instability and impaired balance (30). Postural deficits in osteoporosis are a major contributor to increased fall and fracture risk, making their assessment and management crucial in clinical practice (31). Postural deformities and reduced spinal mobility in osteoporosis are strongly linked to lower quality of life, greater fear of falling, and reduced functional independence (9).

The positive relationships observed between T-score, postural awareness, posture and balance have revealed that decreases in BMD have a significant effect on these three parameters in this study. Lower BMD is associated with postural changes such as increased thoracic kyphosis, spinal deformities, and altered body alignment. These changes further compromise postural control and awareness (32). Poor balance and postural deficits in those with low BMD are strong predictors of falls and fractures. Balance and functional mobility tests independently predict

BMD status and fracture risk (33). Large-scale genetic and clinical studies confirm a significant negative correlation between BMD (especially at the femoral neck and lumbar spine) and postural instability. Lower BMD increases the risk of postural instability and impaired balance, making individuals with osteoporosis more susceptible to falls (31). In contrast, a negative relationship was found between TUG duration and these parameters. This indicates that movement safety decreases alongside a reduction in functional capacity. Studies concluded that women with lower BMD have greater postural sway, reduced limits of stability, and poorer performance on balance tests. These deficits are more pronounced in osteoporosis than in osteopenia or normal BMD (34).

The current findings have important clinical implications. The identification of high fall risk in osteoporosis patients highlights the urgent need for targeted fall-prevention strategies. Interventions should not only aim to improve bone density through pharmacological treatment but also incorporate physiotherapy programs that enhance balance, postural control, and functional awareness. Previous studies have shown that exercise interventions focusing on strength, balance, and proprioception significantly reduce fall incidence and improve functional performance in osteoporotic populations (35). Finally, the findings support the concept of tailored rehabilitation approaches. Given the inter-individual variability observed in postural and functional parameters, exercise interventions should be personalised according to baseline performance and awareness levels. This aligns with current perspectives in precision rehabilitation, advocating for interventions that address both skeletal and neuromuscular dimensions of osteoporosis.

Study Limitations

This study has several limitations. The sample size was relatively small, which may limit the generalisability of findings. Furthermore, the cross-sectional design precludes causal inference regarding the relationship between bone density and functional performance. Longitudinal studies are needed to clarify the directionality of these associations and to examine whether improvements in postural awareness and balance can mitigate bone loss or reduce fracture risk. Future research should also explore the role of psychosocial factors, such as fear of falling, which may further influence the interaction between osteoporosis and functional decline.

Conclusion

In conclusion, this study shows that, in contrast to osteopenia, osteoporosis is linked to significantly worse postural awareness, poorer postural alignment, and decreased balance. The interdependence of skeletal and neuromuscular health is highlighted by the strong relationships found between BMD and functional parameters. To maintain independence and lower fall-related morbidity in this population, these findings emphasize the necessity of comprehensive rehabilitation strategies that combine functional training with traditional osteoporosis management.

Ethics

Ethics Committee Approval: This study had ethical approval from the Firat University Ethics Committee (approval number: 2024/15-32, date: 19.12.2024).

Informed Consent: Informed consent forms were obtained from the participants who volunteered to participate in the study.

Footnotes

Authorship Contributions

Concept: M.Ş.E., K.Ç., S.B.Y., Design: K.Ç., S.B.Y., Data Collection or Processing: M.Ş.E., K.Ç., Analysis or Interpretation: M.Ş.E., Literature Search: K.Ç., S.B.Y., Writing: M.Ş.E., S.B.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Osteoporosis WG. What is osteoporosis? *Med Clin North Am.* 2023;107:213-25.
2. Cosman F, De Beur SJ, LeBoff MS, Lewiecki EM, Tanner B, Randall S, et al. Clinician's guide to prevention and treatment of osteoporosis. *Osteoporos Int.* 2014;25:2359-81.
3. Sabri SA, Chavarria JC, Ackert-Bicknell C, Swanson C, Burger E. Osteoporosis: an update on screening, diagnosis, evaluation, and treatment. *Orthopedics.* 2023;46:e20-6.
4. Geusens P. Osteoporosis: clinical features. *Minerva Med.* 2008;99:167-75.
5. Waters DL, Hale L, Grant AM, Herbison P, Goulding A. Osteoporosis and gait and balance disturbances in older sarcopenic obese New Zealanders. *Osteoporos Int.* 2010;21:351-7.
6. Granito RN, Aveiro MC, Renno AC, Oishi J, Driusso P. Comparison of thoracic kyphosis degree, trunk muscle strength and joint position sense among healthy and osteoporotic elderly women: a cross-sectional preliminary study. *Arch Gerontol Geriatr.* 2012;54:e199-202.
7. Lee JS, Lee HS, Shin JK, Goh TS, Son SM. Prediction of sagittal balance in patients with osteoporosis using spinopelvic parameters. *Eur Spine J.* 2013;22:1053-8.
8. Lynn SG, Sinaki M, Westerlind KC. Balance characteristics of persons with osteoporosis. *Arch Phys Med Rehabil.* 1997;78:273-7.
9. Gunay Ucurum S, Altas EU, Ozer Kaya D. Comparison of the spinal characteristics, postural stability and quality of life in women with and without osteoporosis. *J Orthop Sci.* 2020;25:960-5.
10. Regolin F, Carvalho GA. Relationship between thoracic kyphosis, bone mineral density, and postural control in elderly women. *Rev Bras Fisioter.* 2010;14:464-9. English, Portuguese.
11. Yamak B, İmamoğlu O, İslamoğlu İ, Çebi M. The effects of exercise on body posture. *Turkish Studies.* 2018;13:1377-88.
12. Yasmeen S, Shahrukh M, Farooqui Z. Postural awareness in school going students and teachers. *Pakistan Journal of Rehabilitation.* 2014;3:39-45.
13. Gopinathan NR, Sen RK, Behera P, Aggarwal S, Khandelwal N, Sen M. Awareness of osteoporosis in postmenopausal Indian women: an evaluation of osteoporosis health belief scale. *J Midlife Health.* 2016;7:180-4.
14. Tardi P, Szilagyi B, Makai A, Gyuro M, Acs P, Jaromi M, et al. The development of a reliable and valid instrument to measure the osteoporosis-related knowledge: validation of the Hungarian version of osteoporosis knowledge assessment tool (OKAT). *BMC Public Health.* 2021;21(Suppl 1):1515.

15. Alshahrani MS, Reddy RS. Kinesiophobia, limits of stability, and functional balance assessment in geriatric patients with chronic low back pain and osteoporosis: a comprehensive study. *Front Neurol*. 2024;15:1354444.
16. Beauchet O, Fantino B, Allali G, Muir SW, Montero-Odasso M, Annweiler C. Timed up and go test and risk of falls in older adults: a systematic review. *J Nutr Health Aging*. 2011;15:933-8.
17. Sahin F, Yilmaz F, Ozmaden A, Kotevolu N, Sahin T, Kuran B. Reliability and validity of the Turkish version of the Berg balance scale. *J Geriatr Phys Ther*. 2008;31:32-7.
18. Cramer H, Mehling WE, Saha FJ, Dobos G, Lauche R. Postural awareness and its relation to pain: validation of an innovative instrument measuring awareness of body posture in patients with chronic pain. *BMC Musculoskelet Disord*. 2018;19:109.
19. Dursun Ö, Önen C. Turkish reliability and validity of postural awareness scale in office workers. *Turkish Journal of Physiotherapy and Rehabilitation*. 2024;35:114-22.
20. McRoberts LB, Cloud RM, Black CM. Evaluation of the New York posture rating chart for assessing changes in postural alignment in a garment study. *Clothing and Textiles Research Journal*. 2013;31:81-96.
21. Zverev YP, Tulichev AA, Builova TV, Iosko NV, Ignatieva MO, Bormotkina NA. Features of postural control of elderly patients with osteoporosis: overview. *Physical and Rehabilitation Medicine, Medical Rehabilitation*. 2023;5:255-64.
22. Brooke-Wavell K, Skelton DA, Barker KL, Clark EM, De Biase S, Arnold S, et al. Strong, steady and straight: UK consensus statement on physical activity and exercise for osteoporosis. *Br J Sports Med*. 2022;56:837-46.
23. Abreu DC, Trevisan DC, Costa GC, Vasconcelos FM, Gomes MM, Carneiro AA. The association between osteoporosis and static balance in elderly women. *Osteoporos Int*. 2010;21:1487-91.
24. Hsu WL, Chen CY, Tsauo JY, Yang RS. Balance control in elderly people with osteoporosis. *J Formos Med Assoc*. 2014;113:334-9.
25. Fechtenbaum J, Etcheto A, Kolta S, Feydy A, Roux C, Briot K. Sagittal balance of the spine in patients with osteoporotic vertebral fractures. *Osteoporos Int*. 2016;27:559-67.
26. Dotevall A, Krantz E, Barrenäs ML, Landin-Wilhelmsen K. Hearing and balance exceed initial bone mineral density in predicting incident fractures: a 25-year prospective observational study in menopausal women with osteoporosis. *JBMR Plus*. 2021;6:e10551.
27. Buyukavci R, Akturk S, Evren B, Ersoy Y. Impacts of combined osteopenia/osteoporosis and sarcopenia on balance and quality of life in older adults. *North Clin Istanbul*. 2020;7:585-90.
28. Gargeshwari A, Jha RH, Singh NK, Kumar P. Behavioural and objective vestibular assessment in persons with osteoporosis and osteopenia: a preliminary investigation. *Braz J Otorhinolaryngol*. 2018;84:744-53.
29. Ahmad I, Reddy RS, Alqhtani RS, Tedla JS, Dixit S, Ghulam HSH, et al. Exploring the nexus of lower extremity proprioception and postural stability in older adults with osteoporosis: a crosssectional investigation. *Front Public Health*. 2023;11:1287223.
30. Simon A, Rupp T, Hoenig T, Vettorazzi E, Amling M, Rolvien T. Evaluation of postural stability in patients screened for osteoporosis: a retrospective study of 1086 cases. *Gait Posture*. 2021;88:304-10.
31. Zhu K, An Z, Li Y, Zhang Q, Zhang F, Zhao R, et al. A causal association between osteoporosis and postural instability: a Mendelian randomization study. *Sci Rep*. 2025;15:10234.
32. de Matos O, Ruthes EMP, Lenardt BCC, Beira De Andrade A, Petroski CA, De Mello MF, et al. Relationship between postural changes, osteoarthritis and bone mineral density in postmenopausal women. *Gynecol Endocrinol*. 2022;38:983-7.
33. Sadeghi H, Ashraf A, Zeynali N, Ebrahimi B, Jehu DA. Balance and functional mobility predict low bone mineral density among postmenopausal women undergoing recent menopause with osteoporosis, osteopenia, and normal bone mineral density: a cross-sectional study. *Geriatr Nurs*. 2021;42:33-6.
34. Rezaei MK, Torkaman G, Bahrami F, Bayat N. Are weight shifting and dynamic control strategies different in postmenopausal women with and without type-I osteoporosis? *Exp Gerontol*. 2021;154:111529.
35. Giangregorio LM, Papaioannou A, MacIntyre NJ, Ashe MC, Heinonen A, Shipp K, et al. Too fit to fracture: exercise recommendations for individuals with osteoporosis or osteoporotic vertebral fracture. *Osteoporos Int*. 2014;25:821-35.