

Association of Frailty and Preoperative Vitamin D Status with Postoperative Outcomes After Fragility Hip Fracture Surgery

Natnaree Bunsiraphatsorn¹; Napawan Somboon²; Chittima Tiyaapun²; Thawee Songpatanasilp²



Natnaree Bunsiraphatsorn

¹ Prevention and Wellness Clinic, BDMS

Wellness Clinic, Bangkok, Thailand

² Department of Orthopedics, Bangkok International Hospital, Bangkok, Thailand

* Address Correspondence to author:
Natnaree Bunsiraphatsorn, MD
BDMS Wellness Clinic
2/4 Wireless Rd.,
Lumpini, Pathumwan,
Bangkok 10330, Thailand.
email: natnaree.bu@bdmswellness.com

Received: July 8, 2026
Revision received: August 7, 2026
Accepted after revision: August 16, 2026
BKK Med J 2026;22(2): 126-132.
DOI: 10.31524/bkkmedj.2026.21.007
www.bangkokmedjournal.com

Abstract

OBJECTIVES: This study aimed to evaluate the associations of preoperative vitamin D status with postoperative outcomes in geriatric hip fracture patients managed within an integrated orthogeriatric pathway.

MATERIALS AND METHODS: This retrospective observational cohort study included 549 patients (aged ≥ 60 years) who underwent surgery for fragility hip fractures at Bangkok Hospital Headquarters between 2016 and 2025. A sub-analysis was conducted on 334 patients with available preoperative serum 25-hydroxyvitamin D (25(OH)D) levels. Key variables included age, Charlson Comorbidity Index (CCI), and prefracture frailty assessed using the Clinical Frailty Scale (CFS). The primary outcome was overall postoperative complications.

RESULTS: The mean age was 79.9 years, and 69.0% of participants were female. Frailty assessment showed that 48.8% were fit (CFS ≤ 3), 31.1% were vulnerable (CFS 4–5), and 20.0% were frail (CFS ≥ 6). Among 334 patients with available preoperative 25(OH)D measurements, vitamin D deficiency (VDD; < 20 ng/mL) was present in 46.4%. Overall postoperative complications occurred in 184 patients (55.1%), including 93/155 (60.0%) in the VDD group and 91/179 (50.8%) in the non-deficient group ($p = 0.117$). Lower vitamin D levels were significantly associated with higher comorbidity burden ($p = 0.033$) and greater frailty ($p = 0.012$), but not with overall postoperative complications or delirium (all $p > 0.05$).

CONCLUSION: While frailty remains an important clinical consideration in early postoperative vulnerability, preoperative vitamin D status may serve as a biochemical marker of underlying physiological vulnerability. The lack of association between VDD and short-term outcomes in this cohort suggests that vitamin D status alone may not predict acute postoperative outcomes. Nevertheless, routine assessment and correction of vitamin D remain important for long-term musculoskeletal health, mobility recovery, and secondary fracture prevention within the Fracture Liaison Service (FLS) framework.

Keywords: fragility hip fracture, Clinical Frailty Scale (CFS), vitamin D deficiency (VDD), orthogeriatric pathway, postoperative complications.

Fragility hip fractures represent the most severe complication of osteoporosis and constitute a global public health crisis, characterized by profound morbidity, functional decline, and excess mortality in the older population.¹⁻³ Projections suggest that 1 in 3 women and 1 in 6 men will sustain a hip fracture by their ninth decade, with the incidence rising exponentially after age 75.3 While standardized orthogeriatric pathways have been implemented internationally to improve multidisciplinary care and contemporary outcome data from mature systems, particularly in Thailand, remain limited.^{1,3}

The prognosis for these patients is not determined by chronological age alone but is primarily governed by frailty, defined as a state of reduced physiological reserve and increased vulnerability to stressors.^{4,5}

The Clinical Frailty Scale (CFS) has emerged as a robust tool for risk stratification, with higher scores consistently predicting 30-day survival, postoperative complications, and institutionalization.⁵ Furthermore, surgical timing is a critical modifiable determinant; procedures delayed beyond 48 hours are significantly associated with an increased incidence of postoperative complications and delirium, which remains a frequent and severe neurological complication in this population.^{6,7}

Vitamin D plays a foundational role in the pathophysiology of hip fractures through its classical function in maintaining calcium homeostasis and bone mineralization.^{8,9} Beyond its skeletal effects, vitamin D exerts pleiotropic actions on the musculoskeletal system due to the wide distribution of vitamin D receptors throughout skeletal muscle tissue.^{10,11} Consequently, VDD is directly linked to myopathy, impaired postural balance, and an increased risk of falls, all of which serve as immediate precursors to skeletal fractures.¹⁰⁻¹²

The prevalence of VDD in the geriatric population is increasingly recognized as a “stealthy epidemic”.¹³ Reported rates of deficiency range from 60% to over 80% in patients presenting with acute hip fractures.^{3,13} Even in tropical regions such as Thailand, where sunlight is abundant, data indicate a high prevalence of vitamin D insufficiency reaching 38.7% among elderly nursing home residents, underscoring that geographical location does not grant immunity from deficiency due to age-related physiological vulnerabilities.¹⁴ This is partly explained by age-related physiological changes, such as a four-fold reduction in the skin’s capacity for vitamin D synthesis compared to younger individuals.¹¹

VDD is one of the most common yet potentially modifiable risk factors for osteoporosis and fragility hip fractures in older adults.^{9,15} Aging is associated with reduced cutaneous vitamin D synthesis, limited sunlight exposure, inadequate dietary intake, impaired intestinal absorption, declining renal activation of vitamin D, obesity, chronic kidney disease, liver disease, and the use of medications such as glucocorticoids and anticonvulsants, all of which contribute to low serum 25(OH)D concentrations. VDD results in secondary hyperparathyroidism, accelerated bone loss, impaired muscle strength, and an increased risk of falls and fractures. Globally, VDD affects approximately one billion people, with older adults representing one of the highest-risk population.^{16,17} Among patients presenting with fragility hip fractures, the prevalence of VDD has consistently been reported between 46% and 92%, while a recent Thai study demonstrated VDD (< 20 ng/mL) in 57.4% and vitamin D inadequacy (< 30 ng/mL) in 86.1% of elderly patients with osteoporotic hip fractures¹⁸, highlighting the substantial burden of hypovitaminosis D in this population. This study aimed to evaluate the associations of preoperative vitamin D status with postoperative outcomes in geriatric hip fracture patients managed within an integrated orthogeriatric pathway.

Materials and methods

This retrospective observational cohort study included consecutive patients aged ≥ 60 years who underwent surgery for fragility hip fractures at Bangkok Hospital Headquarters, Thailand, between January 1, 2016, and December 31, 2025. Hip fractures were identified using ICD-10 codes S72.0, S72.1, and S72.2 as inclusion criteria. Patients with high-energy trauma, pathological or periprosthetic fractures, non-operative management, previous surgery at another institution, or incomplete records were excluded. The study was approved by the Institutional Review Board, and the requirement for informed consent was waived due to the retrospective use of anonymized data.

Clinical data were retrospectively extracted from the electronic medical record, hospital fracture registry, picture archiving and communication system (PACS), and anesthesia information system. Of the total cohort, preoperative serum 25(OH)D data were available for 334 patients (60.8%), who formed the sub-analysis group for vitamin D-related outcomes. Collected variables included age, sex, fracture type, Charlson Comorbidity Index (CCI), pre-fracture frailty assessed using the 9-point Clinical Frailty Scale (CFS) within 48 hours of admission, and admission serum 25(OH)D level.^{19,22} Postoperative outcomes and complications were retrospectively identified using the corresponding ICD-10 diagnostic codes recorded in the electronic medical record. The primary outcome was at least one postoperative complication during the index hospitalization. Secondary outcomes included postoperative delirium, individual postoperative complications, length of hospital stay and one-year mortality.

Statistical analyses were performed using RStudio. Continuous variables were summarized as mean $\pm$ standard deviation or median (interquartile range), and categorical variables as frequencies and percentages.

Group comparisons were performed using the Wilcoxon rank-sum or Kruskal–Wallis test for continuous variables and the chi-square test for categorical variables. Statistical significance was defined as a two-sided p value < 0.05.

Results

Among 549 patients who underwent surgery for fragility hip fractures, the mean age was 79.9 years (range, 60–100 years), and 71.4% were aged ≥ 75 years. Women accounted for 69.0% of the cohort. High comorbidity burden (CCI ≥ 6) was present in 45.0% of patients, while frailty assessment showed that 48.8% were classified as fit (CFS ≤ 3), 31.1% as vulnerable (CFS 4–5), and 20.0% as frail (CFS ≥ 6). Femoral neck fractures treated with arthroplasty accounted for 57.0% of cases, whereas 43.0% underwent fixation for trochanteric fractures. The mean length of hospital stay was 12.3 ± 12.9 days as seen in Table 1.

Overall postoperative complications occurred in 280 of 549 patients (51.0%). Postoperative complications included urinary tract infection (33.7%) as the most frequent, followed by delirium (19.1%), pneumonia (8.4%), pressure sores (3.5%), In-hospital mortality occurred in 0.7% of patients, and 1-year mortality occurred in 1.6%. Overall postoperative complication rates increased across age groups, as shown in Table 2.

Vitamin D measurements were available in 334 patients. Nearly half of this study (46.4%) had VDD (<20 ng/mL), while 53.6% had serum vitamin D levels ≥ 20 ng/mL. The mean serum calcium concentration was 8.5 ± 0.8 mg/dL as Table 3.

The mean serum vitamin D level was 22.2 ± 11.3 ng/mL. Vitamin D levels did not differ significantly across age groups ($p = 0.054$). However, levels were significantly lower among patients with higher comorbidity burden ($p = 0.033$) and differed across frailty categories ($p = 0.012$), with the lowest mean level observed in patients with CCI ≥ 6 (20.6 ± 11.0 ng/mL) and those with CFS 4–5 (20.2 ± 11.0 ng/mL) as seen in Table 4.

Compares postoperative outcomes according to vitamin D status. No significant differences were observed between patients with and without VDD in overall postoperative complications, delirium, urinary tract infection, pneumonia, pressure sores, length of hospital stay, in-hospital mortality, or 1-year mortality (all $p > 0.05$), as seen in Table 5.

Discussion

This study evaluated the associations of frailty and preoperative vitamin D status with postoperative outcomes in older adults undergoing fragility hip fracture surgery within an integrated orthogeriatric pathway. The principal findings

Table 1: Baseline Characteristics of Surgical Geriatric Hip Fracture Patients (2016–2025) (n = 5491).

Characteristic	n (%)
Age (years)	
Mean	79.9
Min-Max	60 - 100
Age group (years)	
< 65	26 (4.7)
65 - 74	131 (23.9)
75 - 84	208 (37.9)
≥ 85	184 (33.5)
Sex	
Female	379 (69.0)
Male	170 (31.0)
Charlson Comorbidity Index (CCI)	
Low: ≤ 3	79 (14.4)
Moderate: 4 – 5	223 (40.6)
High: ≥ 6	247 (45.0)
Clinical Frailty Scale (CFS)	
Fit: ≤ 3	268 (48.8)
Vulnerable: 4 – 5	171 (31.2)
Frail: ≥ 6	110 (20.0)
Fracture & Operation Type	
Neck (Arthroplasty)	313 (57.0)
Trochanteric (Fixation)	236 (43.0)
Length of stay (days)	
Mean $\pm$ SD	12.3 ± 12.9
Min - Max	2-125

Note: ¹Continuous variables: mean $\pm$ SD | median (IQR). CFS = Clinical Frailty Scale (1–9; higher = frailer)

Table 2: Postoperative Complications and Outcomes by Age Group

Characteristic	Overall n = 549 ¹	< 65 n = 26 ¹	65 - 74 n = 131 ¹	75 - 84 n = 208 ¹	≥ 85 n = 184 ¹	p-value ²
Overall complication	280 (51.0%)	7 (26.9%)	46 (35.1%)	104 (50.0%)	123 (66.8%)	< 0.001*
UTI	185 (33.7)	2 (7.7)	34 (26.0)	67 (32.2)	82 (44.6)	< 0.001*
Delirium	105 (19.1)	1 (3.8)	4 (3.1)	44 (21.2)	56 (30.4)	< 0.001*
Pneumonia	46 (8.4)	2 (7.7)	8 (6.1)	9 (4.3)	27 (14.7)	0.002*
Pressure sore	19 (3.5)	0 (0.0)	3 (2.3)	6 (2.9)	10 (5.4)	0.281
Length of stay, days	12.3 ± 12.9	14.5 ± 16.0	13.0 ± 18.8	10.9 ± 7.2	12.9 ± 12.1	0.047*
In-hospital mortality	4 (0.72)	0 (0.0)	1 (0.76)	2 (0.96)	1 (0.54)	0.933
1-Year mortality	9 (1.64)	0 (0.0)	0 (0.0)	3 (1.44)	6 (3.26)	0.129

Note: ¹n (%); Mean $\pm$ SD, ²Pearson's Chi-squared test; Kruskal-Wallis rank sum test

Table 3: Vitamin D status (n=334).

Vitamin D status,	n (%)
Deficient (< 20 ng/mL)	155 (46.4)
Non-deficiency (≥ 20 ng/mL)	179 (53.6)
Calcium, mg/dL (8.5 to 10.5)	8.5 ± 0.8

Note: Vitamin D deficiency defined as < 20 ng/mL (Endocrine Society guidelines).

Association of Frailty and Preoperative Vitamin D Status with Postoperative Outcomes After Fragility Hip Fracture Surgery

Table 4: Serum vitamin D levels according to age group, comorbidity burden, and frailty status

Variable	Category	Vitamin D (ng/mL) mean $\pm$ SD	Min–max	p-value
Overall		22.2 $\pm$ 11.3	3.5 – 75.5	—
Age group	< 65 years	30.5 $\pm$ 15.8	10.6 – 65.4	0.054
	65 – 74 years	21.7 $\pm$ 11.4	3.5 – 75.1	
	75 – 84 years	22.9 $\pm$ 10.4	6.3 – 48.5	
	$\geq$ 85 years	20.9 $\pm$ 11.3	4.7 – 75.5	
CCI category	$\leq$ 3 (Low)	24.2 $\pm$ 12.5	6.6 – 75.1	0.033*
	4 – 5 (Moderate)	23.4 $\pm$ 11.1	3.5 – 65.4	
	$\geq$ 6 (High)	20.6 $\pm$ 11.0	4.5 – 75.5	
Clinical Frailty Scale	CFS $\leq$ 3	24.0 $\pm$ 11.6	—	0.012*
	CFS 4 – 5	20.2 $\pm$ 11.0	—	
	CFS $\geq$ 6	21.3 $\pm$ 10.7	—	

Table 5: Vitamin D Status and Outcomes (n = 334)

Characteristic	Deficient (< 20 ng/mL) n = 155 (n (%))	Non-deficiency ($\geq$ 20 ng/mL) n = 179, (n (%))	p-value ²
Overall complication	93 (60.0)	91 (50.8)	0.117
Delirium	42 (27.1)	36 (20.1)	0.169
UTI	63 (40.6)	62 (34.6)	0.309
Pneumonia	16 (10.3)	12 (6.7)	0.321
Pressure sore	4 (2.6)	5 (2.8)	> 0.999
Length of stay(days)	13.2 $\pm$ 13.6	12.1 $\pm$ 13.2	0.790
In-hospital mortality	1 (0.6)	1 (0.6)	> 0.999
1-Year mortality	4 (2.6)	2 (1.1)	0.554

were threefold. First, frailty was associated with early postoperative complications. Second, although VDD was common (46.4%), it was not associated with short-term postoperative outcomes. Third, vitamin D levels were associated with frailty and comorbidity burden, suggesting that vitamin D may reflect underlying physiological vulnerability.

Frailty represents reduced physiological reserve and is clinically relevant in older adults undergoing hip fracture surgery. In this cohort, 51.2% of patients were classified as vulnerable or frail according to the Clinical Frailty Scale (CFS $\geq$ 4), highlighting a substantial burden of pre-fracture vulnerability. Serum vitamin D levels differed significantly across frailty categories ($p = 0.012$); however, the observational design precludes causal inference.

Frailty has been consistently associated with adverse postoperative outcomes after hip fracture surgery, including complications, delirium, prolonged hospitalization, functional decline, and mortality.^{5,20} Incorporating the CFS into routine preoperative assessment may therefore help identify patients who require comprehensive geriatric assessment and individualized perioperative planning.^{20,22} In the present study, the observed postoperative outcomes should be interpreted alongside patients' baseline frailty and comorbidity burden. Prospective studies with standardized outcome assessment are needed to clarify the independent association between CFS category and postoperative outcomes in this population.

The Clinical Paradox of Vitamin D Prevalence

In contrast to the strong prognostic value of frailty, preoperative vitamin D status presented a clinical paradox. The reported prevalence of VDD in our study was 46.4%. While significantly lower than the 70% to 87% rates documented in many Western cohorts (e.g., 87% in Germany, 80% in the Netherlands) and other Asian hip fracture populations, this confirms that VDD remains a substantial clinical challenge even in tropical, sun-rich regions.²¹ We observed a significant inverse association where vitamin D levels tracked with frailty severity and comorbidity burden. These findings suggest that vitamin D status may serve as a biochemical marker of underlying physiological vulnerability.²¹

Short-Term Outcomes and the Role of Optimized Care

Our study found no significant association between VDD and short-term postoperative complications, delirium, or in-hospital mortality in the unadjusted comparisons. This null finding aligns with results from other high-quality orthogeriatric studies, such as a large French cohort of 1,197 patients, which similarly reported that comorbidities and functional status—rather than vitamin D—are the primary determinants of acute outcomes.²¹ This suggests that system-level care quality may be more critical than individual biochemical parameters in determining acute outcomes. These findings should be interpreted within the context of an integrated orthogeriatric pathway with standardized perioperative care and complication prevention.²²

Conversely, several international studies have reported positive associations between VDD and acute morbidity. For instance, a Norwegian registry study identified VDD as a risk factor for delirium and 30-day medical readmissions²³, while an Austrian study reported that preoperative 25(OH)D levels < 30 ng/mL were associated with a higher risk of early postoperative complications.²⁴ These discrepancies likely reflect methodological differences, including varying deficiency thresholds and the quality of perioperative care, which may modify the clinical expression of VDD.²¹

Long-Term Functional Recovery and Mortality

While vitamin D may not drive acute surgical events, external literature demonstrates more consistent associations with long-term functional and survival trajectories—domains not captured in our short-term analysis.^{21,25} Meta-analyses and rehabilitation studies indicate that sufficient vitamin D levels are important for bone healing and mobility recovery.^{25,26} Low levels have been linked to poorer 6-month Parker Mobility Scores and lower Barthel Index scores at discharge.^{21,26}

Furthermore, the impact on mortality appears more pronounced over longer time horizons. Studies from Brazil and the UK have documented that preoperative VDD is independently associated with increased 1-year and 2-year mortality risks.^{27,28} These long-term effects are biologically plausible; VDD triggers secondary hyperparathyroidism, which accelerates bone loss, and impairs muscle function through vitamin D receptors (VDR) distributed throughout skeletal muscle tissue.^{30,31} This dual impact increases the risk of subsequent falls and secondary fractures.^{30,32}

Clinical Implications for Orthogeriatric Management

The results of this study support a paradigm where system-level care quality is more critical for short-term outcomes than individual biochemical parameters.²¹ However, the high prevalence of deficiency—even in tropical regions—and its established link to long-term musculoskeletal health underscore the clinical importance of assessment.^{18,32,34} Correction of VDD should remain an important component of fracture liaison services (FLS) to support bone health and secondary prevention beyond the acute perioperative period.^{32,34} Although vitamin D levels may not directly impact short-term clinical outcomes, routine assessment remains highly recommended. Evaluating baseline vitamin D, calcium homeostasis, and underlying comorbidities is essential prior to initiating anti-osteoporosis therapy. This comprehensive approach facilitates robust secondary prevention of osteoporosis, which should be integrated with structured rehabilitation and fall prevention programs to effectively mitigate the risk of recurrent fractures. Future research should integrate frailty assessment with long-term functional monitoring to clarify the role of personalized supplementation strategies for this high-risk population.

Based on our study findings indicating that preoperative vitamin D levels were not significantly associated with acute complications within our integrated Orthogeriatric Pathway, the research team posits that serum 25(OH)D assessment remains “essential” and should be standard practice for all elderly individuals presenting with hip fractures. This evaluation can be initiated during the preoperative phase or upon early admission to establish the patient’s baseline status.^{22,32,33} Although abnormal vitamin D levels do not constitute an acute contraindication to surgery, if insufficiency or deficiency is detected, the team emphasizes the critical importance of implementing systematic replacement therapy and longitudinal follow-up in conjunction with postoperative physical therapy and rehabilitation.^{22,32} Consequently, the correction of VDD should be integrated as a primary objective within the Fracture Liaison Service (FLS) framework to enhance skeletal muscle mass, improve postural stability, and mitigate the risk of recurrent falls.^{33,34} Ultimately, vitamin D status has been associated with long-term survival and functional ambulatory recovery (over 1–2 years) in these patients, rather than merely with short-term acute outcomes.^{26–28} The correction of vitamin D status should be established as an important objective of Fracture Liaison Services (FLS) to support long-term bone health and secondary fracture prevention, regardless of its limited association with immediate surgical recovery.

In conclusion, frailty severity is an important clinical consideration in the assessment of early postoperative vulnerability after fragility hip fracture surgery. Preoperative vitamin D status may serve as a marker of biological vulnerability, although it was not associated with short-term postoperative outcomes in this cohort. Vitamin D assessment remains clinically important because of its established role in bone health, muscle function, and long-term recovery. These findings support the routine integration of frailty assessment for perioperative risk stratification, while emphasizing vitamin D screening and correction as key components of fracture liaison services and long-term secondary fracture prevention. Future prospective multicenter studies with long-term functional follow-up are warranted to clarify the interaction between frailty, vitamin D status, and patient outcomes.

Limitation

This study has several limitations. Preoperative serum 25(OH)D levels were available for only 334 patients, primarily because of practical barriers related to payment and insurance coverage, particularly among patients for whom vitamin D testing was not covered as part of urgent fracture care. Seasonal variation in 25(OH)D concentrations could not be evaluated because the timing of blood collection was not consistently available. In addition, the limited number of participants with severe VDD and acute outcome events precluded reliable analyses using alternative thresholds or modelling 25(OH)D as a continuous variable.

Patients who underwent vitamin D testing may not have been fully representative of the overall study population, potentially resulting in selection bias and underestimation of the true prevalence of VDD. Information on postoperative vitamin D supplementation, rehabilitation adherence, nutritional status, and other factors that could affect long-term recovery was also unavailable. Finally, given the observational design, the association between vitamin D status and postoperative outcomes should not be interpreted as causal.

Conclusion

Frailty was a common clinical feature among older adults undergoing surgery for fragility hip fractures, whereas VDD was not significantly associated with postoperative outcomes in this cohort. Despite the study limitations, the large cohort, standardized orthogeriatric care pathway, and routine frailty assessment provide useful real-world data on preoperative frailty, vitamin D status, and postoperative outcomes after fragility hip fracture surgery.

References

1. Rojviroj S, Visutipol B, Jisarojito S, et al. Geriatric hip fracture pathway in private hospital: early results. *J SEA Ortho* [Internet]. 2014 [cited 2026 March 15];38(3-4):57-62. Available from: <https://www.jseaortho.org/index.php/jsao/article/view/103>
2. Bischoff-Ferrari HA. Fragility fractures: the future epidemic and its challenges. *Skeletal Radiol*. 2013;42(11):1-2. doi: 10.1007/s00256-012-1549-4.
3. Royal College of Physicians. A broken hip—three steps to recovery: the 2024 National Hip Fracture Database report on 2023 [Internet]. London: Royal College of Physicians; 2024 [cited 2026 March 15]. Available from: <https://www.nhfd.co.uk/reportopen/NHFD-2024%2BAnnual%2BReport>
4. Rockwood K, Theou O. Clinical frailty scale. In: Ruiz JG, Theou O, editors. *Frailty: a multidisciplinary approach to assessment, management, and prevention*. Cham: Springer; 2024. p. 121-3. doi: 10.1007/978-3-031-57361-3_16
5. Ikram A, Norrish AR, Marson BA, et al. Can the Clinical Frailty Scale on admission predict 30-day survival, postoperative complications, and institutionalization in patients with fragility hip fracture? A cohort study of 1,255 patients. *Bone Joint J*. 2022;104-B(8):980-6. doi: 10.1302/0301-620X.104B8.BJJ-2020-1835.R2.
6. Seong YJ, Shin WC, Moon NH, et al. Timing of hip-fracture surgery in elderly patients: literature review and recommendations. *Hip Pelvis*. 2020;32(1):11-6. doi: 10.5371/hp.2020.32.1.11.
7. Yang Q, Fu J, Pan X, et al. A retrospective analysis of the incidence of postoperative delirium and the importance of database selection for its definition. *BMC Psychiatry*. 2023;23(1):88. doi: 10.1186/s12888-023-04576-4.
8. Wimalawansa SJ. Vitamin D: what clinicians need to know. *Sri Lanka J Diabetes Endocrinol Metab*. 2012;2(2):73-88. doi: 10.4038/sjdem.v2i2.4776
9. Winzenberg T, van der Mei I, Mason RS, et al. Vitamin D and the musculoskeletal health of older adults. *Aust Fam Physician*. 2012;41(3):92-99.
10. Cherniack EP, Levis S, Troen BR. Hypovitaminosis D: a widespread epidemic. *Geriatrics*. 2008;63(4):24-30.
11. Kruavit A, Chailurkit L, Thakkestian A, et al. Prevalence of vitamin D insufficiency and low bone mineral density in elderly Thai nursing home residents. *BMC Geriatr*. 2012;12:49. doi: 10.1186/1471-2318-12-49.
12. Thai Osteoporosis Foundation. Clinical practice guide for the care of osteoporosis. Bangkok: Chulalongkorn University Press; 2022.
13. Bischoff-Ferrari HA. Vitamin D in geriatric patients. *Internist (Berl)*. 2020;61(6):535-40. doi: 10.1007/s00108-020-00803-2.
14. Holick MF. Vitamin D deficiency. *N Engl J Med*. 2007;357:266-81. doi: 10.1056/NEJMra070553.
15. Pilz S, März W, Cashman KD, et al. Rationale and Plan for Vitamin D Food Fortification: A Review and Guidance Paper. *Front Endocrinol (Lausanne)*. 2018;9:373. doi: 10.3389/fendo.2018.00373
16. Hill TR, Aspray TJ. The role of vitamin D in maintaining bone health in older people. *Ther Adv Musculoskelet Dis*. 2017;9(4):89-95. doi: 10.1177/1759720X17692502.
17. Giustina A, Bouillon R, Dawson-Hughes B, et al. Vitamin D in the older population: a consensus statement. *Endocrine*. 2023;79(1):31-44. doi: 10.1007/s12020-022-03208-3.
18. Amphansap T, Wongthanakitcharoen P, Stitkitti N, et al. Prevalence and risk factors of vitamin D inadequacy among Thai elderly patients with osteoporotic hip fracture. *J Southeast Asian Med Res*. 2022.
19. Rockwood K, Song X, MacKnight C, et al. A global clinical measure of fitness and frailty in elderly people. *CMAJ*. 2005;173(5):489-95. doi: 10.1503/cmaj.050051.
20. Lv Q-B, Gao X, Liu X, et al. Vitamin D status and site-specific fracture pattern associations in older adults with fragility fractures: a cross-sectional analysis of 2543 patients. *Front Nutr*. 2026;13:1810545. doi: 10.3389/fnut.2026.1810545.

Acknowledgements

The authors would like to thank multidisciplinary health-care team involved in the care of patients with fragility hip fractures. We also acknowledge the clinical and research staff for their support in data collection and study coordination.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflicts of interest.

21. Dauny V, Thietart S, Cohen-Bittan J, et al. Association between vitamin D deficiency and prognosis after hip fracture surgery in older patients in a dedicated orthogeriatric care pathway. *J Nutr Health Aging*. 2022;26(4):324-31. doi: 10.1007/s12603-022-1762-3.
22. Charlson M, Szatrowski TP, Peterson J, et al. Validation of a combined comorbidity index. *J Clin Epidemiol*. 1994;47:1245-51. doi: 10.1016/0895-4356(94)90129-5.
23. Ingstad F, Solberg LB, Nordsletten L, et al. Vitamin D status and complications, readmissions, and mortality after hip fracture. *Osteoporos Int*. 2021;32(5):873-81. doi: 10.1007/s00198-020-05739-9.
24. Fink A, Puchwein P, Fahrleitner-Pammer A, et al. Increased early postoperative complication rate after osteoporotic hip fracture in patients with low 25(OH) vitamin D levels. *Nutrients*. 2024;16(12):1917. doi:10.3390/nu16121917.
25. Komasa P, Szwarc T, Kałwik M, et al. The impact of vitamin D3 levels on recovery and rehabilitation following surgical treatment of femoral neck fractures: a narrative review. *Int J Innov Technol Soc Sci*. 2025;3(47). doi: 10.31435/ijitss.3(47).2025.3562.
26. Di Monaco M, Castiglioni C, Di Carlo S, et al. Classes of vitamin D status and functional outcome after hip fracture: a prospective, short-term study of 1350 inpatients. *Eur J Phys Rehabil Med*. 2019;55(3):361-7. doi: 10.23736/S1973-9087.18.05191-2.
27. Guerra MTE, Wagner MB, Vargas A, et al. Low serum levels of vitamin D significantly increase the risk of death in older adults with hip fractures: a prospective cohort. *Rev Col Bras Cir*. 2022 Apr 1;49:e20223054. doi: 10.1590/0100-6991e-20223054.
28. Bayram JM, Kanesan H, Clement ND. Vitamin D deficiency in hip fracture patients is associated with an increased mortality risk. *Eur J Orthop Surg Traumatol*. 2024;35(1):33. doi: 10.1007/s00590-024-04162-8.
29. Bischoff-Ferrari HA. Vitamin D: its role in health and disease in older people. In: Michel JP, Beattie BL, Martin FC, et al., editors. *Oxford textbook of geriatric medicine*. 3rd ed. Oxford: Oxford University Press; 2017. doi: 10.1093/med/9780198701590.003.0061.
30. Capatina C, Carsote M, Poiana C, et al. Vitamin D deficiency and musculoskeletal function in the elderly. *Strength Cond J*. 2015;37(1):24-9. doi: 10.1519/SSC.0000000000000115.
31. Lips P. Vitamin D deficiency and secondary hyperparathyroidism in the elderly: consequences for bone loss and fractures and therapeutic implications. *Endocr Rev*. 2001;22(4):477-501. doi: 10.1210/edrv.22.4.0437.
32. Chevalley T, Brandi ML, Cavalier E, et al. How can the orthopedic surgeon ensure optimal vitamin D status in patients operated for an osteoporotic fracture? *Osteoporos Int*. 2021;32(10):1921-35. doi:10.1007/s00198-021-05957-9.
33. Wijnen H, Jansen M, Stalpers-Konijnenburg S, et al. Vitamine D-deficiëntie bij patiënten met een heupfractuur. *Ned Tijdschr Traumatol*. 2011;19(6):150-6. doi: 10.1007/s12506-011-0043-2.
34. Cianferotti L, Bifulco G, Caffarelli C, et al. Nutrition, Vitamin D, and Calcium in Elderly Patients before and after a Hip fracture and Their Impact on the Musculoskeletal System: A Narrative Review. *Nutrients*. 2024;16(11):1773. doi: 10.3390/nu16111773.