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Original Research Article

Cross-Sectional Analysis of Vitamin D Deficiency and Fracture Risk among Perimenopausal Women

Avinash Kumar[1], Gauri Rani[2], Shiv Shankar Bharti[3]

[1]Assistant Professor, Department of Orthopaedics, MGM Medical College and LSK Hospital Kishanganj Bihar

[2]Assistant Professor, Department of Obstetrics and Gynecology, MGM Medical College and LSK Hospital Kishanganj Bihar

[3]Associate Professor, Department of Biochemistry, MGM Medical College and LSK Hospital Kishanganj Bihar

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Corresponding author: Dr. Avinash Kumar

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Abstract

Background: Vitamin D plays a vital role in calcium homeostasis and bone metabolism, yet its deficiency remains widespread, particularly among women undergoing menopausal transition. Perimenopause represents a critical phase of hormonal fluctuation that accelerates bone demineralization and increases fracture susceptibility. This study aimed to evaluate the prevalence of vitamin D deficiency and its association with fracture risk among perimenopausal women.

Methods: A cross-sectional observational study was conducted on 100 perimenopausal women aged 40–55 years attending the outpatient department of MGM Medical College & LSK Hospital a tertiary care hospital between March 2021 and February 2022. Serum 25-hydroxyvitamin D [25(OH)D], calcium, and phosphate levels were measured using standard biochemical methods. "Vitamin D status was categorized as deficient (<20 ng/mL), insufficient (20–30 ng/mL), or sufficient (>30 ng/mL). Fracture risk was assessed using the WHO FRAX tool, incorporating clinical risk factors and bone mineral density (BMD) data. Statistical analysis included Chi-square tests and Pearson's correlation, with significance set at $p < 0.05$.

Results: Vitamin D deficiency was found in 64% of participants, insufficiency in 26%, and sufficiency in only 10%. Women with deficient vitamin D levels demonstrated significantly higher FRAX-calculated 10-year fracture probabilities ($p < 0.01$). A strong negative correlation ($r = -0.61$) was observed between serum vitamin D levels and fracture risk scores, independent of BMI and age.

Conclusion: Vitamin D deficiency is highly prevalent among perimenopausal women and is significantly associated with increased fracture risk. Early detection and correction of vitamin D deficiency may serve as an effective preventive measure against osteoporosis and related fractures.

Keywords: Vitamin D deficiency, Perimenopause, FRAX score, Bone mineral density, Fracture risk, Osteoporosis prevention.

Introduction

The most visible change in hormone levels during perimenopause is a progressive descent in oestrogen production. This time between 40 and 55 affects women's health most due to physiological and metabolic changes. Most importantly, bone metabolism changes increase the risk of fragility fractures and osteoporosis. Oestrogen regulates bone density by suppressing osteoclastic activity and increasing osteoblastic bone formation. Perimenopause causes progressive bone loss due to oestrogen deficiency-induced bone resorption and production imbalance [1]. Women are more likely to have skeletal fragility, making them more susceptible to hip, spine, and wrist fractures from even minor stress. Vitamin D deficiency is a global problem, although it is especially frequent in South Asian countries like India. Vitamin D, a fat-soluble secosteroid hormone, stabilises calcium and phosphorus and prevents bone breakage [2]. It regulates bone remodelling, protects muscle strength and balance, and aids intestinal calcium absorption to reduce fractures and falls. Vitamin D's biologically active form is calcitriol. It binds to intestinal and bone receptors to increase calcium absorption and mineralization [4]. Vitamin D deficiency causes BMD loss, secondary hyperparathyroidism, bone turnover, and calcium absorption issues. Lifestyle variables include being

indoors too much, wearing sunscreen too generously, being too busy, and being outside too little have caused hypovitaminosis D, even though the skin synthesises vitamin D under sunlight. Vitamin D deficiency and inadequate diets plague many developing nations [5].

From 50% to 90% of Indian women, regardless of socioeconomic class, lack vitamin D. This includes city, rural, and high-income women. As this deficiency is usually asymptomatic, women may have musculoskeletal pain, weakness, or fragility fractures before anybody notices. Oestrogen and vitamin D decrease increase bone demineralisation in perimenopausal women [6]. Physical activity, weight increase, obesity, and body composition can impact vitamin D metabolism during this phase. Vitamin D's bioavailability is reduced by adipose tissue storage. The physiological and lifestyle changes in older women increase fracture risk and osteopenia and osteoporosis risk.

Fractures, especially minor trauma ones, are a major public health issue in perimenopause and postmenopause [7]. Along with discomfort and damage, such breaks severely impede mobility, autonomy, and quality of life.

Osteoporotic fractures are costly due to extensive hospital stays, costly surgery, and long-term rehabilitation. In low-resource areas, vitamin D and bone density screening is not common, increasing the burden. Studying vitamin D insufficiency and fracture risk in perimenopausal women has great therapeutic and preventative potential [8]. If this link is better understood, clinicians can identify at-risk patients and adopt targeted treatments including vitamin D supplementation, dietary modification, and lifestyle changes to prevent fractures.

Fractures increase with bone density, quality, muscular strength, stability, and fall risk. Vitamin D affects the above parameters simultaneously [9]. Vitamin D promotes calcium absorption, neuromuscular coordination, and muscle function, reducing the chance of falling. Lack of it makes it harder to keep proper posture and strong muscles, increasing the risk of falls and fractures. Vitamin D directly affects bone cells by affecting bone formation and resorption genes. Vitamin D insufficiency, obesity, ageing, lack of activity, and calcium deficiency enhance bone fragility during perimenopause [10]. Medical fracture risk assessment is easier thanks to tools like the FRAX score.

Age, BMI, family history, smoking, alcohol intake, and secondary osteoporosis factors are considered in this score. With or without bone mineral density measurements, the FRAX technique can predict a significant osteoporotic fracture in the next decade. When combined with biochemical indicators such blood 25(OH)D, the FRAX score can show how hormonal, nutritional, and metabolic factors affect bone health. This method's fracture risk understanding allows early detection and prevention [11].

Vitamin D deficiency prevention seems promising for perimenopausal women, but researchers have paid little attention to them. Early vitamin D effects during menopause are little studied because most data comes from postmenopausal individuals. Sunlight exposure, skin pigmentation, eating habits, and cultural traditions affect vitamin D synthesis and metabolism, making this gap more critical in India. Cross-sectional investigations of vitamin D levels and fracture risk in perimenopausal women can inform public health policies, health education, and therapeutic recommendations [12]. This study used Fracture Risk Assessment and Evaluation (FRAX) to examine vitamin D insufficiency and fracture risk in perimenopausal women. This study will assess the strength of the association between serum vitamin D levels and fracture risk during perimenopause to better understand how dietary and hormonal factors affect bone health. The study also examines how BMI, sun exposure, and lifestyle affect vitamin D status. This study should emphasise the necessity of early screening, preventative supplements, and lifestyle changes for menopausal women to maintain bone health and reduce fracture risk. Vitamin D deficiency is a modifiable factor affecting skeletal health throughout the perimenopausal transition, as this study shows. We can help women age better and live better by doing so.

Materials and Methods

Study Design and Setting: This study was a cross-sectional, hospital-based observational study conducted in the Department of Orthopedics at MGM Medical College & LSK Hospital Kishanganj Bihar, a tertiary care teaching hospital. The study period extended from March 2021 to February 2022.

Ethical clearance was obtained from the Institutional Ethics Committee prior to commencement of the study, and all participants provided informed written consent before enrolment.

Study Population and Sample Size: A total of 100 perimenopausal women aged between 40 and 55 years were recruited for this study using a simple random sampling technique from women attending the outpatient department (OPD). The sample size was calculated considering an anticipated prevalence of vitamin D deficiency of approximately 60%, with a 10% allowable error and 95% confidence interval, yielding a minimum

sample size of 92; hence, 100 subjects were included to ensure adequate representation.

Inclusion Criteria

- Women aged between 40 and 55 years, experiencing irregular menstrual cycles consistent with the perimenopausal transition.
- Willingness to participate and provide informed consent.
- No known systemic illness that could interfere with bone metabolism.

Exclusion Criteria

- Women currently receiving vitamin D or calcium supplementation.
- History of chronic renal, hepatic, thyroid, or parathyroid disorders.
- History of metabolic bone diseases, malignancy, or prolonged corticosteroid use.
- Postmenopausal women (defined as cessation of menstruation for ≥12 months).

Data Collection and Clinical Assessment: All participants were interviewed using a structured questionnaire to obtain information regarding sociodemographic details, menstrual history, dietary habits, physical activity, sun exposure duration, and use of sunscreen or protective clothing. Anthropometric measurements were taken, including height, weight, and body mass index (BMI), calculated as weight (kg)/height (m^2). Participants were categorized based on WHO BMI classification for Asian women. Sun exposure was estimated as the average duration of daily outdoor exposure without sunscreen use.

Biochemical Investigations: Venous blood samples were collected under aseptic conditions after overnight fasting. Serum was separated and stored at −20°C until analysis.

- Serum 25-hydroxyvitamin D [25(OH)D] concentration was measured using an enzyme-linked immunosorbent assay (ELISA) method.
- Serum calcium and serum phosphate levels were estimated using standard colorimetric assays.
- Internal and external quality controls were maintained throughout all biochemical estimations.
- Vitamin D status was classified according to Endocrine Society guidelines as:
- Deficient: <20 ng/mL
- Insufficient: 20–30 ng/mL
- Sufficient: >30 ng/mL

Fracture Risk Assessment: Fracture risk was evaluated using the FRAX (Fracture Risk Assessment) tool, developed by the World Health Organization.

The FRAX algorithm was applied individually to estimate the 10-year probability of a major osteoporotic fracture and hip fracture, considering parameters such as age, BMI, smoking status, prior fracture history, and family history of osteoporosis, glucocorticoid use, and secondary causes of osteoporosis. Bone mineral density (BMD) data were included where available, obtained using dual-energy X-ray absorptiometry (DEXA) at the lumbar spine or femoral neck. Participants were categorized into low, moderate, and high fracture risk groups based on FRAX outcomes.

Statistical Analysis: Data were entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. The prevalence of vitamin D deficiency and insufficiency was calculated.

- Comparisons between categorical groups (vitamin D status vs. fracture risk categories) were made using the Chi-square test.
- Correlations between serum vitamin D levels, age, BMI, and FRAX scores were determined using Pearson's correlation coefficient.
- Multivariate regression analysis was performed to identify independent predictors of fracture risk among the study population. A p-value < 0.05 was considered statistically significant.

Ethical Considerations

The study adhered to the principles outlined in the Declaration of Helsinki (2013). Participants were informed about the study objectives, procedures, and the voluntary nature of participation.

Confidentiality of all collected data was strictly maintained, and participants found to be vitamin D deficient were counseled and referred for appropriate supplementation and follow-up.

Results

A total of 100 perimenopausal women aged between 40 and 55 years participated in the study.

The demographic, biochemical, and clinical parameters were analyzed to evaluate the prevalence of vitamin D deficiency and its relationship with fracture risk.

Table 1: Baseline Characteristics of the Study Population (n = 100)

Parameter	Mean ± SD / n (%)
Age (years)	47.3 ± 4.2
BMI (kg/m²)	27.1 ± 3.4
Duration of sun exposure (min/day)	21.5 ± 9.6
Serum 25(OH)D (ng/mL)	18.6 ± 7.9
Serum Calcium (mg/dL)	8.7 ± 0.5
Serum Phosphate (mg/dL)	3.5 ± 0.6
Vitamin D Deficient (<20 ng/mL)	62 (62%)
Vitamin D Insufficient (20–30 ng/mL)	26 (26%)
Vitamin D Sufficient (>30 ng/mL)	12 (12%)

The mean age of the study population was 47.3 years, with an average BMI of 27.1 kg/m², indicating that the majority were overweight. The mean serum vitamin D level was 18.6 ng/mL, demonstrating a high prevalence of vitamin D deficiency (62%). Only 12% of the participants had sufficient vitamin D levels. Average daily sun exposure was approximately 21 minutes, which is below the recommended duration for adequate vitamin D synthesis. These findings reflect a clear trend of hypovitaminosis D among perimenopausal women, even in a region with abundant sunlight.

Table 2: Association of Vitamin D Status with BMI and Sun Exposure

Variable	Vitamin D Deficient (n=62)	Vitamin D Insufficient (n=26)	Vitamin D Sufficient (n=12)	p-value
Mean BMI (kg/m²)	28.2 ± 3.1	26.4 ± 3.0	24.9 ± 2.7	0.01*
Mean Sun Exposure (min/day)	17.8 ± 7.5	23.4 ± 8.6	29.6 ± 10.1	0.002**

A statistically significant inverse relationship was observed between vitamin D levels and BMI (p = 0.01). Women with higher BMI tended to have lower serum vitamin D concentrations, suggesting sequestration of vitamin D in adipose tissue and reduced bioavailability. Additionally, sun exposure duration showed a positive correlation with vitamin D status (p = 0.002), indicating that reduced outdoor activity and cultural clothing practices may contribute to the high prevalence of deficiency.

Table 3: Distribution of Participants According to Fracture Risk (Based on FRAX Score)

Risk Category	n (%)	Mean Vitamin D (ng/mL)
Low Risk (<10%)	48 (48%)	23.5 ± 6.8
Moderate Risk (10–20%)	36 (36%)	17.4 ± 5.2
High Risk (>20%)	16 (16%)	11.9 ± 4.6

According to the FRAX scoring system, 48% of the participants were in the low fracture risk group, while 36% had moderate and 16% had high fracture risk. The mean vitamin D level was significantly lower in women with high fracture risk (11.9 ng/mL) compared to those at low risk (23.5 ng/mL). This demonstrates a negative correlation between vitamin D concentration and fracture risk, highlighting that hypovitaminosis D contributes to skeletal fragility in perimenopausal women.

Table 4: Correlation between Serum Vitamin D Levels and Selected Parameters

Parameter	Correlation Coefficient (r)	p-value	Interpretation
Age	-0.12	0.23	Weak, non-significant negative correlation
BMI	-0.31	0.005**	Significant negative correlation
Sun Exposure	+0.45	<0.001**	Strong positive correlation
FRAX Score	-0.42	<0.001**	Strong negative correlation

Correlation analysis revealed that serum vitamin D levels were inversely related to BMI (r = -0.31) and fracture risk (r = -0.42), while positively correlated with sun exposure duration (r = +0.45). These results suggest that women with higher body fat percentage and limited sunlight exposure are more likely to be vitamin D deficient and at higher risk of fractures. The negative correlation between vitamin D levels and FRAX score underscores the significant role of vitamin D in maintaining bone strength and reducing fracture susceptibility.

Discussion

Overview of the Findings: In the current cross-sectional study, vitamin D insufficiency was linked to fractures in women nearing menopause. Despite abundant of sunshine, 62% of the study participants had vitamin D deficiencies and 26% had insufficiencies. Vitamin D insufficiency affected 12% of individuals. If their vitamin D levels were low, FRAX calculations showed that overweight, sedentary, or rarely outside women had a far higher

fracture risk. Sun exposure time positively correlates with vitamin D status, but serum vitamin D levels inversely correlate with fracture risk ($r = -0.42$, $p < 0.001$). These findings demonstrate vitamin D's importance in perimenopausal bone health and fragility prevention.

Role of Vitamin D in Bone Health and Perimenopausal Changes: Vitamin D regulates phosphorus and calcium metabolism, affecting bone formation, remodelling, and mineralisation. Insufficiency of intestinal calcium absorption and secondary hyperparathyroidism accelerate bone turnover and induce osteoporosis and osteoopenia. Perimenopause's low oestrogen levels accelerate bone resorption and reduce calcium retention. Low oestrogen and vitamin D deficiency harm bones multiplicatively. Women are at risk for fractures due to falling, and vitamin D inadequacy reduces muscle strength and neuromuscular coordination. This study found that perimenopause is a vital time for prevention. Vitamin D during menopause may halt bone loss, enhance muscular function, and reduce the chance of fragility fractures later in life.

Lifestyle, Sun Exposure, and Obesity as Determinants of Deficiency: We found that vitamin D deficient risk variables were a lack of sun exposure and a higher BMI. Vitamin D deficiency was more likely in people who spent less than 20 minutes outside daily. Modern lifestyle changes, urbanisation, indoor jobs, and traditional clothing styles make it harder for South Asian women to synthesise vitamin D from sunlight. UVB rays are also reduced by air pollution and other environmental factors. The adverse relationship between BMI and vitamin D in this study supports the hypothesis that adipose tissue sequesters vitamin D, reducing its bioavailability. Besides a lack of outdoor activity, obesity is connected to metabolic alterations that inhibit the liver's vitamin D activation. Overweight during perimenopause increases fracture risk and hypovitaminosis D risk. Moderate exercise, 30 minutes of safe sun exposure, and vitamin D-fortified meals can reduce this insufficiency. The findings emphasise the necessity for public education about vitamin D's non-skeletal benefits and importance for musculoskeletal health during menopause.

Association between Vitamin D Deficiency and Fracture Risk: The FRAX tool, used in this study to assess 10-year fracture probability, demonstrated a clear gradient of risk with decreasing vitamin D levels. Women in the high fracture risk category had mean serum 25(OH)D levels of 11.9 ng/mL, significantly lower than those in the low-risk group (23.5 ng/mL). This indicates that inadequate vitamin D not only affects bone mineral density but also influences the overall fracture risk profile through its effects on bone microarchitecture and muscular coordination. Vitamin D supplementation and optimization of calcium intake have been shown to improve bone mineral density and reduce falls in several interventional trials. Thus, regular screening for vitamin D deficiency in perimenopausal women can serve as an important preventive strategy for osteoporosis and related fractures. Identifying and correcting deficiency at this stage could delay the onset of postmenopausal osteoporosis and improve quality of life.

Comparison with Previous Studies: Many research have demonstrated that vitamin D deficiency is frequent and closely connected to poor bone health. This study confirms that. [13] Found that most perimenopausal Indian women had serum 25(OH)D levels < 20 ng/mL, corresponding to our mean of 18.6 ng/mL. Vitamin D inadequacy affects rich and poor countries worldwide, according to [14]. Their research showed that even in countries with ample sunlight, lack of outdoor exposure, sunscreen use, and darker skin pigmentation can reduce vitamin D production. [15] Reported that postmenopausal women with low vitamin D levels had higher fragility fractures. Our findings, which apply to perimenopausal women, show that vitamin D shortage has deleterious effects earlier in the menopausal transition. We also found that sedentary lifestyle and BMI independently lowered vitamin D levels. The new study shows that early detection and intervention during perimenopause, which is critical for bone health preservation but usually receives less clinical attention, is crucial. Previous studies focused on postmenopausal women. Our findings address a knowledge gap and demonstrate the need to consider vitamin D deficiency as a modifiable component in bone health and fracture risk, not just a nutritional issue.

Conclusion

Perimenopausal women often have vitamin D insufficiency, and this study reveals that it increases fracture risk, which is worrying. Despite living in sunny areas, most participants had low vitamin D levels. This reveals that lifestyle variables like lack of sun, inactivity, and obesity cause most hypovitaminosis D. As predicted by FRAX, lower blood vitamin D concentrations were associated with an increased incidence of fractures, underscoring the necessity to maintain vitamin D levels throughout menopause for bone health. Find and treat modifiable risk factors during perimenopause, a time of hormonal instability and accelerated bone loss, to reduce the risk of osteoporosis and fragility fractures later in life. Based on these findings, perimenopausal women should undergo regular vitamin D deficiency screenings, lifestyle advice, dietary fortification, and individualised supplementation strategies to maintain bone health. Safe sunlight and weight-

bearing activity can boost bone strength and fracture risk. Vitamin D insufficiency is subtle yet ubiquitous and has long-term effects. The report emphasises the necessity to educate clinicians and women about this for public health. Despite the study's cross-sectional design, the findings strongly suggest longitudinal research to better understand how early vitamin D optimisation affects fracture prevention. Maintaining vitamin D levels in perimenopausal women is an efficient and cost-effective method to keep bones strong, prevent fractures, and improve quality of life.

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