

# Association between bone mineral density and clinical-demographic characteristics in patients with post-stroke hemiplegia

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**Cite this article as:** Ceyhan Z, Karaçesme MA. Association between bone mineral density and clinical-demographic characteristics in patients with post-stroke hemiplegia. *J Orthop Res Rehabil.* 2026;4(2):34-39.

Received: 17.03.2026

Accepted: 27.04.2026

Published: 30.04.2026

## ABSTRACT

**Aims:** This study aimed to investigate the association between bone mineral density and clinical-demographic characteristics in patients with post-stroke hemiplegia and to evaluate potential factors associated with osteoporosis.

**Methods:** This retrospective, cross-sectional study included 80 patients with post-stroke hemiplegia who met the inclusion criteria and were followed at Physical Medicine and Rehabilitation Hospital between January 1, 2025, and October 1, 2025. Data were obtained through retrospective review of hospital information system records and patient files. Demographic and clinical characteristics were recorded. Bone mineral density (BMD) values were obtained from dual-energy X-Ray absorptiometry (DXA) measurements. Functional status and independence were assessed using the functional independence measure (FIM), while ambulation level was evaluated using the Functional Ambulation Scale (FAS). Serum calcium, parathyroid hormone (PTH), and vitamin D levels were also recorded. Associations between variables were analyzed using Spearman's correlation analysis, and statistical significance was set at  $p < 0.05$ .

**Results:** The mean age of the patients was  $65.8 \pm 9.5$  years, and 56.2% were female. Ischemic stroke was present in 86.2% of patients, and the median stroke duration was 16 (1-288) months. A diagnosis of osteoporosis established after stroke but prior to DXA assessment was present in 16.2% of patients, and this rate increased to 37.5% when newly diagnosed cases were included. No significant difference was found in stroke duration between patients with and without osteoporosis ( $p = 0.167$ ). No significant differences were observed in FIM, FAS, calcium, PTH, and vitamin D levels according to sex, osteoporosis status, comorbidities, or smoking/alcohol use (all  $p > 0.05$ ). Only PTH levels were significantly lower in the hemorrhagic stroke group ( $p = 0.046$ ), while vitamin D levels tended to be lower in the osteoporosis group ( $p = 0.059$ ). A statistically significant, moderate, negative correlation was found between age and femoral neck bone mineral density ( $r = -0.451$ ,  $p < 0.001$ ).

**Conclusion:** Osteoporosis is common in patients with post-stroke hemiplegia, and age has a significant negative impact on femoral neck bone mineral density. However, functional status and ambulation level alone are insufficient to explain bone loss. These findings highlight the multifactorial nature of post-stroke osteoporosis and emphasize the clinical importance of early screening and preventive strategies in at-risk patients.

**Keywords:** Bone density, rehabilitation, vitamin D, risk factors, activities of daily living

## INTRODUCTION

Stroke is a major cause of mortality and long-term disability worldwide and may result from ischemic or hemorrhagic mechanisms.<sup>1,2</sup> It is commonly associated with hemiplegia, which leads to reduced mobility, functional impairment, and secondary musculoskeletal complications.<sup>3</sup> These changes not only limit independence but also contribute to the development of various systemic complications in the post-stroke period.

Osteoporosis is a systemic skeletal disorder characterized by decreased bone mineral density (BMD) and deterioration of bone microarchitecture, leading to an increased risk of fractures.<sup>4</sup> Epidemiological studies have reported a global prevalence of approximately 18%.<sup>5</sup> Osteoporotic fractures,

particularly at the hip and vertebral levels, are associated with substantial morbidity, mortality, and reduced quality of life.<sup>6</sup>

In the post-stroke period, immobilization, muscle weakness, and reduced mechanical loading negatively influence bone metabolism, contributing to progressive bone loss, particularly at the femoral neck.<sup>7,8</sup> Stroke patients also have an increased risk of falls due to balance impairment and motor dysfunction, further increasing the risk of osteoporotic fractures.<sup>9,10</sup>

Osteoporosis and related fractures developing after stroke prolong the rehabilitation process, delay functional recovery, and impose an additional burden on the healthcare system.<sup>8,10</sup> Therefore, early identification of post-stroke osteoporosis

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and determination of associated risk factors are of critical importance for both the prevention of fractures and the improvement of rehabilitation outcomes.

The aim of this study was to investigate the association between bone mineral density and clinical-demographic characteristics in patients with post-stroke hemiplegia and to evaluate potential factors associated with osteoporosis.

## METHODS

Ethical approval for the study was obtained from the Ondokuz Mayıs University Clinical Researches Ethics Committee (Approval Date: 17.11.2025, Decision No: OMUKAEK 2025/538). The study was conducted in accordance with the Declaration of Helsinki.

In this retrospective, cross-sectional study, 80 patients who were followed at Physical Medicine and Rehabilitation Hospital between January 1, 2025, and October 1, 2025, with a diagnosis of post-stroke hemiplegia and who met the study criteria were included. Data were obtained through retrospective review of hospital information system records and patient files.

Patients aged 18 years and older who developed hemiplegia following ischemic or hemorrhagic stroke and had undergone BMD assessment during their treatment process were included in the study. Patients with a prior diagnosis or history of osteoporosis before stroke, those with severe additional neurological or orthopedic conditions (such as multiple sclerosis, Parkinson's disease, hip fracture, or spinal cord injury), a history of malignancy or bone metastasis, renal failure, hypercalcemia, or diseases significantly affecting vitamin D metabolism, as well as those with incomplete medical records, were excluded from the study. However, patients who were diagnosed with osteoporosis after stroke but before the dual-energy X-Ray absorptiometry (DXA) assessment were not excluded and were included in the analysis.

The demographic and clinical data of the patients were obtained from hospital information system records and patient files. Within this scope, age, sex, height, weight, type of stroke (ischemic/hemorrhagic), duration of stroke, hemiplegic side, occupation, and comorbidities were recorded.

BMD values of the patients were obtained from previously performed measurements using DXA.<sup>11</sup> In BMD assessments, femoral neck T-scores of the hemiplegic side were primarily considered; additionally, lumbar spine (L1-L4 and L2-L4) measurements were also recorded. T-score values of the relevant regions were used in the analysis. Osteoporosis was defined as a T-score of  $\leq -2.5$  in any of the measured regions.<sup>4</sup>

The patients' functional status, activities of daily living, and levels of independence were evaluated using the FIM scores available in the medical records.<sup>12</sup> FIM consists of 18 items covering motor and cognitive domains, including self-care, sphincter control, transfers, locomotion, communication, and social cognition. Each item is scored on a scale from 1 (complete dependence) to 7 (complete independence), with a total score ranging from 18 to 126. Higher scores indicate better functional independence. The Turkish version of the scale has been validated and shown to be reliable by Küçükdeveci et al.<sup>12</sup>

Ambulation level was assessed using the FAS scores recorded for each patient.<sup>13</sup> This scale is scored from 0 to 5, where 0 indicates inability to walk and 5 indicates independent ambulation in all environments.

In addition, within the scope of biochemical parameters, serum calcium (mg/dl), parathyroid hormone (PTH) (pg/ml), and vitamin D (ng/ml) levels were recorded.

## Statistical Analysis

The obtained data were analyzed using the SPSS 26.0 statistical software package. Descriptive variables were expressed as median, first and third quartiles, frequency, and percentage. The normality of continuous variables was assessed using the Shapiro-Wilk test. Variables with normal distribution were presented as mean  $\pm$  standard deviation (SD), while non-normally distributed variables were compared between independent groups using the Mann-Whitney U test. The relationships between variables were analyzed using Spearman's correlation analysis. Correlation coefficients were interpreted as weak for values between 0 and 0.29, moderate for values between 0.30 and 0.69, and strong for values between 0.70 and 1. Statistical significance was set at  $p < 0.05$ .

## RESULTS

The sociodemographic characteristics of the patients are presented in **Table 1**. The mean age of the study population was  $65.8 \pm 9.5$  years, and the majority were female. The clinical and disease-related characteristics are summarized in **Table 2**, showing that ischemic stroke was the predominant subtype.

**Table 1. Sociodemographic characteristics of the patients**

Variables	n (%)
Age (years), mean $\pm$ SD	65.8 $\pm$ 9.5
Sex	
Male	35 (43.8)
Female	45 (56.2)
Education level	
Illiterate	16 (20.0)
Primary school	40 (50.0)
Middle school	9 (11.2)
High school	11 (13.8)
University or higher	4 (5.0)
Marital status	
Married	75 (93.8)
Single	5 (6.2)
Employment status/occupation	
Civil servant	2 (2.5)
Worker	26 (32.5)
Retired	12 (15.0)
Housewife	40 (50.0)
<b>Total</b>	<b>80 (100.0)</b>
SD: Standard deviation	

A diagnosis of osteoporosis established after stroke but prior to the DXA assessment was present in 16.2% of the patients, and this rate increased to 37.5% when newly diagnosed cases were

Variables	n (%)
<b>Stroke type</b>	
Ischemic	69 (86.2)
Hemorrhagic	11 (13.8)
<b>Hemiplegic side</b>	
Right	42 (52.5)
Left	38 (47.5)
<b>Previous diagnosis of osteoporosis</b>	
Yes	13 (16.2)
No	67 (83.8)
<b>Osteoporosis diagnosis (including newly diagnosed cases)</b>	
Yes	30 (37.5)
No	50 (62.5)
<b>Family history of osteoporosis</b>	
Yes	7 (8.8)
No	73 (91.2)
<b>History of fragility fracture</b>	
Yes	14 (17.5)
No	66 (82.5)
<b>Receiving osteoporosis treatment</b>	
Yes	13 (16.2)
No	67 (83.8)
<b>Total</b>	<b>80 (100.0)</b>

included. Among patients diagnosed with osteoporosis prior to the DXA assessment, the median duration of diagnosis was 1 (0.5-4) years. The rate of osteoporosis treatment was relatively low. Additional clinical characteristics related to osteoporosis are presented in **Table 2**.

In the evaluation of functional independence, the median FIM score was 74.50 (Q1: 55.25-Q3: 98.25). The median FAS score was 3.00 (Q1: 2.00-Q3: 4.00).

Regarding biochemical parameters, the median calcium level was 9.70 mg/dl (Q1: 9.39-Q3: 10.03), the median parathyroid hormone (PTH) level was 31.00 pg/ml (Q1: 20.00-Q3: 51.99), and the median vitamin D level was 18.50 ng/ml (Q1: 13.00-Q3: 24.24).

When newly diagnosed cases were included, the median stroke duration was 18 (Q1: 9.5-Q3: 30.7) months in patients with osteoporosis and 14.5 (Q1: 3-Q3: 26) months in those without osteoporosis. No statistically significant difference was found between the groups in terms of stroke duration (p=0.167).

In subgroup analyses, no significant differences were observed in FIM, FAS, calcium, PTH, and vitamin D levels according to sex or osteoporosis status (all p>0.05). However, PTH levels were significantly lower in the hemorrhagic stroke group (median: 25 pg/ml vs. 34.4 pg/ml, p=0.046). In analyses including newly diagnosed cases, vitamin D levels were lower in the osteoporosis group, although the difference did not reach statistical significance (p=0.059). No statistically significant differences were found between comorbidities, smoking or alcohol use, and scale scores or biochemical parameters (all p>0.05). The detailed results of the subgroup analyses are presented in **Table 3**.

When patients with and without osteoporosis were compared, the median BMI values were 28.2 (Q1: 24.1-Q3: 32.1) and 29.0 (Q1: 27.0-Q3: 31.0), respectively. Although BMI was higher in the non-osteoporotic group, this difference was not statistically significant (p=0.178).

In Spearman correlation analysis, a statistically significant, strong, and positive correlation was found between FAS and FIM (r=0.725, p<0.001) (**Table 4**).

Among BMD measurements, statistically significant positive correlations were observed between the femoral neck and L1-L4 (r=0.608, p<0.001), between L1-L4 and L2-L4 (r=0.949, p<0.001), and between the femoral neck and L2-L4 (r=0.572,

Variables	Functional independence measure score	Functional Ambulation Scale score	Calcium (mg/dl) Median (Q1-Q3)	Parathyroid hormone (pg/ml) Median (Q1-Q3)	Vitamin D (ng/ml) Median (Q1-Q3)
<b>Sex</b>					
Male	79 (60-100)	3 (2-4)	9.7 (9.5-9.9)	29.1 (17.9-52.6)	20.3 (13-30)
Female	72 (48-95.5)	3 (2-4)	9.6 (9.3-10.1)	33.4 (21.9-50.9)	16.8 (12.4-20.8)
p-value*	0.367	0.877	0.981	0.734	0.135
<b>Stroke type</b>					
Ischemic	74 (48-106)	3 (2-4)	9.6 (9.3-10)	34.4 (21-54.4)	18 (12.4-22.1)
Hemorrhagic	78 (19-89)	3 (2-4)	9.7 (9.3-10)	25 (12-33.6)	20.4 (14.6-44)
p*	0.630	0.556	0.839	0.046	0.133
<b>Previous osteoporosis diagnosis</b>					
Yes	84 (53.5-95.5)	3 (1.5-4.5)	9.6 (9.3-9.9)	25.2 (21.9-42.8)	18 (12.1-22.7)
No	74 (55-100)	3 (2-4)	9.7 (9.4-10.0)	33.6 (18.2-54.3)	19 (13.2-26.1)
p-value*	0.819	0.601	0.583	0.300	0.548
<b>Osteoporosis diagnosis (including newly diagnosed cases)</b>					
Yes	74.5 (47.5-97)	2.5 (1.7-4)	9.6 (9.2-9.9)	29 (19.5-45.3)	16.2 (12.5-20.1)
No	75 (56-99.2)	3 (2-4)	9.7 (9.4-10.1)	34 (19.4-55)	20 (13.3-28.6)
p-value*	0.945	0.500	0.109	0.518	0.059

\*Mann-Whitney U test

Table 4. Correlations between functional scores, stroke duration, DXA T-scores, and age

Variables	Functional independence measure score	Functional Ambulation Scale score	Stroke duration (months)	Lumbar spine (L1-L4) T-score	Lumbar spine (L2-L4) T-score	Femoral neck T-score	Age (years)
<b>Functional independence measure score</b>							
r	1						
p	.						
<b>Functional Ambulation Scale score</b>							
r	.725	1					
p	<0.001	.					
<b>Stroke duration (months)</b>							
r	.013	.143	1				
p	.909	.206	.				
<b>Lumbar spine (L1-L4) T-score</b>							
r	-.014	-.001	-.106	1			
p	.905	.995	.349	.			
<b>Lumbar spine (L2-L4) T-score</b>							
r	-.023	.038	-.059	.949	1		
p	.842	.738	.606	<0.001	.		
<b>Femoral neck T-score</b>							
r	.087	.051	-.157	.608	.572	1	
p	.445	.651	.165	<0.001	<0.001	.	
<b>Age (years)</b>							
r	-.134	-.118	.049	-.239	-.232	-.451	1
p	.236	.298	.668	.033	.039	<0.001	.

r: Correlation coefficient

p<0.001). The correlations were strong between L1-L4 and L2-L4, and moderate between the femoral neck and L2-L4 (Table 4).

Age showed statistically significant negative correlations with L1-L4 (r=-0.239, p=0.033) and L2-L4 (r=-0.232, p=0.039), both at a weak level, while a moderate negative correlation was observed with the femoral neck (r=-0.451, p<0.001) (Table 4).

## DISCUSSION

In this study, the prevalence of osteoporosis in post-stroke hemiplegic patients was 37.5% when newly diagnosed cases were included. Bone mineral density decreased with increasing age, particularly at the femoral neck. However, no significant association was observed between osteoporosis and functional independence, ambulation level, or biochemical parameters. These findings are consistent with previous studies suggesting that post-stroke bone loss may be more pronounced in the paretic extremity, especially at the femoral neck.<sup>14,15</sup>

The prevalence of osteoporosis observed in our study is higher than that expected in the general population, supporting the notion that post-stroke patients constitute a specific high-risk group in terms of bone health. Watanabe reported that approximately 40% of subacute stroke patients evaluated at rehabilitation admission had osteoporosis, a finding that is consistent with our results.<sup>16</sup> Furthermore, previous reviews have emphasized that post-stroke bone loss is often detected only through DXA assessment or after fracture occurrence, and that routine screening remains insufficient.<sup>8,15</sup> This may partly explain the higher prevalence of osteoporosis (37.5%)

observed in our study when newly diagnosed cases were included.

A negative association between age and BMD was observed, particularly at the femoral neck, where the correlation was moderate and statistically significant. This finding is consistent with both general osteoporosis literature and studies investigating post-stroke bone loss.<sup>17,18</sup> Age-related bone loss and reduced mechanical loading after stroke may contribute to this process.

In our study, despite the expected higher prevalence of osteoporosis in women, no significant differences were observed between sexes in terms of FIM, FAS, calcium, PTH, and vitamin D levels. This finding is consistent with previous studies suggesting that post-stroke bone loss is more closely related to immobilization and reduced mechanical loading than to sex.<sup>15,19</sup> Although Watanabe reported an association between BMD and both age and sex, bone resorption markers were also found to be related to disability level.<sup>16</sup> The absence of a significant sex-related difference in our study may therefore be attributed to the effects of post-stroke immobilization and sample characteristics.

When patients with and without osteoporosis were compared, BMI values were slightly higher in the non-osteoporotic group; however, this difference was not statistically significant (p=0.178). Although higher BMI has been suggested as a potential protective factor against osteoporosis, with previous studies demonstrating a positive association between body weight and BMD,<sup>18</sup> our findings did not confirm this relationship. Similarly, PTH levels were lower in the hemorrhagic stroke group, while no other

significant differences were observed according to stroke type. This finding may indicate that bone metabolism in post-stroke patients is more strongly influenced by immobilization and reduced mechanical loading than by stroke subtype.<sup>15,19</sup> However, given the limited number of patients in the hemorrhagic stroke group, this result should be interpreted with caution. In addition, vitamin D levels tended to be lower in the osteoporosis group, although the difference did not reach statistical significance ( $p=0.059$ ). This trend may still be clinically relevant, as factors such as reduced sun exposure, malnutrition, immobilization, and disturbances in vitamin D metabolism have been reported to contribute to post-stroke bone loss.<sup>15,19</sup>

In our study, no significant correlation was found between FIM and FAS scores and DXA T-scores. This finding differs from previous studies reporting an association between functional status and bone health. Schnitzer et al.<sup>20</sup> reported lower BMD in patients with impaired ambulation, particularly on the paretic side, while Yavuzer et al.<sup>21</sup> demonstrated greater bone loss in patients with increased motor impairment and functional dependence. However, FIM and FAS reflect current functional status, whereas bone loss represents the cumulative effect of reduced mechanical loading over time, which may explain the lack of a significant association. In addition, variability in stroke duration and the absence of standardized timing of DXA assessments may have further influenced this finding.

A strong positive correlation between FAS and FIM observed in our study indicates internal consistency among functional measures. However, the lack of association with BMD suggests that bone loss cannot be explained solely by ambulatory capacity. In post-stroke osteoporosis, multiple factors such as reduced mechanical loading, muscle changes, and metabolic influences may contribute to bone loss.<sup>15,19</sup> These findings indicate that functional status alone may not adequately reflect bone health, and relying solely on functional assessments in clinical practice may be insufficient.

Although a positive correlation was observed between lumbar spine measurements and the femoral neck, the most pronounced negative association with age was identified at the femoral neck. This finding is consistent with previous studies reporting that post-stroke bone loss is more prominent at the femoral neck, while changes in the lumbar spine are less evident.<sup>14,21</sup> These findings suggest that the femoral neck may be a more sensitive region for detecting post-stroke bone loss.

No significant association was found between stroke duration and osteoporosis. Previous studies have shown that bone loss is most rapid in the early months following stroke and may continue at a slower rate thereafter.<sup>14,15</sup> However, the wide variability in stroke duration and the cross-sectional design of our study may have limited the ability to detect this temporal relationship. In addition, the lack of standardized timing of DXA measurements may have further influenced this finding.

One of the key clinical implications of this study is that bone loss in post-stroke hemiplegic patients should not be considered only after the occurrence of fractures. Previous studies have emphasized that the use of DXA in post-stroke patients remains insufficient and that osteoporosis is frequently underdiagnosed in the absence of routine screening.<sup>8</sup> Schnitzer et al.<sup>20</sup> highlighted the importance of screening in patients with limited ambulation, while Lee et

al.<sup>22</sup> demonstrated that low femoral BMD in acute ischemic stroke may be associated with poor functional outcomes.

In our study, the prevalence of osteoporosis was 37.5%, supporting the notion that post-stroke patients constitute a high-risk group. These findings suggest that bone health in hemiplegic stroke patients may require more systematic evaluation, even in the absence of overt clinical symptoms.

### Limitations

This study has several important limitations. First, due to its retrospective and cross-sectional design, causal relationships cannot be established. The data were obtained from hospital information systems and patient records; therefore, the findings are dependent on the accuracy and completeness of these records.

Second, only patients who underwent DXA as part of routine clinical practice were included; therefore, the sample may not represent all post-stroke hemiplegic patients but rather a selected group requiring evaluation of bone health, which may have introduced selection bias.

Third, bilateral femoral neck measurements were not performed, as DXA assessments are not routinely conducted bilaterally in standard clinical practice, and the retrospective design limited the availability of such data. Therefore, only measurements from the paretic side were included in the analysis, and direct comparison between the paretic and non-paretic sides could not be performed.

Fourth, several variables that may influence bone health, such as physical activity level, daily load-bearing, sun exposure, nutritional status, menopausal status, muscle mass, and medication use, could not be systematically evaluated.

Finally, the sample size may have been insufficient for certain subgroup analyses, which may have limited the statistical power, particularly for borderline findings such as vitamin D levels.

### CONCLUSION

As a result, osteoporosis is a common and clinically significant condition in post-stroke hemiplegic patients. The findings of this study demonstrate a high prevalence of osteoporosis and indicate that age has a negative impact on BMD, particularly at the femoral neck. In contrast, functional independence and ambulation level alone appear insufficient to explain bone loss. Our results suggest that post-stroke osteoporosis is a multifactorial process and that bone health in hemiplegic patients should be evaluated not only after the occurrence of fractures but also during routine clinical follow-up. Early screening and appropriate preventive strategies, particularly in older patients and those at increased clinical risk, may contribute to reducing long-term fracture risk. Future prospective studies with larger sample sizes, incorporating standardized timing of BMD assessments and comprehensive evaluation of factors influencing bone metabolism, are warranted to further elucidate the mechanisms underlying post-stroke osteoporosis.

### ETHICAL DECLARATIONS

#### Ethics Committee Approval

This study was approved by the Ondokuz Mayıs University Clinical Researches Ethics Committee (Approval Date: 17.11.2025, Decision No: OMUKAEK 2025/538).

## Informed Consent

As this was a retrospective study, formal written informed consent was not required and was therefore not obtained.

## Peer Review Process

This manuscript was subject to external peer review.

## Conflict of Interest

The authors declare no conflicts of interest related to this study.

## Financial Disclosure

The authors received no financial support for the conduct or publication of this research.

## Author Contributions

Concept: ZC, MAK; Design: ZC, MAK; Control: ZC, MAK; Resources: ZC, MAK; Materials: ZC, MAK; Data Collection and/or Processing: ZC, MAK; Analysis and/or Interpretation: ZC; Literature Review: ZC, MAK; Writing the Article: ZC; Critical Review: MAK.

## Acknowledgments

The authors would like to thank Dr. Zeliha Ceyhan for her valuable contributions to the writing and proofreading of the manuscript.

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