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Reduced Bone Mineral Density as an Independent Predictor of Fragility Fractures in Older Adults: A Case–Control Analysis

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Abstract

Background: Fragility fractures represent a significant public health concern among older adults and are associated with substantial morbidity, mortality, reduced quality of life, and increased healthcare costs. Osteoporosis, characterized by decreased bone mineral density (BMD) and deterioration of bone microarchitecture, is a major underlying risk factor for these fractures. Early identification of individuals at high risk through BMD assessment may facilitate timely preventive interventions and reduce fracture burden.
Objectives: To evaluate the association between bone mineral density and fragility fractures in elderly patients and to estimate fracture risk across different World Health Organization (WHO) BMD diagnostic categories.
Methods: This case–control study included elderly patients aged 60 years and above with clinically confirmed fragility fractures (cases) and age- and sex-matched controls without a history of fracture. All participants underwent dual-energy X-ray absorptiometry (DXA) scanning for assessment of BMD at the femoral neck and lumbar spine. T-scores were categorized according to WHO criteria as normal, osteopenia, or osteoporosis. Differences in BMD parameters between groups were analyzed using appropriate statistical tests. Multivariable logistic regression analysis was performed to identify independent predictors of fragility fractures and calculate adjusted odds ratios (aORs).
Results: Patients with fragility fractures exhibited significantly lower mean femoral neck T-scores compared with controls (approximately −2.7 vs. −1.4; $p < 0.001$). Osteoporosis was considerably more prevalent among cases and was independently associated with an increased risk of fragility fracture (aOR ≈ 3.6). Advanced age and a previous history of fracture also emerged as significant independent risk factors. Fracture risk increased progressively across worsening BMD categories.
Conclusion: Reduced bone mineral density was strongly and independently associated with fragility fractures in elderly patients. These findings support routine DXA-based screening, early identification of osteoporosis, and timely initiation of preventive and therapeutic strategies to reduce fracture risk and improve skeletal health in older adults.

Keywords: Bone mineral density; DXA; Osteoporosis; Fragility fracture; T-score; Elderly

1. Introduction

Fragility fractures, defined as fractures occurring following low-energy trauma such as a fall from standing height or less, represent a major public health challenge in ageing populations worldwide (1). These fractures are among the most common consequences of skeletal fragility and are associated with substantial morbidity, mortality, disability, and healthcare expenditure (3). Older adults who sustain fragility fractures frequently experience chronic pain, reduced mobility, diminished quality of life, and loss of functional independence. In particular, hip and vertebral fractures are associated with prolonged hospitalization, institutionalization, and increased risk of death within the first year after injury (4). As life expectancy continues to rise globally, the burden of fragility fractures is expected to increase considerably, placing additional strain on healthcare systems and caregivers. The most frequently affected sites include the hip, vertebrae, distal radius, proximal humerus, and pelvis (5,6). These fractures often occur in the setting of osteoporosis, a systemic skeletal disorder characterized by reduced bone mass and deterioration of bone microarchitecture, resulting in increased bone fragility and susceptibility to fracture. Osteoporosis is frequently underdiagnosed and undertreated despite its significant clinical consequences, particularly among elderly individuals (7). Bone mineral density (BMD), measured using dual-energy X-ray absorptiometry (DXA), remains the gold standard for the diagnosis of osteoporosis and assessment of fracture risk. The World Health Organization defines osteoporosis as a T-score of −2.5 or lower, while osteopenia is defined by a T-score between −1.0 and −2.5. Numerous epidemiological studies have demonstrated a strong

inverse relationship between BMD and fracture risk, with fracture incidence increasing progressively as BMD declines (8). However, fractures also occur in individuals with osteopenia, indicating that factors such as age, previous fractures, comorbidities, medication use, and propensity to fall contribute to overall fracture risk. Accurate quantification of the association between BMD and fragility fractures is essential for identifying high-risk individuals, guiding screening strategies, and informing treatment decisions. Understanding fracture risk across different BMD categories may also improve the use of fracture prediction models and support targeted preventive interventions. Furthermore, locally generated evidence is important because demographic characteristics, lifestyle factors, and healthcare access may influence fracture patterns and osteoporosis prevalence (9). Therefore, the present case–control study was undertaken to examine the association between bone mineral density and fragility fractures among elderly patients and to estimate fracture risk across diagnostic BMD categories.

Aim: To examine the association between BMD and fragility fractures in elderly patients.

Primary objective: To compare BMD T-scores between patients with and without fragility fractures.

Secondary objectives: (i) To estimate fracture odds across WHO BMD categories; (ii) to assess independent contributions of clinical risk factors.

Hypotheses: Null (H_0) — BMD does not differ between fracture cases and controls. Alternative (H_1) — lower BMD is associated with higher odds of fragility fracture.

2. Materials and Methods

This study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for case–control studies.

2.1 Study Design and Setting

A hospital-based case–control study was conducted in the Department of Orthopaedics at [Institution Name], [City, Country], over a period of [study period]. The study aimed to evaluate the association between bone mineral density (BMD) and fragility fractures among elderly individuals and to estimate fracture risk across different BMD categories.

2.2 Ethical Considerations

The study protocol was reviewed and approved. Written informed consent was obtained from all participants before enrolment. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and subsequent amendments.

2.3 Study Participants

The study included elderly individuals aged 60 years and above. Cases consisted of patients presenting with fragility fractures resulting from low-energy trauma, such as a fall from standing height or less. Common fracture sites included the hip, vertebrae, distal radius, and proximal humerus. Controls were age- and sex-matched individuals attending the orthopaedic outpatient department or undergoing routine health evaluations who had no history of fragility fracture.

Participants were excluded if they had sustained fractures due to high-energy trauma, had pathological or metastatic fractures, were diagnosed with metabolic bone diseases other than osteoporosis (such as osteomalacia or Paget's disease), had chronic conditions or medications known to markedly affect bone metabolism, or had contraindications preventing DXA assessment.

2.4 Data Collection and Measurements

Demographic and clinical information was collected using a structured data collection form. Variables recorded included age, sex, body mass index (BMI), smoking status, alcohol consumption, comorbid conditions, medication history, and previous fracture history. Bone mineral density was measured using dual-energy X-ray absorptiometry (DXA) at the femoral neck and lumbar spine (L1–L4) by trained technicians following standard operating procedures. T-scores were calculated using reference population data and categorized according to World Health Organization criteria as normal (T-score > -1.0), osteopenia (T-score between -1.0 and -2.5), and osteoporosis (T-score ≤ -2.5). Clinical risk factors known to influence fracture susceptibility, including prior fragility fracture, BMI, and major comorbidities, were also assessed.

2.5 Sample Size Calculation

Sample size estimation was based on detecting a clinically meaningful difference in mean T-score between cases and controls. Assuming a difference of 0.6 units, a standard deviation of approximately 1.0, a two-sided significance level of 5%, and 80% statistical power, a minimum of 45 participants per group was required. To improve the precision of estimates, allow adjustment for multiple covariates, and account for potential missing data, a target sample size of approximately 240 participants (120 cases and 120 controls) was planned.

2.6 Statistical Analysis

Data were analysed using Statistical Package for the Social Sciences (SPSS) version ___ (IBM Corp., Armonk, NY, USA) / R version ___. Continuous variables were expressed as mean ± standard deviation (SD) and categorical variables as frequencies and percentages. Comparisons between cases and controls were performed using the independent-samples t-test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Multivariable logistic regression analysis was conducted to identify independent predictors of fragility fracture and to estimate adjusted odds ratios (aORs) with 95% confidence intervals (CIs). Variables with clinical relevance or a univariable p-value <0.20 were entered into the multivariable model. Model fit was assessed using standard diagnostic measures. All statistical tests were two-sided, and a p-value of less than 0.05 was considered statistically significant.

3. Results

3.1 Participant characteristics

A total of 240 elderly participants were included in the study, comprising 120 patients with fragility fractures (cases) and 120 age- and sex-matched individuals without a history of fragility fracture (controls). The overall mean age of the study population was 71 ± 7 years, with no significant difference between cases and controls (72 ± 7 vs. 71 ± 7 years, p = 0.41), indicating successful matching of the study groups. Bone mineral density measurements demonstrated substantially lower values among cases compared with controls. The mean femoral neck T-score was significantly lower in cases (−2.7 ± 0.8) than in controls (−1.4 ± 0.9; p < 0.001). Similarly, the mean lumbar spine T-score was markedly reduced among cases (−2.4 ± 0.9) compared with controls (−1.2 ± 1.0; p < 0.001). These findings indicate a strong association between reduced bone mineral density and the occurrence of fragility fractures. The prevalence of osteoporosis was significantly higher among patients with fragility fractures than among controls. Osteoporosis, defined as a T-score ≤ −2.5, was present in 78 cases (65%) compared with only 30 controls (25%) (p < 0.001). Furthermore, a previous history of fragility fracture was reported more frequently among cases than controls (34% vs. 13%, p < 0.01), suggesting an increased susceptibility to recurrent fractures in this population. Detailed baseline characteristics and BMD measurements are presented in Table 1, while the distribution of BMD values between groups is illustrated in Figure 1.

Table 1. BMD and characteristics by group.

Variable	Cases	Controls	p
Age (years), mean ± SD	72 ± 7	71 ± 7	0.41
Femoral neck T-score	−2.7 ± 0.8	−1.4 ± 0.9	<0.001
Lumbar spine T-score	−2.4 ± 0.9	−1.2 ± 1.0	<0.001
Osteoporosis, n (%)	78 (65)	30 (25)	<0.001
Prior fracture, n (%)	41 (34)	16 (13)	<0.01

3.2 Fracture risk by BMD category

Multivariable logistic regression analysis demonstrated that reduced bone mineral density was independently associated with a higher risk of fragility fracture. After adjustment for potential confounding variables, osteoporosis emerged as the strongest predictor of fracture, increasing the odds of fragility fracture by more than threefold (adjusted odds ratio [aOR] = 3.6, 95% CI: 2.2–5.9; p < 0.001). Individuals with osteopenia also exhibited a significantly elevated fracture risk compared with those with normal BMD (aOR = 1.8, 95% CI: 1.1–2.9; p = 0.02), although the magnitude of risk was lower than that observed for osteoporosis. Additional independent predictors of fragility fracture included a prior history of fragility fracture (aOR = 2.7, 95% CI: 1.6–4.5; p < 0.001) and age ≥75 years (aOR = 2.1, 95% CI: 1.3–3.4; p < 0.01). The progressive increase in fracture risk across worsening BMD categories highlights the importance of osteoporosis screening and early intervention. The adjusted associations between BMD categories and fragility fracture risk are summarized in Table 2 and graphically represented in Figure 2.

Table 2. Adjusted associations with fragility fracture.

Factor	aOR	95% CI	p
Osteoporosis (T ≤ −2.5)	3.6	2.2–5.9	<0.001
Osteopenia	1.8	1.1–2.9	0.02
Prior fragility fracture	2.7	1.6–4.5	<0.001
Age ≥75 years	2.1	1.3–3.4	<0.01

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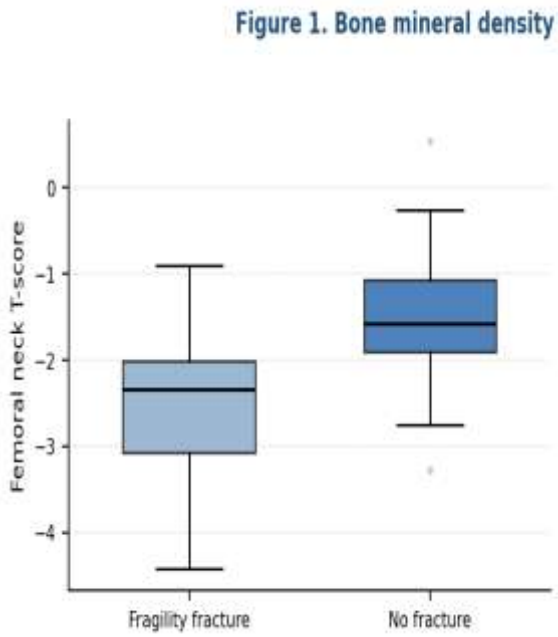

Figure 1. Femoral neck T-score by fracture status. Boxes show median and interquartile range.

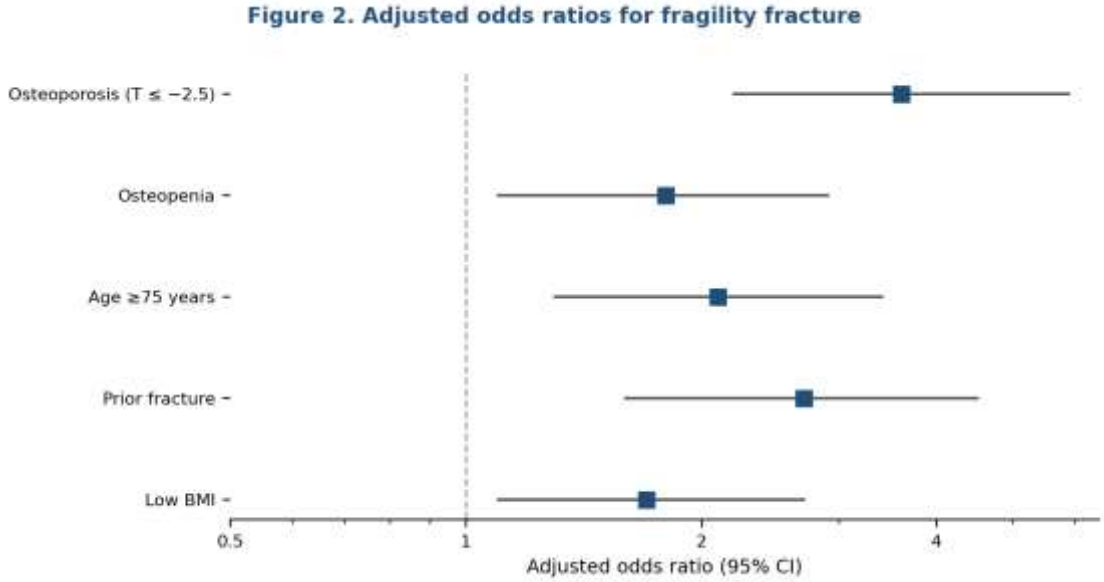

Figure 2. Adjusted odds ratios (95% CI) for fragility fracture.

4. Discussion

In this case–control study of elderly individuals, patients who experienced fragility fractures demonstrated significantly lower bone mineral density (BMD) at both the femoral neck and lumbar spine compared with age- and sex-matched controls. Osteoporosis was strongly and independently associated with fragility fracture, increasing fracture risk by more than threefold after adjustment for potential confounding variables (10). Individuals with osteopenia also exhibited a significantly elevated risk, although the magnitude of risk was lower than that observed in patients with osteoporosis. In addition, a prior history of fragility fracture and advanced age emerged as important independent predictors of fracture occurrence. Collectively, these findings reinforce the pivotal role of skeletal fragility in the pathogenesis of low-trauma fractures among older adults and are consistent with established epidemiological evidence linking declining BMD to increasing fracture risk. The observed association between reduced BMD and fracture risk reflects the fundamental contribution of bone mass and bone microarchitecture to overall skeletal strength. As bone density declines, the ability of

bone tissue to withstand mechanical stress is progressively compromised, resulting in increased susceptibility to fractures even after minimal trauma. The significantly lower femoral neck and lumbar spine T-scores observed among cases support the concept that DXA-derived BMD remains one of the strongest measurable predictors of future fracture risk. Nevertheless, the finding that osteopenia was also associated with an increased risk of fracture highlights that clinically relevant fractures occur across a spectrum of bone loss and are not restricted solely to individuals meeting the diagnostic threshold for osteoporosis. Importantly, our results demonstrate that BMD alone does not fully explain fracture susceptibility. Prior fragility fracture remained an independent predictor after adjustment for BMD, suggesting that factors beyond bone density contribute to skeletal fragility. Previous fractures may reflect cumulative deficits in bone quality, microarchitecture, balance, muscle strength, and fall propensity that are not captured by DXA measurements. Similarly, advanced age independently increased fracture risk, likely reflecting age-related deterioration in bone quality, sarcopenia, impaired mobility, visual impairment, and increased likelihood of falls. These findings support the use of integrated fracture-risk assessment models, such as FRAX, which combine BMD measurements with clinical risk factors to provide a more comprehensive estimation of fracture probability. From a clinical perspective, the findings strongly support routine osteoporosis screening using DXA in older adults, particularly those with previous fractures or advancing age. Early identification of individuals with osteoporosis allows timely initiation of pharmacological therapies, including bisphosphonates, denosumab, or anabolic agents, which have been shown to reduce fracture risk significantly. In addition, non-pharmacological interventions such as fall-prevention programmes, optimisation of calcium and vitamin D intake, regular weight-bearing exercise, and management of secondary causes of bone loss remain essential components of fracture prevention strategies. Particular attention should also be given to individuals with osteopenia who possess additional clinical risk factors, as they may benefit from closer monitoring and targeted preventive interventions. The strengths of this study include the use of age- and sex-matched controls, objective assessment of BMD using DXA, and multivariable analysis to account for potential confounding variables. However, several limitations should be considered. The case–control design is inherently susceptible to selection bias and recall bias and does not permit establishment of a temporal relationship between reduced BMD and fracture occurrence. The study was conducted at a single centre, which may limit the generalisability of the findings to other populations. Furthermore, certain factors influencing fracture risk, including vitamin D status, physical activity, nutritional status, sarcopenia, and detailed fall history, were not evaluated and may have contributed residual confounding. Finally, DXA primarily measures bone density and does not fully capture aspects of bone quality and microarchitectural integrity that also influence fracture susceptibility. Future research should focus on prospective longitudinal studies that integrate BMD measurements with clinical risk assessment tools, bone turnover markers, and emerging measures of bone quality. Such approaches may improve fracture prediction, facilitate more precise risk stratification, and help refine treatment thresholds for preventing fragility fractures in ageing populations.

5. Conclusion

Reduced bone mineral density (BMD) was strongly and independently associated with the occurrence of fragility fractures among elderly patients, with osteoporosis conferring the greatest fracture risk and osteopenia demonstrating an intermediate level of risk. In addition to low BMD, advanced age and a previous history of fragility fracture were important independent predictors of fracture occurrence. These findings reinforce the central role of osteoporosis in skeletal fragility and highlight the value of BMD assessment in identifying individuals at increased risk. Routine DXA-based screening, particularly among older adults and those with additional clinical risk factors, may facilitate early diagnosis and timely initiation of evidence-based osteoporosis therapies. Combined with fall-prevention strategies, lifestyle modification, and management of secondary causes of bone loss, such interventions have the potential to substantially reduce fracture incidence and associated morbidity. Further prospective, multicentre studies incorporating clinical risk assessment tools and measures of bone quality are warranted to improve fracture prediction and optimize preventive strategies in ageing populations.

References

1. Johnell O, Kanis JA. An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. Osteoporos Int. 2006;17(12):1726–1733.
2. Cooper C, Campion G, Melton LJ. Hip fractures in the elderly: a world-wide projection. Osteoporos Int. 1992;2(6):285–289.
3. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury. 2006;37(8):691–697.
4. Kanis JA. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. Osteoporos Int. 1994;4(6):368–381.

5. Cosman F, de Beur SJ, LeBoff MS, et al. Clinician's guide to prevention and treatment of osteoporosis. Osteoporos Int. 2014;25(10):2359–2381.
6. Kanis JA, Johnell O, Oden A, et al. FRAX and the assessment of fracture probability in men and women from the UK. Osteoporos Int. 2008;19(4):385–397.
7. Marshall D, Johnell O, Wedel H. Meta-analysis of how well measures of bone mineral density predict occurrence of osteoporotic fractures. BMJ. 1996;312(7041):1254–1259.
8. Black DM, Rosen CJ. Postmenopausal osteoporosis. N Engl J Med. 2016;374(3):254–262.
9. Siris ES, Miller PD, Barrett-Connor E, et al. Identification and fracture outcomes of undiagnosed low bone mineral density in postmenopausal women: results from the NORA study. JAMA. 2001;286(22):2815–2822.
10. Schuit SC, van der Klift M, Weel AE, et al. Fracture incidence and association with bone mineral density in elderly men and women: the Rotterdam Study. Bone. 2004;34(1):195–202.