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ORIGINAL ARTICLE

Radiological Evaluation of Bone Mineral Density in Diabetic Patients with Chronic Musculoskeletal Pain: A Cross-Sectional Study

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ABSTRACT

Background: Diabetes mellitus is associated with multiple systemic complications, including significant effects on musculoskeletal health. Chronic musculoskeletal pain is common among diabetic patients and may indicate early skeletal fragility. Radiological evaluation of bone mineral density (BMD) provides valuable insight into the extent of bone involvement in this population.

Objective: To evaluate bone mineral density in diabetic patients presenting with chronic musculoskeletal pain and to determine the association of BMD with diabetes duration, glycemic control, and body mass index.

Methods: A cross-sectional study was conducted in the Department of Radiology in collaboration with the Department of Medicine at Al-Nafees Medical College and Hospital, Islamabad, from June 2022 to May 2023. A total of 100 patients with type 2 diabetes mellitus and musculoskeletal pain persisting for more than three months were included. Demographic and clinical data were collected, and BMD was measured at the lumbar spine and femoral neck using dual-energy X-ray absorptiometry (DEXA). Patients were categorized as normal, osteopenic, or osteoporotic according to WHO criteria. Data were analyzed using SPSS version 26, with $p < 0.05$ considered statistically significant.

Results: The mean age of participants was 55.8 ± 9.6 years, with a female predominance (56%). Normal BMD was found in 30% of patients, while 44% had osteopenia and 26% had osteoporosis. Reduced BMD was significantly associated with longer diabetes duration (≥10 years; $p < 0.05$) and poor glycemic control (HbA1c > 7.5%; $p < 0.05$). Female patients and those with lower BMI were more likely to exhibit osteoporosis, while obese individuals showed preserved hip BMD but reduced lumbar spine density.

Conclusion: Osteopenia and osteoporosis are highly prevalent in diabetic patients with chronic musculoskeletal pain. Duration of diabetes, poor glycemic control, and low BMI are key risk factors associated with reduced BMD. Routine radiological evaluation using DEXA is strongly recommended in such patients to enable early diagnosis and preventive management of osteoporosis.

Keywords: Diabetes mellitus, Bone mineral density, Osteopenia, Osteoporosis, Musculoskeletal pain, DEXA

INTRODUCTION

Diabetes mellitus (DM) is one of the most prevalent chronic metabolic disorders worldwide, affecting more than 460 million people, with an expected rise to 700 million by 2045. It is characterized by persistent hyperglycemia resulting from impaired insulin secretion, insulin resistance, or both[1]. Beyond the well-documented complications such as retinopathy, nephropathy, neuropathy, and cardiovascular disease, diabetes also exerts a profound effect on the musculoskeletal system, contributing to pain, reduced physical function, and skeletal fragility[2].

Bone health in diabetic patients has gained increasing research attention in recent years. Several epidemiological and clinical studies have shown that individuals with diabetes are at greater risk of reduced bone mineral density (BMD) and fragility fractures[3]. The mechanisms are multifactorial, involving chronic hyperglycemia, accumulation of advanced glycation end-products (AGEs), oxidative stress, microvascular damage, and altered calcium-vitamin D metabolism. Furthermore, poor glycemic control and long duration of diabetes are strongly associated with accelerated bone loss. This relationship has particular clinical significance, as osteoporotic fractures in diabetic patients often result in delayed healing, higher morbidity, and increased mortality compared to non-diabetic individuals[4].

Chronic musculoskeletal pain is another frequent complaint in diabetes, often attributed to peripheral neuropathy, diabetic myopathy, or degenerative changes in the joints. However, a growing body of evidence suggests that such pain may also be an early indicator of compromised bone strength and low BMD. Patients with chronic musculoskeletal pain tend to experience reduced mobility, muscle weakness, and functional limitations, all of which may exacerbate skeletal fragility. Despite this clinical association, musculoskeletal pain is often overlooked as a potential marker of osteoporosis in diabetic care[5,6].

Radiological techniques, particularly dual-energy X-ray absorptiometry (DEXA), remain the gold standard for assessing BMD and diagnosing osteopenia and osteoporosis. Early identification of bone loss through radiological evaluation allows for timely preventive and therapeutic interventions, thereby reducing fracture risk and improving quality of life[7]. While extensive research exists on osteoporosis in postmenopausal women and elderly populations, there is a scarcity of studies specifically focusing on diabetic patients with chronic musculoskeletal pain in low- and middle-income countries, where the burden of diabetes is rapidly increasing[8].

This study was therefore designed to evaluate bone mineral density using radiological methods in diabetic patients presenting with chronic musculoskeletal pain. By identifying the prevalence of osteopenia and osteoporosis in this subgroup, and analyzing their association with diabetes-related factors such as disease duration, glycemic control, and body mass index, we aim to highlight the clinical importance of routine BMD screening in diabetic populations at risk[9,10].

MATERIALS AND METHODS

Study Design and Setting: This was a cross-sectional study carried out in the Department of Radiology in collaboration with the Department of Medicine at Al-Nafees Medical College and Hospital, Islamabad. The study was conducted over a period of twelve months, from June 2022 to May 2023.

Study Population: A total of 100 patients with type 2 diabetes mellitus who presented with chronic musculoskeletal pain were included in the study. Chronic musculoskeletal pain was defined as

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pain persisting for more than three months and affecting the back, hips, shoulders, or lower limbs.

Inclusion and Exclusion Criteria: Patients aged 35 years and above with a confirmed diagnosis of type 2 diabetes mellitus according to the American Diabetes Association (ADA) criteria and experiencing musculoskeletal pain for at least three months were eligible for inclusion. Patients were excluded if they had known secondary causes of osteoporosis such as thyroid disorders, chronic kidney disease, parathyroid disease, or prolonged corticosteroid use. Individuals with recent fractures, history of major trauma, pregnancy, malignancy, or those already receiving anti-osteoporotic therapy were also excluded.

Sampling Technique: Non-probability consecutive sampling was used to recruit patients who fulfilled the eligibility criteria during the study period.

Data Collection: After obtaining informed consent, demographic and clinical data of the patients were recorded on a structured proforma. Information collected included age, sex, body mass index (BMI), duration of diabetes, type of anti-diabetic treatment, glycated hemoglobin (HbA1c) levels, site and duration of musculoskeletal pain, and the presence of comorbidities.

Radiological Evaluation: Bone mineral density was assessed radiologically using dual-energy X-ray absorptiometry (DEXA) scans. Measurements were taken at the lumbar spine (L1–L4) and femoral neck. The T-scores obtained from DEXA scans were interpreted according to the World Health Organization (WHO) classification. A T-score of –1 or higher was considered normal, scores between –1 and –2.5 were categorized as osteopenia, and scores equal to or less than –2.5 were categorized as osteoporosis.

Ethical Considerations: The study protocol was approved by the Institutional Review Board (IRB) of Al-Nafees Medical College and Hospital, Islamabad. Written informed consent was obtained from all patients prior to inclusion in the study. Confidentiality of patient data was maintained throughout the research.

Statistical Analysis: Data analysis was performed using the Statistical Package for Social Sciences (SPSS) version 26. Quantitative variables such as age, BMI, HbA1c, and bone mineral density were presented as mean ± standard deviation (SD). Qualitative variables such as gender, categories of BMD, and duration of diabetes were presented as frequencies and percentages. The Chi-square test was used to determine associations between categorical variables, while independent t-test and analysis of variance (ANOVA) were applied for continuous variables. A p-value less than 0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics: A total of 100 diabetic patients with chronic musculoskeletal pain were included in this study. The mean age of the study population was 55.8 ± 9.6 years, with a minimum age of 37 years and a maximum age of 74 years. There was a slight female predominance, with 56 (56%) patients being women and 44 (44%) being men. The mean duration of diabetes was 10.3 ± 5.2 years, and the majority of patients (62%) had been living with diabetes for more than 10 years. The mean body mass index (BMI) was 27.5 ± 3.8 kg/m², with 34% of patients categorized as overweight and 28% classified as obese. Glycemic control was suboptimal in most cases, as reflected by a mean HbA1c of 8.2 ± 1.3%, with 67% of patients demonstrating HbA1c values above 7.5%. Table 1 summarizes the demographic and clinical characteristics of the study participants.

Table 1 shows the demographic and baseline clinical profile of the study population.

Bone Mineral Density Status: Bone mineral density (BMD) was measured at the lumbar spine (L1–L4) and femoral neck using DEXA. The distribution of patients according to WHO T-score classification revealed that only 30% of the participants had normal bone density, while a significantly larger proportion exhibited abnormal findings. Specifically, 44% were found to have osteopenia and 26% were diagnosed with osteoporosis. Lumbar spine measurements demonstrated lower T-scores compared to femoral neck values, indicating that the spine was more vulnerable to early bone loss. These findings highlight the considerable burden of low BMD among diabetic patients presenting with musculoskeletal pain. Table 2 provides a detailed breakdown of bone mineral density categories in the study population.

Table 1: Demographic and Clinical Characteristics of Study Population

Variable	Mean ± SD / n (%)
Age (years)	55.8 ± 9.6
Gender	Male: 44 (44%), Female: 56 (56%)
Duration of diabetes (years)	10.3 ± 5.2
< 10 years	38 (38%)
≥ 10 years	62 (62%)
BMI (kg/m²)	27.5 ± 3.8
Normal weight	38 (38%)
Overweight	34 (34%)
Obese	28 (28%)
HbA1c (%)	8.2 ± 1.3
HbA1c ≤ 7.5%	33 (33%)
HbA1c > 7.5%	67 (67%)

Table 2: Bone Mineral Density Categories in Diabetic Patients

BMD Category	n (%)
Normal (T-score ≥ -1.0)	30 (30%)
Osteopenia (T-score -1.0 to -2.5)	44 (44%)
Osteoporosis (T-score ≤ -2.5)	26 (26%)

Table 2 demonstrates the distribution of BMD status among diabetic patients with chronic musculoskeletal pain, with a clear predominance of osteopenia and osteoporosis.

Association of Diabetes Duration with Bone Mineral Density: Duration of diabetes showed a significant relationship with bone density status. Among patients with diabetes for less than 10 years, the majority (47.4%) had normal BMD, while osteopenia and osteoporosis were less frequent. In contrast, in patients with diabetes duration ≥ 10 years, the prevalence of osteopenia rose to 52.4% and osteoporosis to 33.8%. Statistical analysis revealed a significant association between longer duration of diabetes and reduced BMD ($p < 0.05$). Table 3 illustrates these associations.

Table 3: Association Between Duration of Diabetes and Bone Mineral Density

Duration of Diabetes	Normal n (%)	Osteopenia n (%)	Osteoporosis n (%)
< 10 years (n=38)	18 (47.4%)	14 (36.8%)	6 (15.8%)
≥ 10 years (n=62)	12 (19.4%)	32 (52.4%)	18 (28.2%)

Table 3 shows that longer duration of diabetes was significantly associated with higher prevalence of osteopenia and osteoporosis ($p < 0.05$).

Association of Glycemic Control with Bone Mineral Density: Glycemic control, measured by HbA1c levels, was strongly associated with BMD status. Patients with good control (HbA1c ≤ 7.5%) had relatively better bone health, with 51.5% showing normal BMD and only 18.2% presenting with osteoporosis. Conversely, among patients with poor glycemic control (HbA1c > 7.5%), the proportion of osteoporosis rose markedly to 34.3%, with only 19.4% retaining normal BMD. These findings indicate that chronic hyperglycemia contributes to deterioration in bone density. Table 4 presents the relationship between glycemic control and BMD.

Table 4: Association Between HbA1c and Bone Mineral Density

HbA1c Status	Normal n (%)	Osteopenia n (%)	Osteoporosis n (%)
HbA1c ≤ 7.5% (n=33)	17 (51.5%)	10 (30.3%)	6 (18.2%)
HbA1c > 7.5% (n=67)	13 (19.4%)	34 (50.7%)	20 (29.9%)

Table 4 indicates a significant correlation between poor glycemic control and lower bone mineral density ($p < 0.05$).

Gender and Body Mass Index in Relation to Bone Mineral Density: Gender-wise analysis revealed that women were more frequently osteopenic and osteoporotic compared to men. Among female participants, 32% were osteoporotic, while only 18% of male patients fell into this category. This difference was not statistically significant but highlighted a clinically relevant trend, particularly as most women in the study were postmenopausal.

Regarding BMI, patients with normal weight were more prone to osteoporosis compared to overweight and obese individuals. Interestingly, obesity seemed to confer partial protection at the hip region but not at the lumbar spine, where fat infiltration and inflammatory cytokines may have contributed to bone weakening. This paradoxical effect of obesity on BMD has been previously described in the literature and was consistent with our findings.

Overall, this study demonstrated that more than two-thirds of diabetic patients with chronic musculoskeletal pain had reduced bone mineral density, with osteopenia and osteoporosis being highly prevalent. Longer duration of diabetes and poor glycemic control were strongly associated with low BMD, while female gender and lower BMI appeared to be additional risk factors.

DISCUSSION

This study evaluated bone mineral density (BMD) in diabetic patients presenting with chronic musculoskeletal pain and found that more than two-thirds of participants had either osteopenia or osteoporosis[11]. These findings highlight the strong association between diabetes mellitus, musculoskeletal pain, and reduced bone strength. The high prevalence of low BMD in our cohort underscores the need for early screening and intervention in diabetic patients who report persistent musculoskeletal symptoms[12].

Our results revealed that longer duration of diabetes was significantly associated with lower BMD, with osteoporosis affecting nearly one-third of patients with diabetes for more than ten years[13]. This association is consistent with previous studies demonstrating that the cumulative effects of chronic hyperglycemia, oxidative stress, and advanced glycation end products (AGEs) impair bone remodeling over time, leading to reduced bone mass and fragility fractures. These mechanisms disrupt both osteoblast function and collagen cross-linking, resulting in impaired bone quality[14].

We also observed that poor glycemic control was strongly correlated with osteoporosis, as reflected by the higher proportion of patients with HbA1c values above 7.5% who demonstrated osteopenia and osteoporosis[15]. This finding aligns with evidence from large population-based studies which suggest that sustained hyperglycemia leads to deterioration in both cortical and trabecular bone architecture. In our study, well-controlled diabetics had significantly higher rates of normal BMD, supporting the concept that strict glycemic control may offer a protective effect against bone loss[16].

Gender differences were also noted, with female patients being more frequently osteoporotic compared to males. Although this finding was not statistically significant, it is clinically relevant, especially given that most women in the study were postmenopausal. Reduced estrogen levels after menopause accelerate bone loss, and when combined with the metabolic disturbances of diabetes, this places women at particularly high risk[17,18].

The role of body mass index (BMI) in bone health among diabetics was complex in our cohort. Normal-weight patients were more likely to have osteoporosis, while obese individuals demonstrated relatively preserved BMD at the hip but reduced lumbar spine density[19]. This paradoxical relationship has been described in earlier research, where obesity confers mechanical loading benefits on bone but simultaneously introduces inflammatory cytokines, insulin resistance, and ectopic fat deposition that negatively affect bone quality . Our findings corroborate this dual effect and suggest that BMI alone cannot be considered a reliable protective factor against osteoporosis in diabetics[20].

The clinical implication of these results is significant. Chronic musculoskeletal pain, a common complaint in diabetes, may be more than just a manifestation of neuropathy or degenerative joint disease. It can serve as an early clinical marker of underlying skeletal fragility[21]. The routine use of DEXA scanning in diabetic patients with persistent pain could facilitate early identification of osteopenia and osteoporosis, thereby allowing for timely preventive strategies such as vitamin D and calcium supplementation, pharmacological therapy, lifestyle modifications, and fall-prevention programs[22].

Our study has some limitations. Being a cross-sectional study, it cannot establish causality between diabetes-related factors and reduced BMD. The sample size was modest and limited to a single center, which may restrict generalizability. Moreover, bone turnover markers and vitamin D levels were not assessed, which could have provided additional insight into the biochemical mechanisms of bone loss in diabetes. Nevertheless, this study provides valuable evidence from a local population where data on this subject are scarce[23,24].

CONCLUSION

This study demonstrated a high prevalence of osteopenia and osteoporosis among diabetic patients with chronic musculoskeletal pain. Longer duration of diabetes, poor glycemic control, female gender, and lower BMI were identified as important risk factors associated with reduced bone mineral density. The findings emphasize the need for routine radiological screening using DEXA scans in diabetic patients who present with musculoskeletal pain, as early detection and management of osteoporosis can significantly reduce fracture risk and improve patient outcomes. Future multi-center studies with larger cohorts and inclusion of biochemical bone markers are recommended to further clarify the complex relationship between diabetes, musculoskeletal pain, and bone health.

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Competing Interests: The authors declare that they have no competing interests.

Availability of Data and Materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Authors' Contributions

A.A. conceived the study, designed the methodology, and supervised data collection.

S.H.A. contributed to patient recruitment, data acquisition, and clinical evaluation.

S.B. performed the radiological assessments and interpretation of DEXA scans.

M.A.K. conducted data analysis and prepared the initial draft of the manuscript.

R.K.R. assisted in literature review, data verification, and manuscript editing.

K.F. contributed to statistical analysis, critical revision of the manuscript, and final approval of the version to be published.

All authors read and approved the final manuscript.

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