University Heart Journal
Vol. 22, No. 1, January 2026

ORIGINAL ARTICLE

Association of Serum Vitamin D Levels with Cardiovascular Risk in Patients with Osteoarthritis

MOHAMMOD ZAFOR IQBAL JAMALI[1], SHARIF MD MUSA[2], IFTEKHAR AL MAMUN[3], MD. ALAUDDIN[4], SOHEL MAHMUD[1], KHONDAKER QUMRUZZAMAN[1], MD. SAIFUL ISLAM[5]

[1]Department of Cardiology, Bangladesh Medical University, Dhaka, Bangladesh, [2]Department of Orthopedic Surgery, Bangladesh Medical University, Dhaka, Bangladesh, [3]Department of Surgery, Bangladesh Medical University, Dhaka, Bangladesh, [4]Department of Cardiac Surgery, Bangladesh Medical University, Dhaka, Bangladesh, [5]Department of Laboratory Medicine, Bangladesh Medical University, Dhaka, Bangladesh,

Address of Correspondence: Md. Saiful Islam, Associate Professor, Department of Laboratory Medicine, Bangladesh Medical University, Dhaka, Bangladesh, E-mail: saifullabmed@bmu.ac.bd, orcid id: https://orcid.org/0009-0003-3515-2602

Abstract

Background: *Osteoarthritis (OA) is a prevalent degenerative joint disorder increasingly associated with systemic comorbidities, particularly cardiovascular disease. Vitamin D deficiency is common in OA patients and may contribute to adverse cardiovascular outcomes through metabolic and inflammatory mechanisms.*

Aim of the study: *To evaluate the association between serum vitamin D levels and cardiovascular risk in patients with osteoarthritis.*

Methods: *This cross-sectional study included 110 patients with clinically and radiologically confirmed OA. Serum 25(OH)D levels were categorized as deficient (<20 ng/mL) or sufficient (eŠ20 ng/mL). Cardiovascular risk was assessed using lipid profile, blood pressure, and fasting blood glucose. OA severity was graded using the Kellgren–Lawrence system. Statistical analysis was performed using SPSS version 26.0, with p<0.05 considered significant.*

Result: *Vitamin D deficiency was found in 48.18% of participants. Deficient patients had significantly higher total cholesterol (224.6 ± 36.5 vs 197.8 ± 34.2 mg/dL, p<0.001), LDL (145.3 ± 30.7 vs 120.5 ± 28.9 mg/dL, p<0.001), triglycerides (192.1 ± 42.8 vs 162.3 ± 40.5 mg/dL, p=0.001), and systolic BP (144.2 ± 17.6 vs 133.5 ± 18.1 mmHg, p=0.003), along with lower HDL levels (38.6 ± 7.9 vs 43.8 ± 8.2 mg/dL, p=0.002). High cardiovascular risk was more prevalent among deficient patients (49.06% vs 26.32%, p=0.01). Severe OA was also significantly associated with vitamin D deficiency (69.81% vs 47.37%, p=0.02). Multivariable analysis showed vitamin D deficiency independently predicted high cardiovascular risk (AOR 2.9, 95% CI 1.4–6.1, p=0.004).*

Conclusion: *Vitamin D deficiency is significantly associated with increased cardiovascular risk and greater disease severity in osteoarthritis patients, highlighting the importance of integrated clinical evaluation and management.*

Keywords: *Osteoarthritis; Vitamin D deficiency; Cardiovascular risk; Lipid profile; Kellgren–Lawrence grade*

University Heart Journal 2026; 22(1): 21-27
DOI: https://doi.org/10.3329/uhj.v22i1.90760

Introduction

Osteoarthritis (OA) is a chronic, progressive degenerative joint disorder characterized by the breakdown of articular cartilage, subchondral bone remodeling, synovial inflammation, and gradual loss of joint function.[1] It is the most prevalent form of arthritis worldwide, affecting an estimated 7.6% of the global population, and represents a major cause of pain, disability, and reduced quality of life, particularly among the aging population.[2] With increasing life expectancy and the global rise in obesity and sedentary lifestyles, the burden of osteoarthritis is steadily increasing, posing significant challenges to healthcare systems, especially in developing countries.[3] Traditionally, osteoarthritis has been considered a localized

Received: 30 October, 2025 **Accepted:** 15 December, 2025

musculoskeletal condition; however, contemporary research increasingly supports its systemic nature [4]. OA is now recognized as being associated with chronic low-grade inflammation and metabolic dysregulation, which may contribute to the development of comorbid conditions beyond the joints.[5,6] Among these, cardiovascular disease (CVD) has gained considerable attention due to its high prevalence and major contribution to morbidity and mortality in patients with osteoarthritis.[7] Individuals with OA are at an increased risk of cardiovascular events, including ischaemic heart disease, hypertension, and stroke. This association may be explained by shared risk factors such as aging, obesity, physical inactivity, insulin resistance, and systemic inflammatory pathways.[8-10] Vitamin D, a secosteroid hormone primarily involved in calcium-phosphate homeostasis and bone metabolism, has also been implicated in various non-skeletal physiological processes, including immune regulation, inflammation modulation, and cardiovascular function.[11, 12] Vitamin D receptors are widely distributed in multiple tissues, including vascular smooth muscle cells, endothelial cells, and cardiomyocytes, suggesting its potential role in cardiovascular health. Deficiency of vitamin D is highly prevalent globally and has been associated with several adverse health outcomes, including hypertension, endothelial dysfunction, arterial stiffness, atherosclerosis, and increased cardiovascular morbidity and mortality.[13] In patients with osteoarthritis, vitamin D deficiency is frequently observed due to multiple factors such as reduced mobility, decreased outdoor activity, limited sun exposure, aging-related skin changes, and possible dietary insufficiency.[14] Additionally, chronic pain and functional limitation may further contribute to sedentary behavior, thereby exacerbating vitamin D deficiency.[15] Low serum vitamin D levels may be associated with increased severity of osteoarthritis symptoms, reduced muscle strength, and impaired physical performance, all of which may indirectly influence cardiovascular risk.[16] Despite growing interest in the relationship between vitamin D status and cardiovascular health, evidence specifically addressing its association with cardiovascular risk in patients with osteoarthritis remains limited and inconsistent. Given this background, there is a clear need to explore the relationship between serum vitamin D levels and cardiovascular risk in patients with osteoarthritis. Therefore, the present study aims to evaluate the association of serum vitamin D levels with cardiovascular risk in patients with osteoarthritis, with the objective of contributing to a more comprehensive and integrated approach to patient management.

Methodology & Materials

This study was a cross-sectional observational study conducted among patients diagnosed with osteoarthritis (OA). The study was carried out in the Department of laboratory Medicine and Department of Orthopedic Surgery, Bangladesh Medical University, Dhaka, Bangladesh, from January 2024 to December 2024. A total of 110 patients with clinically and radiologically confirmed osteoarthritis were included in the study.

Inclusion Criteria:

- Adults aged e”18 years
- Radiological confirmation of osteoarthritis
- Patients with symptomatic osteoarthritis for at least 3 months
- Individuals not currently enrolled in any other interventional clinical study

Exclusion Criteria:

- Patients receiving vitamin D supplementation within the last 6 months
- Individuals with chronic kidney disease, liver disease, malignancy, or endocrine disorders affecting vitamin D metabolism
- Patients on lipid-lowering or steroid therapy
- Pregnant or lactating women

Ethical Considerations

The study protocol was approved by the institutional ethics committee. Written informed consent was obtained from all participants prior to data collection, and confidentiality was maintained throughout the study.

Data Collection

Data were collected using a structured, pretested questionnaire along with detailed clinical examination and laboratory investigations. Sociodemographic information, including age and gender, as well as lifestyle factors such as smoking status, were recorded. Clinical parameters including body mass index (BMI) and the presence of comorbid conditions such as hypertension and diabetes mellitus were documented. Osteoarthritis-related information was obtained by recording the affected joint, duration of disease, and severity, which was assessed using the Kellgren–Lawrence grading system and categorized into mild (Grade I–II) and severe (Grade III–IV).

For biochemical analysis, fasting venous blood samples were collected after an overnight fast to measure serum

25-hydroxyvitamin D [25(OH)D] levels, lipid profile parameters (total cholesterol, low-density lipoprotein [LDL], high-density lipoprotein [HDL], and triglycerides), and fasting blood glucose. Vitamin D status was categorized as deficient (<20 ng/mL) or sufficient (e”20 ng/mL). Blood pressure was measured using a standard sphygmomanometer, with both systolic and diastolic values recorded, and the average of two readings was used for analysis. Cardiovascular risk was assessed based on combined clinical and biochemical parameters, including lipid profile, blood pressure, and glucose levels, and participants were subsequently classified into low, moderate, or high cardiovascular risk categories.

Statistical Analysis

Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Differences in mean values between vitamin D deficient and sufficient groups were assessed using the independent t-test. Associations between categorical variables were evaluated using the chi-square test. Furthermore, multivariable logistic regression analysis was performed to identify independent predictors of high cardiovascular risk, adjusting for potential confounders. A p-value of less than 0.05 was considered statistically significant.

Result

The majority of patients were aged 50–60 years and above 60 years (38.18% each), while 23.64% were younger than 50 years. Females constituted a higher proportion of the study population (60.0%). Most participants were overweight (43.64%), followed by obese (31.82%) and normal weight (24.55%). Hypertension was present in 53.64% of patients and 41.82% had diabetes mellitus. Additionally, 28.18% of participants were current smokers (Table 1). Knee osteoarthritis was the most common type (64.55%), followed by hip (21.82%) and hand osteoarthritis (13.64%). Most patients had a disease duration of 5–10 years (40.0%). Grade III was the most common severity level (34.55%), with Grade II accounting for 30.0%, Grade IV for 23.64%, and Grade I being the least frequent at 11.82% (Table II). Nearly half (48.18%) of the study participants were found to have deficient Vitamin D levels (Figure 1). Participants showed a mean total cholesterol of 210.5 ± 38.6 mg/dL, LDL 132.4 ± 32.1 mg/dL, HDL 41.2 ± 8.5 mg/dL, triglycerides 176.8 ± 45.2 mg/dL, systolic BP 138.7 ± 18.3 mmHg, diastolic BP 86.5 ± 10.7 mmHg, and fasting blood glucose 6.8 ± 1.9 mmol/L (Table III). Participants with vitamin D deficiency demonstrated a significantly worse cardiovascular risk profile compared to those with sufficient vitamin D levels, showing higher total cholesterol (224.6 ± 36.5 vs 197.8 ± 34.2 mg/dL, p<0.001), LDL (145.3 ± 30.7 vs 120.5 ± 28.9 mg/dL, p<0.001), triglycerides (192.1 ± 42.8 vs 162.3 ± 40.5 mg/dL, p=0.001), and systolic BP (144.2 ± 17.6 vs 133.5 ± 18.1 mmHg, p=0.003), along with lower HDL levels (38.6 ± 7.9 vs 43.8 ± 8.2 mg/dL, p=0.002) (Table IV). Vitamin D deficiency was significantly associated with a higher cardiovascular risk burden, where nearly half of deficient participants (49.06%) were in the high-risk category compared to 26.32% in the sufficient group, while low-risk status was more common among those with sufficient vitamin D (38.60% vs 16.98%; p=0.01) (Table V). Severe OA (Grade III–IV) was more prevalent in the vitamin D–deficient group (69.81%) than in the sufficient group (47.37%), whereas mild disease was more frequent among those with adequate vitamin D levels (52.63% vs 30.19%; p=0.02) (Table VI). Multivariable logistic regression analysis identified vitamin D deficiency (AOR: 2.9, 95% CI: 1.4–6.1, p=0.004), severe OA (AOR: 2.5, 95% CI: 1.2–5.1, p=0.01), age >60 years (AOR: 2.2, 95% CI: 1.1–4.5, p=0.03), obesity (AOR: 2.4, 95% CI: 1.2–5.0, p=0.01), and hypertension (AOR: 3.1, 95% CI: 1.5–6.4, p=0.002) as significant independent predictors of high cardiovascular risk (Table VII).

Table-I

Baseline characteristics of study participants (n=110)

Variable	Frequency (n)	Percentage (%)
Age (years)		
<50	26	23.64
50–60	42	38.18
>60	42	38.18
Gender		
Male	44	40.00
Female	66	60.00
BMI (kg/m²)		
Normal (<25)	27	24.55
Overweight (25–29.9)	48	43.64
Obese (e”30)	35	31.82
Co-morbidity		
Hypertension	59	53.64
Diabetes Mellitus	46	41.82
Smoking Status		
Current smoker	31	28.18
Non-smoker	79	71.82

Table-II

Osteoarthritis characteristics of respondents (n=110)

Variable	Frequency (n)	Percentage (%)
Type of OA		
Knee	71	64.55
Hip	24	21.82
Hand	15	13.64
Duration of OA (years)		
<5	39	35.45
5–10	44	40.00
>10	27	24.55
Severity (Kellgren–Lawrence Grade)		
Grade I	13	11.82
Grade II	33	30.00
Grade III	38	34.55
Grade IV	26	23.64

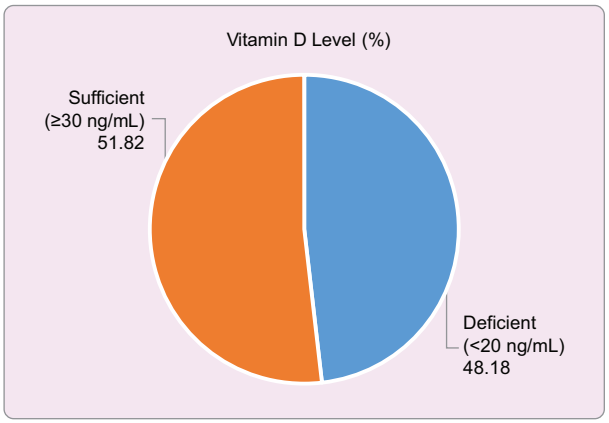

Figure 1: *Serum Vitamin D status among population (n=110)*

Table-III

Cardiovascular risk profile

Variable	Mean ± SD
Total Cholesterol (mg/dL)	210.5 ± 38.6
LDL Cholesterol (mg/dL)	132.4 ± 32.1
HDL Cholesterol (mg/dL)	141.2 ± 8.5
Triglycerides (mg/dL)	176.8 ± 45.2
Systolic BP (mmHg)	138.7 ± 18.3
Diastolic BP (mmHg)	86.5 ± 10.7
Fasting Blood Glucose (mmol/L)	6.8 ± 1.9

Table-IV

Association between vitamin d status and cardiovascular risk factors

Variable	Deficient (Mean ± SD)	Sufficient (Mean ± SD)	p-value
Total Cholesterol (mg/dL)	224.6 ± 36.5	197.8 ± 34.2	<0.001
LDL (mg/dL)	145.3 ± 30.7	120.5 ± 28.9	<0.001
HDL (mg/dL)	38.6 ± 7.9	43.8 ± 8.2	0.002
Triglycerides (mg/dL)	192.1 ± 42.8	162.3 ± 40.5	0.001
Systolic BP (mmHg)	144.2 ± 17.6	133.5 ± 18.1	0.003

Table-V

Cardiovascular risk categories by Vitamin D status

Cardiovascular Risk Level	Deficient (n=53)		Sufficient (n=57)		p-value
	n	%	n	%	
Low Risk	9	16.98	22	38.60	0.01
Moderate Risk	18	33.96	20	35.09	
High Risk	26	49.06	15	26.32	

Table-VI

Association of Vitamin D status with osteoarthritis severity

OA Severity	Deficient (n=53)		Sufficient (n=57)		p-value
	n	%	n	%	
Mild (Grade I–II)	16	30.19	30	52.63	0.02
Severe (Grade III–IV)	37	69.81	27	47.37	

Table-VII

Multivariable logistic regression for high cardiovascular risk

Variable	Adjusted Odds Ratio (AOR)	95% CI	p-value
Vitamin D Deficiency	2.9	1.4–6.1	0.004
Severe OA (Grade III–IV)	2.5	1.2–5.1	0.01
Age >60 years	2.2	1.1–4.5	0.03
Obesity	2.4	1.2–5.0	0.01
Hypertension	3.1	1.5–6.4	0.002a

Discussion

Patients with osteoarthritis frequently exhibit altered serum vitamin D levels, and accumulating evidence suggests that vitamin D deficiency may be linked with an increased cardiovascular risk profile, potentially through its effects on inflammatory pathways, endothelial function, and metabolic regulation [17]. This study evaluated the association between serum vitamin D levels and cardiovascular risk among patients with osteoarthritis (OA), focusing on metabolic risk clustering, OA severity, and vitamin D status. In this study, 23.64% of participants were aged <50 years, while 38.18% were in the 50–60 years group and 38.18% were aged >60 years. Females constituted 60.00% and males 40.00% of the study population. Regarding BMI, 24.55% were normal weight, 43.64% were overweight, and 31.82% were obese. Hypertension was present in 53.64% and diabetes mellitus in 41.82% of participants, while 28.18% were current smokers. These findings are consistent with previous epidemiological evidence showing that OA predominantly affects older individuals and females, with a strong association with overweight, obesity, and cardiometabolic comorbidities. Cross et al. & Yang et al. reported that OA prevalence increases with age and is strongly linked with obesity and metabolic disorders [18, 19]. Similarly, Dickson et al. highlighted obesity as a central shared risk factor between OA and cardiovascular disease due to systemic inflammation and metabolic dysfunction, supporting the pattern observed in this study [20]. Knee OA was the most common type (64.55%), followed by hip OA (21.82%) and hand OA (13.64%). Regarding duration of disease, 35.45% had OA for <5 years, 40.00% for 5–10 years, and 24.55% for >10 years. In terms of radiological severity, 11.82% had Grade I, 30.00% Grade II, 34.55% Grade III, and 23.64% Grade IV OA. These findings are consistent with Qiao et al. & Swailem et al. who reported knee OA as the most prevalent form of osteoarthritis globally [21,22]. In this study, 48.18% of participants were vitamin D deficient, while 51.82% had sufficient vitamin D levels. This finding aligns with Swailem et al., who reported a high prevalence of vitamin D insufficiency among patients with osteoarthritis [22]. The mean lipid and metabolic parameters in this study showed elevated total cholesterol (210.5 ± 38.6 mg/dL), LDL cholesterol (132.4 ± 32.1 mg/dL), reduced HDL cholesterol (41.2 ± 8.5 mg/dL), elevated triglycerides (176.8 ± 45.2 mg/dL), increased systolic blood pressure (138.7 ± 18.3 mmHg), diastolic blood pressure (86.5 ± 10.7 mmHg), and fasting blood glucose (6.8 ± 1.9 mmol/L). These findings are consistent with Ren et al., who reported that patients with OA frequently exhibit features of metabolic syndrome, including dyslipidemia, hypertension, and impaired glucose metabolism [23]. Vitamin D–deficient patients had significantly higher total cholesterol (224.6 ± 36.5 mg/dL) compared to those with sufficient levels (197.8 ± 34.2 mg/dL) ($p<0.001$). LDL cholesterol was higher in the deficient group (145.3 ± 30.7 mg/dL) compared to the sufficient group (120.5 ± 28.9 mg/dL) ($p<0.001$). HDL cholesterol was lower in the deficient group (38.6 ± 7.9 mg/dL) than in the sufficient group (43.8 ± 8.2 mg/dL) ($p=0.002$). Triglycerides were higher in vitamin D–deficient patients (192.1 ± 42.8 mg/dL) compared to sufficient patients (162.3 ± 40.5 mg/dL) ($p=0.001$). Systolic blood pressure was also higher in deficient individuals (144.2 ± 17.6 mmHg) compared to sufficient individuals (133.5 ± 18.1 mmHg) ($p=0.003$). These results are supported by Wang et al., who demonstrated inverse associations between serum 25(OH)D levels and cardiovascular risk factors, including lipid abnormalities and hypertension [24]. Among vitamin D–deficient patients, 16.98% had low cardiovascular risk, 33.96% had moderate risk, and 49.06% had high cardiovascular risk. In contrast, among vitamin D–sufficient patients, 38.60% had low risk, 35.09% had moderate risk, and 26.32% had high risk ($p=0.01$). These findings are in agreement with Giovannucci et al., who reported that low vitamin D status is associated with a higher incidence of cardiovascular events in longitudinal cohort analysis [25]. Among vitamin D–deficient patients, 30.19% had mild OA (Grade I–II), while 69.81% had

severe OA (Grade III–IV). In contrast, among vitamin D–sufficient patients, 52.63% had mild OA and 47.37% had severe OA (p=0.02). These findings are consistent with Zhang et al., who reported that lower vitamin D levels are associated with greater radiographic progression of knee OA [26]. Similarly, Zheng et al. found that vitamin D insufficiency is linked with increased OA severity and worse clinical outcomes, supporting the structural association observed in this study [27]. In multivariable analysis, vitamin D deficiency was independently associated with high cardiovascular risk (AOR 2.9, 95% CI 1.4–6.1, p=0.004). Severe OA (Grade III–IV) (AOR 2.5, 95% CI 1.2–5.1, p=0.01), age >60 years (AOR 2.2, 95% CI 1.1–4.5, p=0.03), obesity (AOR 2.4, 95% CI 1.2–5.0, p=0.01), and hypertension (AOR 3.1, 95% CI 1.5–6.4, p=0.002) were also significant predictors. These findings are consistent with Wang et al., who reported that vitamin D deficiency independently predicts cardiovascular disease after adjusting for traditional risk factors [24]. Pilz et al. also demonstrated that low vitamin D levels are associated with increased cardiovascular mortality independent of obesity and hypertension, supporting the robustness of the adjusted model in this study [28].

Limitations of the study: This study has several limitations. Its cross-sectional design limits the ability to establish causal relationships between vitamin D deficiency and cardiovascular risk. The sample size (n=110) was relatively small and derived from a single center, which may restrict generalizability. Seasonal variation in vitamin D levels and dietary intake were not assessed. Additionally, residual confounding factors such as physical activity and sun exposure could not be fully controlled. Longitudinal, multicenter studies are needed to confirm these findings.

Conclusion

This study demonstrates a significant association between serum vitamin D deficiency and increased cardiovascular risk among patients with osteoarthritis. Individuals with deficient vitamin D levels exhibited significantly higher total cholesterol (224.6 ± 36.5 mg/dL vs 197.8 ± 34.2 mg/dL), LDL (145.3 ± 30.7 mg/dL vs 120.5 ± 28.9 mg/dL), triglycerides (192.1 ± 42.8 mg/dL vs 162.3 ± 40.5 mg/dL), and systolic blood pressure (144.2 ± 17.6 mmHg vs 133.5 ± 18.1 mmHg), along with lower HDL levels (38.6 ± 7.9 mg/dL vs 43.8 ± 8.2 mg/dL). Vitamin D deficiency independently predicted high cardiovascular risk (AOR 2.9, 95% CI 1.4–6.1, p=0.004). These findings highlight the importance of assessing vitamin D status in osteoarthritis patients to improve comprehensive cardiovascular risk management.

Funding: No funding sources

Conflict of interest: None declared

References

1. Sen R, Hurley JA. Osteoarthritis. 2023 Feb 20. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan–. PMID: 29493951.
2. Courties A, Kouki I, Soliman N, Mathieu S, Sellam J. Osteoarthritis year in review 2024: epidemiology and therapy. Osteoarthritis and cartilage. 2024 Nov 1;32(11):1397-404.
3. Wu R, Guo Y, Chen Y, Zhang J. Osteoarthritis burden and inequality from 1990 to 2021: a systematic analysis for the global burden of disease Study 2021. Scientific Reports. 2025 Mar 10;15(1):8305.
4. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. Bulletin of the world health organization. 2003 Sep;81(9): 646-56.
5. Robinson WH, Lepus CM, Wang Q, Raghu H, Mao R, Lindstrom TM, Sokolove J. Low-grade inflammation as a key mediator of the pathogenesis of osteoarthritis. Nature Reviews Rheumatology. 2016 Oct;12(10):580-92.
6. Liu B, Zhang M, Gao L, Yang H. Targeting inflammation-metabolism crosstalk: current status and challenges of novel therapeutic strategies for osteoarthritis. Frontiers in Medicine. 2025;12:1754693.
7. Wang H, Bai J, He B, Hu X, Liu D. Osteoarthritis and the risk of cardiovascular disease: a meta-analysis of observational studies. Scientific reports. 2016 Dec 22;6(1):39672.
8. Hall AJ, Stubbs B, Mamas MA, Myint PK, Smith TO. Association between osteoarthritis and cardiovascular disease: systematic review and meta-analysis. European journal of preventive cardiology. 2016 Jun;23(9):938-46.
9. Magnusson K, Turkiewicz A, Dell'Isola A, Englund M. Shared genetic factors between osteoarthritis and cardiovascular disease may underlie common etiology. Nature communications. 2024 Nov 6;15(1):9569.
10. Mathieu S, Couderc M, Tournadre A, Soubrier M. Cardiovascular profile in osteoarthritis: a meta-analysis of cardiovascular events and risk factors. Joint Bone Spine. 2019 Nov 1;86(6):679-84.
11. Shifrin A. Brief overview of calcium, vitamin D, parathyroid hormone metabolism, and calcium-sensing receptor function. Advances in Treatment and Management in Surgical Endocrinology. 2020 Jan 1:63-70.
12. Dey SK, Kumar S, Rani D, Maurya SK, Banerjee P, Verma M, Senapati S. Implications of vitamin D deficiency in systemic inflammation and cardiovascular health. Critical reviews in food science and nutrition. 2024 Nov 5;64(28):10438-55.
13. Kim DH, Meza CA, Clarke H, Kim JS, Hickner RC. Vitamin D and endothelial function. Nutrients. 2020 Feb 22;12(2):575.
14. Della Nera G, Sabatino L, Gaggini M, Gorini F, Vassalle C. Vitamin D determinants, status, and antioxidant/anti-inflammatory-related effects in cardiovascular risk and disease: not the last word in the controversy. Antioxidants. 2023 Apr 18;12(4):948.

15. Hibler EA, Molmenti CL, Dai Q, Kohler LN, Anderson SW, Jurutka PW, Jacobs ET. Physical activity, sedentary behavior, and vitamin D metabolites. Bone. 2016 Feb 1;83:248-55.

16. Manoy P, Anomasiri W, Yuktanandana P, Tanavalee A, Ngarmukos S, Tanpowpong T, Honsawek S. Elevated serum leptin levels are associated with low vitamin D, sarcopenic obesity, poor muscle strength, and physical performance in knee osteoarthritis. Biomarkers. 2017 Nov 17;22(8):723-30.

17. Amirkhizi F, Asoudeh F, Hamedi-Shahraki S, Asghari S. Vitamin D status is associated with inflammatory biomarkers and clinical symptoms in patients with knee osteoarthritis. The Knee. 2022 Jun 1;36:44-52.

18. Cross M, Smith E, Hoy D, Nolte S, Ackerman I, Fransen M, Bridgett L, Williams S, Guillemin F, Hill CL, Laslett LL. The global burden of hip and knee osteoarthritis: estimates from the global burden of disease 2010 study. Annals of the rheumatic diseases. 2014 Jul 1;73(7):1323-30.

19. Yang S, Zhou L, Gong W, Guo B, Wang L. Global burden of osteoarthritis from 1990 to 2019 attributable to high body mass index. Archives of Medical Science: AMS. 2024 Apr 28;20(6):1841.

20. Dickson BM, Roelofs AJ, Rochford JJ, Wilson HM, De Bari C. The burden of metabolic syndrome on osteoarthritic joints. Arthritis research & therapy. 2019 Dec 16;21(1):289.

21. Qiao L, Li M, Deng F, Wen X, Deng H, Xue Z, Zhou J, Lin J, Amhare AF, Xiang R, Fan X. Epidemiological trends of osteoarthritis at the global, regional, and national levels from 1990 to 2021 and projections to 2050. Arthritis Research & Therapy. 2025 Oct 28;27(1):199.

22. Swailem K, Sadhan M, Al-Mashramah GA, Saghir MA. Association between vitamin D deficiency, inflammatory markers, and knee osteoarthritis: a retrospective study. Journal of Orthopaedic Surgery and Research. 2025 Aug 23;20(1):794.

23. Ren HC, Wang YC, Cheng JB, Tao HC, Feng H, Feng ML. Revisiting the Subtle Relationship Between Metabolic Syndrome and Osteoarthritis. Journal of Inflammation Research. 2026 Dec 31:597686.

24. Wang L, Song Y, Manson JE, Pilz S, März W, Michaëlsson K, Lundqvist A, Jassal SK, Barrett-Connor E, Zhang C, Eaton CB. Circulating 25-hydroxy-vitamin D and risk of cardiovascular disease: a meta-analysis of prospective studies. Circulation: Cardiovascular Quality and Outcomes. 2012 Nov;5(6):819-29.

25. Giovannucci E. Vitamin D and cardiovascular disease. Current atherosclerosis reports. 2009 Nov;11(6):456-61.

26. Zhang FF, Driban JB, Lo GH, Price LL, Booth S, Eaton CB, Lu B, Nevitt M, Jackson B, Garganta C, Hochberg MC. Vitamin D deficiency is associated with progression of knee osteoarthritis. The Journal of nutrition. 2014 Dec 1;144(12):2002-8.

27. Zheng S, Jin X, Cicuttini F, Wang X, Zhu Z, Wluka A, Han W, Winzenberg T, Antony B, Aitken D, Blizzard L. Maintaining vitamin D sufficiency is associated with improved structural and symptomatic outcomes in knee osteoarthritis. The American Journal of Medicine. 2017 Oct 1;130(10):1211-8.

28. Wang L, Song Y, Manson JE, Pilz S, März W, Michaëlsson K, Lundqvist A, Jassal SK, Barrett-Connor E, Zhang C, Eaton CB. Circulating 25-hydroxy-vitamin D and risk of cardiovascular disease: a meta-analysis of prospective studies. Circulation: Cardiovascular Quality and Outcomes. 2012 Nov;5(6):819-29.

29. Pilz S, Tomaschitz A, März W, Drechsler C, Ritz E, Zittermann A, Cavalier E, Pieber TR, Lappe JM, Grant WB, Holick MF. Vitamin D, cardiovascular disease and mortality. Clinical endocrinology. 2011 Nov;75(5):575-84.