Prevalence of Vitamin D Deficiency and Low Energy Fractures: a Cross-Sectional Study

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Received: August 2025. Accepted: August 2025; Published: September/October, 2025.
Citation: Waleed Ali Alhirabi et al. Prevalence of Vitamin D Deficiency and Low Energy Fractures a Cross-Sectional Study. World Family Medicine September 2025; 23(6): 32 - 42. DOI: 10.5742/MEWFM.2025.805257886

Abstract

Background: Vitamin D plays a critical role in bone mineralization and musculoskeletal health. In regions such as Hail, Saudi Arabia, factors like sun exposure habits, clothing practices, and lifestyle may influence vitamin D levels and fracture risks. This study investigates the association between vitamin D levels, sun exposure patterns, and fracture characteristics among residents in the Hail region.

Methods: A cross-sectional study was conducted among 2,951 residents of the Hail region. Participants completed a structured questionnaire covering fracture history, sun exposure frequency and duration, clothing coverage, and vitamin D testing and levels. Among them, 1,342 individuals reported a history of bone fractures confirmed by X-ray. Descriptive statistics and chi-square tests were used to assess associations between variables using SPSS version 28, with significance set at $p < 0.05$.

Results: Out of 2,951 participants, 45.5% reported a history of confirmed bone fractures. The majority occurred between ages 6–10 years (30.0%), with falls being the most common cause (70.0%). Upper extremities were the most frequently fractured site (40.1%). Most participants with fractures had limited sun exposure; 65.1% for less than 10 minutes per day, and only 15.0% had daily exposure. Full body coverage was reported by 45.0%. Among those with fractures, 55.0% had never tested their vitamin D levels, and 66.7% of those tested had low levels (20–40 ng/mL). Morning sun exposure correlated significantly with normal vitamin D levels (75.0%), while full-body coverage and midday/sunset exposure were associated with deficiency ($p < 0.001$). Participants with normal vitamin D levels experienced fractures primarily between ages 6–10 and more than six years ago, while those with low vitamin D had broader and more recent fracture histories. Low vitamin D levels were significantly linked to lower limb fractures and falls, whereas normal levels correlated with upper limb and exercise-related fractures.

Conclusion: This study highlights a significant association between low vitamin D levels and recent, lower extremity fractures in the Hail population, especially among individuals with poor sun exposure and full-body clothing. Routine vitamin D testing and public awareness campaigns promoting early morning sun exposure and bone health education are recommended to reduce fracture risk in the region.

Keywords
Vitamin D deficiency, bone fractures, sun exposure, Saudi Arabia, orthopedic health, Hail region

Introduction

Bone fractures remain a significant global health concern, carrying substantial personal, societal, and economic consequences. This burden is particularly evident in individuals affected by osteoporosis or chronic conditions that compromise bone integrity, increasing their susceptibility to fractures from minor or low-impact trauma. Such injuries often result in diminished mobility, loss of independence, a decline in quality of life, and increased healthcare utilization and caregiver demands (1). While numerous studies have explored fracture epidemiology, many have not sufficiently examined the modifiable risk factors underlying these events. In response to this gap, large-scale epidemiological efforts such as the Global Burden of Disease (GBD) study have played a critical role in quantifying the prevalence, incidence, and disability burden of fractures. The 2019 iteration of the GBD offers comprehensive data across various age groups and regions, providing valuable insights to inform prevention and management strategies on national and global scales (2). In Saudi Arabia, particularly Hail region there remains a notable deficiency in research addressing the relationship between low-energy fractures and vitamin D deficiency, despite the well-established role of vitamin D in calcium homeostasis and bone metabolism (3,4). Low serum vitamin D levels are known to impair bone mineralization, potentially increasing fracture risk, particularly in populations already predisposed due to age, comorbidities, or limited sun exposure. Hip fractures are among the most serious types of fragility fractures, with studies indicating that up to 30% of affected individuals may die within a year of the injury, while many survivors endure long-term functional impairment and reduced quality of life (5,6). The World Health Organization defines fragility fractures as those occurring from minimal trauma—commonly in older adults—and attributes their rising incidence to factors such as aging populations, diabetes, obesity, polypharmacy, and social or environmental influences (7). Projections from high-income countries illustrate the scale of this issue. For example, in Sweden, the population aged 50 and above is expected to grow by 18% between 2010 and 2025, with a predicted 26% rise in fracture incidence during the same period (8). Epidemiological data consistently identify the distal radius, hip, ankle, and proximal humerus as the most frequently fractured sites, with distal radius fractures accounting for a considerable proportion in both pediatric and geriatric populations (9). This trend has been attributed to increased participation in physical activities among children and greater mobility in the elderly, alongside improved diagnostic practices. In Saudi Arabia, national estimates suggest that the incidence of hip fractures among adults aged 50 and older could increase nearly sevenfold by 2050 (10). While the overall risk of osteoporotic fractures may currently be lower than in some neighboring countries, this has been partly attributed to elevated all-cause mortality in the elderly population (11). Nevertheless, the escalating burden of fragility fractures underscores the urgent need for targeted prevention, including improved screening for risk factors such as vitamin D deficiency. This study aims to investigate the association between vitamin D deficiency and low-energy fractures in the Hail region of Saudi Arabia, where data remain limited. By better understanding this relationship, the research seeks to contribute to the development of evidence-based public health initiatives focused on fracture prevention and bone health optimization across the population.

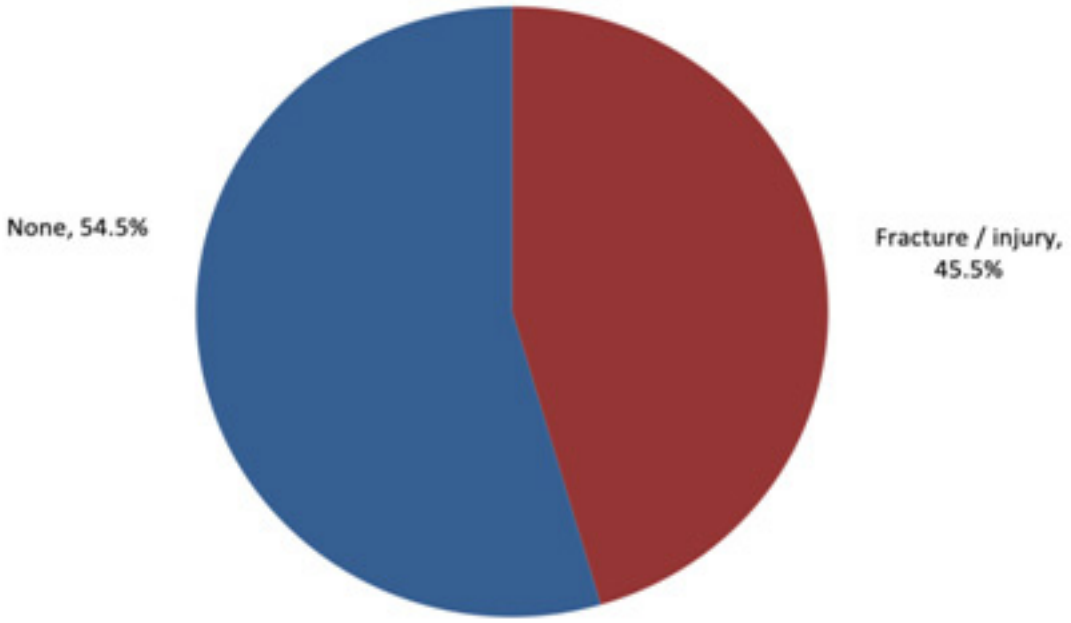
Methodology

This cross-sectional study was conducted using a structured, self-administered electronic questionnaire designed to collect information on demographics, fracture history, vitamin D status, lifestyle, and dietary habits. The questionnaire was previously validated and available in Arabic. The target population included residents of Hail Province, Saudi Arabia, from both urban and rural settings. Participants were selected from the general population, regardless of gender or nationality, provided they were currently living in the Hail region. Individuals who were not residing in Hail were excluded from participation. The sample size was calculated using the Raosoft sample size calculator, assuming a 95% confidence level and a 5% margin of error. Based on these parameters, a total of 3286 responses were deemed sufficient for statistical analysis and generalizability to the local population. After data collection, responses were reviewed for completeness, then coded and entered into IBM SPSS Statistics (version 22) for analysis. Descriptive statistics, including frequencies and percentages, were used to summarize all variables such as age, gender, fracture site and type, associated risk factors, and vitamin D-related behaviors (e.g., supplement use, sun exposure). To examine associations between vitamin D deficiency and the occurrence of low-energy fractures, inferential statistical tests were applied. Cross-tabulation was used to assess relationships between categorical variables, while Pearson's chi-square test (or exact probability tests when cell counts were small) was used to evaluate statistical significance. A p-value of less than 0.05 was considered statistically significant in all analyses.

Results

A total of 2,951 participants were included in the study. When asked whether they had ever experienced a bone fracture or injury (such as a hairline fracture) that was diagnosed and confirmed by X-ray, 1,342 participants (45.5%) reported having such a history, while 1,609 participants (54.5%) reported no history of confirmed bone fractures (Figure 1).

Figure 1. Participant History of X-ray Confirmed Bone Fractures in Hail Region, Saudi Arabia (N=2951)



Among the 1342 participants who reported having experienced a confirmed bone fracture in the Hail region, the majority had their fractures between the ages of 6–10 years (402; 30.0%), followed by 16–18 years (268; 20.0%), and 3–5 years and 11–15 years (each with 202 cases; 15.1%). As for the approximate duration of injury, the highest proportion of participants (470; 35.0%) reported having their fracture 6–10 years ago, followed by 1–3 weeks (268; 20.0%) and 1–2 years or less than a week (each around 10.0%). Fewer participants reported injuries that occurred 4–6 months ago (134; 10.0%), 1–3 months (67; 5.0%), 3–5 years (67; 5.0%), or 6–11 months ago (67; 5.0%). When examining the cause of fractures, falls were the most common cause, reported by 940 participants (70.0%), followed by injuries sustained while exercising (134; 10.0%), traffic accidents (134; 10.0%), objects falling on the body (67; 5.0%), and fights (67; 5.0%). About the site of fracture, the most frequently affected areas were the bones of the upper extremities including the humerus, ulna, and elbow reported by 538 participants (40.1%), followed by bones of the leg and foot (469; 34.9%). Fractures in the carpal bones (134; 10.0%), lower extremities such as the thigh and knee (134; 10.0%), and specifically the patella (67; 5.0%) were less common.

Table 1. Characteristics of Bone Fractures among Affected Participants in Hail Region, Saudi Arabia (N=1342)

Items	No	%
Age at fracture time		
Less than 1 year	67	5.0%
1-2 years	67	5.0%
3-5 years	202	15.1%
6-10 years	402	30.0%
11-15 years	202	15.1%
16-18 years	268	20.0%
19-25 years	134	10.0%
Approximate duration of injury?		
Less than 1 week	134	10.0%
1-3 weeks	268	20.0%
1-3 months	67	5.0%
4-6 months	134	10.0%
6-11 months	67	5.0%
1-2 years	135	10.1%
3-5 years	67	5.0%
6-10 years	470	35.0%
The reason for fracture		
Fall	940	70.0%
While exercising	134	10.0%
Traffic accident	134	10.0%
An object falling on the body	67	5.0%
During fight	67	5.0%
Site of fracture		
In the bones of the upper extremities (including the humerus, ulna and elbow)	538	40.1%
In the bones of the leg and foot (including the ankle, tibia, fibula, and toes)	469	34.9%
In the carpal bones (including the fingers and wrist)	134	10.0%
In the lower extremities (including the thigh and its joint, the knee, and the patella, commonly known as the kneecap)	134	10.0%
Patella	67	5.0%

Among the 1,342 participants who had experienced bone fractures in the Hail region (Table 2), the majority reported limited sun exposure. Considering the frequency, nearly half (670 participants; 49.9%) stated they were exposed to sunlight "sometimes" during the week, while 25.0% (336) reported rare exposure and 10.1% (135) were very rarely exposed. Only 15.0% (201) had daily sun exposure. Regarding duration, a significant proportion (873 participants; 65.1%) were exposed to sunlight for less than 10 minutes per day, while 402 (30.0%) reported exposure for 10–30 minutes, and only a small minority (67; 5.0%) had exposure for more than 30 minutes. As for the time of day, 603 participants (44.9%) were exposed to sun in the morning (before 10 AM), followed by 538 (40.1%) around midday, and 201 (15.0%) at sunset. When asked about clothing coverage, 604 participants (45.0%) reported covering their entire body, while 537 (40.0%) did not. A further 201 (15.0%) did not respond to this question.

Table 2. Patterns of Sun Exposure among Participants who Experienced Bone Fracture in the Hail Region, Saudi Arabia (N = 1342)

Sun exposure	No	%
Frequency of sun exposure /week		
Very rarely	135	10.1%
Rarely	336	25.0%
Sometimes	670	49.9%
Daily	201	15.0%
Sun exposure duration / time		
Less than 10 minutes	873	65.1%
10-30 minutes	402	30.0%
More than 30 minutes	67	5.0%
Approximate time of sun exposure?		
Morning (before 10 am)	603	44.9%
In the middle of the day (noon)	538	40.1%
At sunset	201	15.0%
Do you cover your whole body?		
Yes	604	45.0%
No	537	40.0%
No response	201	15.0%

Table 3 shows vitamin D assessment among 1,342 participants who had experienced bone fractures in the Hail region. Less than half (604 participants; 45.0%) reported that they had previously tested their vitamin D levels, while the majority (738; 55.0%) had never undergone vitamin D testing. Of those who had been tested, the time since the most recent test varied: about 33.3% (201 participants) had their vitamin D levels assessed 1–3 months ago, and a similar proportion (33.4%; 202 participants) had tested 3–5 years ago, suggesting that for many individuals, testing may not be recent enough to reflect current status. Smaller proportions reported testing done less than 1 week ago (67; 11.1%), 4–6 months ago (67; 11.1%), or 1–2 years ago (67; 11.1%). As for the reported levels, the majority (336 participants; 55.6%) indicated that their vitamin D levels were low (20–40 ng/mL). Another 11.1% (67) knew their levels were low but could not recall the exact values. Only 33.3% (201 participants) reported having normal vitamin D levels (41–80 ng/mL).

Table 3. Vitamin D Testing History and Reported Levels among Participants with Bone Fractures in the Hail Region (N = 1342)

Vitamin D	No	%
Have you had your vitamin D level tested?		
Yes	604	45.0%
No	738	55.0%
How long ago was your last test?		
Less than 1 week	67	11.1%
1-3 months	201	33.3%
4-6 months	67	11.1%
1-2 years	67	11.1%
3-5 years	202	33.4%
Level of assessed vitamin D		
Normal (41 to 80 ng/mL)	201	33.3%
Low (20 to 40 ng/mL)	336	55.6%
Low but do not remember value	67	11.1%

Table 4 assessed the relationship between sun exposure and vitamin D levels among participants in Hail, Saudi Arabia (N=1342). Regarding the frequency of sun exposure per week, individuals who reported being exposed to the sun "sometimes" had the highest proportion of normal vitamin D levels (60.0%), whereas all of those with "very rare," "rare," or "daily" exposure had low vitamin D levels, indicating a possible inconsistency in the effectiveness of sun exposure when it is either too infrequent or potentially at times when synthesis is suboptimal. For duration of sun exposure, participants exposed for less than 10 minutes daily showed a nearly equal distribution between normal (49.9%) and low (50.1%) vitamin D levels. In contrast, all of those exposed for 10–30 minutes had low vitamin D levels. When examining the approximate time of sun exposure, morning exposure (before 10 am) was significantly associated with normal vitamin D levels (75.0%), while noon and sunset exposure were linked to 100% low vitamin D levels. Regarding clothing habits, all participants who reported covering their entire body had low vitamin D levels (100%), while those who did not cover completely showed a better profile, with 39.9% having normal vitamin D. Also all of those who gave no response had normal levels, which may reflect a reporting or categorization bias. All exposure data showed a significant association with p-value less than 0.05.

The analysis of the relationship between vitamin D levels and bone fracture characteristics, several statistically significant associations were reported. With regard to age at the time of fracture, all participants with normal vitamin D levels (100.0%) reported having had fractures between the ages of 6–10 years, while no participants with normal vitamin D levels reported fractures at younger or older age ranges. In contrast, those with low vitamin D levels experienced fractures across a broader range: 33.5% at ages 3–5 years, 33.3% at 16–18 years, and 16.6% each at 11–15 and 6–10 years (p = 0.001). Regarding the approximate duration of injury, participants with normal vitamin D levels overwhelmingly reported fracture events that occurred 6–10 years ago (100.0%), whereas those with low vitamin D had a more recent history of injury, with 16.6% each reporting durations of less than 1 week, 1–3 months, 4–6 months, and 6–11 months, and 33.5% in the 6–10 year range (p = 0.001). As for the cause of fracture, 83.4% of those with low vitamin D reported falls as the main cause, compared to 66.7% among those with normal levels. Interestingly, 33.3% of participants with normal vitamin D levels reported fractures occurring while exercising, while none with low vitamin D did. Fractures due to fights were reported only among the vitamin D–deficient group (16.6%) (p = 0.001). Considering fracture sites, those with normal vitamin D were more likely to have injuries in the upper extremities (66.7%) and carpal bones (33.3%), while those with low vitamin D had a higher occurrence of fractures in the leg and foot bones (49.9%) and upper extremities (50.1%), with no reported carpal fractures (p = 0.001).

Table 4. The relation between Vitamin D Level and Participants' Sun Exposure in Hail, Saudi Arabia (N=1342)

Sun exposure	Level of assessed vitamin D				p-value
	Normal		Low		
	No	%	No	%	
Frequency of sun exposure /week					
Very rarely	0	0.0%	68	100.0%	.001*
Rarely	0	0.0%	134	100.0%	
Sometimes	201	60.0%	134	40.0%	
Daily	0	0.0%	67	100.0%	
Sun exposure duration / time					
Less than 10 minutes	201	49.9%	202	50.1%	.001*
10-30 minutes	0	0.0%	201	100.0%	
Approximate time of sun exposure?					
Morning (before 10 am)	201	75.0%	67	25.0%	.001*
In the middle of the day (noon)	0	0.0%	202	100.0%	
At sunset	0	0.0%	134	100.0%	
Do you cover your whole body?					
Yes	0	0.0%	201	100.0%	.001*
No	134	39.9%	202	60.1%	
No response	67	100.0%	0	0.0%	

P: Exact Probability test
* P < 0.05 (significant)

Table 5. The relation between Vitamin D Level and Bone Fracture Data in Hail, Saudi Arabia (N=1342)

Factors	Level of assessed vitamin D				p-value
	Normal		Low		
	No	%	No	%	
Age at fracture time					
3-5 years	0	0.0%	135	33.5%	.001*
6-10 years	201	100.0%	67	16.6%	
11-15 years	0	0.0%	67	16.6%	
16-18 years	0	0.0%	134	33.3%	
Approximate duration of injury?					
Less than 1 week	0	0.0%	67	16.6%	.001*
1-3 months	0	0.0%	67	16.6%	
4-6 months	0	0.0%	67	16.6%	
6-11 months	0	0.0%	67	16.6%	
6-10 years	201	100.0%	135	33.5%	
The reason for fracture					
Fall	134	66.7%	336	83.4%	.001*
While exercising	67	33.3%	0	0.0%	
During fight	0	0.0%	67	16.6%	
Site of fracture					
In the bones of the upper extremities (including the humerus, ulna and elbow)	134	66.7%	202	50.1%	.001*
In the carpal bones (including the fingers and wrist)	67	33.3%	0	0.0%	
In the bones of the leg and foot (including the ankle, tibia, fibula, and toes)	0	0.0%	201	49.9%	

P: Exact Probability test
* P < 0.05 (significant)

Discussion

This study assessed the relationship between vitamin D deficiency and low-energy fractures in the Hail region of Saudi Arabia, involving a large sample of participants. A significant number of individuals reported a history of fractures, with most occurring during childhood and adolescence, particularly between ages 6–10 and 16–18. Falls were the leading cause of fractures, followed by exercise-related injuries and traffic accidents. The upper extremities, including the humerus and elbow, were the most commonly affected sites, while lower extremity fractures were less frequent.

These findings are consistent with previous research showing the high prevalence of fractures in younger age groups, likely due to increased physical activity and bone development phases. A study in Saudi Arabia by Al-Othman et al. (2012) found similar patterns, with fractures peaking in adolescence and being frequently linked to falls [12] and with other study by Abdulaziz et al. [13]. Additionally, the predominance of upper limb fractures is consistent with global data, as studies such as those by Agrawal et al. (2023) note that arms and wrists are more vulnerable to fractures during falls due to instinctive attempts to break impact [14] and also consistent with Arnold et al. [15], and Berry et al. [16].

As for vitamin D level, our study reveals important findings into vitamin D awareness and testing habits among individuals with a history of fractures in the Hail region. A concerning majority of participants had never been tested for vitamin D deficiency, indicating a defect in routine screening despite their fracture history. Among those who had been tested, many had not done so recently, with a significant portion (33.4%) last tested 3–5 years ago meaning their current vitamin D status remains uncertain. This delay in testing is a challenge, as vitamin D levels can vary over time due to factors such as seasonal changes, dietary intake, and sun exposure.

Most participants who knew their vitamin D levels reported insufficient or deficient levels (55.6% had levels between 20–40 ng/mL, while another 11.1% knew their levels were low but did not recall exact numbers). Only a third had normal levels (41–80 ng/mL). These findings match with previous research demonstrating widespread vitamin D deficiency in Saudi Arabia, particularly among populations with limited sun exposure or dietary intake of fortified foods. A study by Al-Daghri et al. (2017) found that over 60% of Saudi adults had insufficient vitamin D levels (<50 nmol/L), with women and younger individuals being particularly affected [17]. Similarly, a study by Elsammak et al. (2011) reported that 80% of healthy Saudi adults had vitamin D deficiency, likely due to cultural clothing practices, limited outdoor activity, and low dietary vitamin D intake [18].

The high prevalence of low vitamin D levels among fracture patients in this study supports existing evidence associating deficiency to poor bone health. A meta-analysis by Bischoff-Ferrari et al. (2009) found that individuals with low vitamin D levels had a significantly higher risk of fractures, particularly in weight-bearing bones, due to impaired calcium absorption and bone mineralization [19]. Another study by Holick (2007) highlighted that maintaining adequate vitamin D levels (≥30 ng/mL) is crucial for reducing fracture risk, especially in regions with limited sunlight exposure [20].

The study showed remarkable variations in fracture characteristics between individuals with normal and low vitamin D levels, underlining a potential association between vitamin D status and skeletal health. Participants with normal vitamin D experienced fractures exclusively between ages 6–10, while those with low vitamin D suffered fractures across a broader age spectrum, including early childhood (3–5 years) and adolescence (16–18 years). This pattern suggests a possible protective effect of sufficient vitamin D on bone integrity throughout different developmental stages. Fracture timing also varied; those with normal vitamin D typically had fractures that occurred 6–10 years ago, whereas individuals with low levels showed a higher incidence of recent fractures, including within the past year. Regarding fracture causes, falls were predominant in both groups but significantly more common among vitamin D–deficient participants. Also, exercise-related fractures were reported only in those with normal vitamin D possibly due to higher physical activity despite better bone strength. On the contrary, fractures from physical altercations were exclusive to the deficient group reflecting both reduced bone resilience and socio-behavioral factors. Differences were also evident in fracture locations. Participants with normal vitamin D levels sustained injuries primarily to the upper extremities and carpal bones, consistent with typical fall injuries. In contrast, those with low vitamin D showed a higher rate of leg and foot fractures mostly due to possible bone weakness in weight-bearing areas, with an absence of carpal fractures, supporting the hypothesis of altered fracture patterns linked to deficiency.

These findings are consistent with existing literature. LeBoff et al. (2022) observed higher rates of lower limb fractures in vitamin D–deficient individuals due to compromised bone mineralization and muscular function [21]. Similarly, Bischoff-Ferrari et al. (2010) demonstrated that vitamin D supplementation reduced nonvertebral fractures, particularly in those starting with low levels [19]. Age-specific trends observed in this study reflect those reported by Winzenberg et al. (2011), who found vitamin D deficiency associated with increased fracture risk in both children and adolescents [22]. Additionally, the prominence of falls simulate Sanders et al. (2010), who related deficiency to increased fall risk due to reduced muscle strength and balance [23].

The high rate of fractures in populations raises concerns about bone health and potential vitamin D deficiency, which is known to weaken bones and increase fracture risk. A study by Holvik et al. (2015) in Norway found that insufficient vitamin D levels were associated with higher fracture incidence in children and adolescents [24].

fracture incidence in children and adolescents [24]. Similarly, research by Munns et al. (2016) emphasized that vitamin D plays a crucial role in bone mineralization, and its deficiency can lead to rickets or osteomalacia, increasing susceptibility to fractures even from minor trauma [25].

In conclusion, this study showed association between vitamin D status, sun exposure habits, and bone fracture history in the Hail region. A significant portion of participants reported previous fractures, most commonly during childhood. Falls were the leading cause, and the upper limbs were the most frequently affected sites. Among those with a history of fractures, limited sun exposure was common, and the majority had either never tested their vitamin D levels or had low results when tested. Individuals with normal vitamin D levels tended to experience fractures during a narrower age window and had less recent injuries mainly due to stronger bone health. On the other hand, vitamin D–deficient individuals showed broader and more recent fracture patterns, potentially reflecting increased susceptibility or delayed recovery. Sun exposure patterns significantly influenced vitamin D levels. Morning exposure was more likely to be associated with adequate vitamin D, whereas exposure at midday or sunset and full-body coverage were linked to deficiency. Increasing public knowledge on the importance of vitamin D and its role in bone health is highly recommended. Additionally enhancing regular exposure to early morning sunlight as a safe and effective way to support vitamin D synthesis is mandatory. Introduce routine vitamin D testing, particularly for those with limited sun exposure or fracture history is also recommended.

Conclusion and Recommendations

In conclusion, this study showed association between vitamin D status, sun exposure habits, and bone fracture history in the Hail region. A significant portion of participants reported previous fractures, most commonly during childhood. Falls were the leading cause, and the upper limbs were the most frequently affected sites. Among those with a history of fractures, limited sun exposure was common, and the majority had either never tested their vitamin D levels or had low results when tested. Individuals with normal vitamin D levels tended to experience fractures during a narrower age window and had less recent injuries mainly due to stronger bone health. On the other hand, vitamin D–deficient individuals showed broader and more recent fracture patterns, potentially reflecting increased susceptibility or delayed recovery. Sun exposure patterns significantly influenced vitamin D levels. Morning exposure was more likely to be associated with adequate vitamin D, whereas exposure at midday or sunset and full-body coverage were linked to deficiency. Increasing public knowledge on the importance of vitamin D and its role in bone health is highly recommended. Additionally enhancing regular exposure to early morning sunlight as a safe and effective way to support vitamin D synthesis is mandatory. Introduce routine vitamin D testing, particularly for those with limited sun exposure or fracture history is also recommended.

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