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ORIGINAL ARTICLE

Vitamin D Levels Among Iraqi Population: Regional and Seasonal Variations

Sameer M. Mahmood [1], Zaid M. Younus [1], Athir K. Mohammed [2], Sama Al-Shaheeb [3]

[1] College of Pharmacy, University of Mosul, Mosul, Iraq
[2] College of Health and Medical Techniques - Baghdad, Middle Technical University, Baghdad, Iraq
[3] Institute of Medical Technology - Baghdad, Middle Technical University, Baghdad, Iraq

SUMMARY

Background: **Fluctuations in vitamin D (VITD) impact the health status of individuals across the globe. The present study aimed to assess the seasonal and regional variations in VITD status among the Iraqi population and highlight the extent of these differences across age and gender groups.**
Methods: **A total of 5,014 participants attending a single-consultation outpatient clinic for routine blood tests from three different regions of Iraq [the North (N, 825), the Middle (N, 3277), and the South (N, 912) regions] were recruited. The participants from the Middle region were enrolled throughout the seasons of the year (January through December 2023), whereas participants from the North and South regions were enrolled only during the winter season.**
Results: **The study revealed a wide range level of VITD spanning from 3 - 110 ng/mL (mean 26.5 ± 15.7 ng/mL). Deficiency (levels < 20 ng/mL) was found in 39% of participants, including 11% with severe deficiency (< 10 ng/mL). Females had significantly higher VITD levels than males. Seasonal analysis revealed significantly lower VITD levels during the winter season (24.8 ± 14.3 ng/mL) as compared to the spring and summer (28.3 ± 14.6 and 28.5 ± 15.5 ng/mL, respectively), while significantly higher levels were observed in autumn (31.3 ± 16.4 ng/mL). Regionally, lower VITD levels were recorded in the North of Iraq (21.7 ± 17 ng/mL) compared to the Middle and Southern regions (24.8 ± 14.3 and 25.1 ± 14.2 ng/mL, respectively). VITD levels also varied by age, with the youngest age groups (< 15, and 16 – 30 years) consistently exhibiting the highest deficiency rates throughout the year and across all regions, with the highest rates observed in winter and the Northern region.**
Conclusions: **Deficient VITD status in Iraq was found in almost one-third of the population. Deficiency levels were high in the young-age groups in all the regions and seasons. Clear regional and seasonal variations in the 25(OH)D level were spotted among the Iraqi population.**
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Correspondence:
Sameer M. Mahmood
College of Pharmacy
University of Mosul
Mosul
Iraq
Phone: + 964 7503694482
Email: sm.mahmood@uomosul.edu.iq

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KEYWORDS

25(OH)D, calcium, Iraq, season, vitamin D

INTRODUCTION

Vitamin D (VITD) is a key regulator in managing several metabolic processes supporting normal human health and function [1,2]. Bone and musculoskeletal system diseases are linked in many conditions to VITD deficiency, especially in young individuals [3]. Rickets in childhood and osteomalacia in adults are serious health problems related to disturbed VITD levels with a worldwide impact [4]. Recent studies have revealed that lower VITD levels reduce immunity and enhance susceptibility to infections such as human immunodeficiency virus diseases [5]. Therefore, maintaining an adequate VITD level ensures a healthy lifestyle [6].

The major form of VITD in the blood is the 25-hydroxyvitamin D (25(OH)D), which is considered the best indicator of VITD status [7]. VITD levels can vary significantly owing to aspects such as exposure to sunlight, dietary habits, geographic location, and seasonal variations [8]. Adequate sunlight exposure is essential for VITD synthesis. However, populations living at higher latitudes or in places with less sunlight intensity may be at a greater risk of deficiency in some seasons. Additionally, dietary sources of VITD, including fish oil, are crucial, but cultural food habits and availability influence their intake levels. Skin color, age, and body fat also impact VITD status [9]. Measuring VITD levels requires consideration of factors affecting its concentration. Understanding these factors is essential for accurately assessing the clinical conditions linked to VITD deficiency [9]. Accordingly, monitoring VITD in different population groups across a district, country, or even at the continental level will enable a proper assessment of VITD fluctuations worldwide. This approach may serve as an effective strategy to assess VITD deficiency, identify associated risks, and develop balanced supplementation protocols [6].

Like other countries, Iraq represents a model that offers variable climates and population diversity from the Northern to the Southern regions. Available studies on VITD mainly focus on a small population group in a single city or a rural region of Iraq, sometimes limited to a specific season or time of the year [10,11]. The present study aimed to assess VITD levels among the Iraqi population in various regions and seasons across the country; it also aimed to assess these variations based on age and gender to highlight their impact on VITD deficiency status.

MATERIALS AND METHODS

Selection of study participants

In this cross-sectional study, the participants who attended a single-consultation outpatient clinic for a routine blood test as part of their standard clinical care were invited to participate. Participants were included if they were male or female, aged 4 years or older, and did not meet the exclusion criteria outlined below. Leftover blood samples, which are typically discarded after routine sampling, were used in this research. Participants were recruited from three main regions of Iraq: The North region included the cities of Nineveh (lat: 36°30' N) and Erbil (lat: 36°2' N), the Middle region included Baghdad city (lat: 33°2' N), and the South region included cities of Basra (lat: 30°3' N) and Najaf (lat: 30°0' N). The participants from the Middle region were recruited over one year, from January 2023 through December 2023, while the samples from the North and South regions were collected during the winter only. The study excluded individuals taking supplements at the time of sample collection or medications affecting bone health, and those with medical conditions that impact bone or VITD metabolism, such as liver or kidney disease, diabetes, immobility, cancer, pregnancy, and lactation. In total, 5,014 eligible subjects were enrolled: 3,277 from the middle region, 825 from the north, and 912 from the south.

Ethical issues

The study was approved by the Collegiate Committee for Medical Research Ethics at the University of Mosul (code number CCMRE-phA-23-13). All participants gave informal consent before taking part in the study. Those who agreed to participate were asked to complete a simple demographic and clinical information questionnaire. Demographic data included age, gender, and city of residency to assess age-related trends, gender differences, and regional variations in VITD levels. Clinical variables such as medications and existing comorbidities were also recorded, as they could influence the study outcomes.

Biochemical parameters

The collected serum samples were stored at -20°C until analysis. VITD (25(OH)D) levels were assessed using a chemiluminescent immunoassay (CLIA) on a Cobas E 411 analyzer (Roche Diagnostics GmbH). This method employs the Elecsys VITD (25(OH)D) total reagent kit from Roche Diagnostics, which is based on a competitive immunoassay principle using chemiluminescence detection. It is a highly sensitive and specific assay that offers a measuring range of 4.0 to 160 ng/mL, with intra- and inter-assay coefficients of variation (CVs) below 5%. Concurrently, serum calcium levels were measured in samples with sufficient volume remaining after the VITD (25(OH)D) analysis. The calcium measurements were performed using the Cobas c 501 Analyzer (Roche Diagnostics) and the Roche Calcium Gen.2 reagent kit. This assay is based on a colorimetric endpoint method with a measuring range of 2 - 12 mg/dL, and intra- and inter-assay CVs below 2%.

The study participants were initially categorized into three groups based on their 25(OH)D levels: deficient (< 20 ng/mL), insufficient (20 - 30 ng/mL), and sufficient (> 30 ng/mL). Simultaneously, participants were classified into age groups: children and adolescents (< 15 years), young adults (16 - 30 years), middle-aged adults (31 - 45 years), older adults (46 - 60 years), and senior adults (> 60 years).

To study the regional variations in VITD levels among the Iraqi population, the participants were divided into three groups based on their region of residence: South, North, and Middle. Only the samples collected during winter from all the study regions were used to remove any ambiguity in the seasonal variation. Additionally, the participants from the Middle region were analyzed to study seasonal variations in VITD levels, with further subdivision into four subgroups based on the season of sample collection: winter, spring, summer, and autumn.

Statistical analysis

The statistical analysis was conducted using SPSS Statistics software version 22 (IBM, Armonk, NY, USA), with a significance level set at $p < 0.05$. Descriptive statistics were employed to characterize the demographic features of participants. The normality of data was assessed using the Shapiro-Wilk test and the Kolmogorov-Smirnov test. For normally-distributed groups, comparisons were made using either Student's *t*-test or analysis of variance (ANOVA). Non-normally-distributed data were analyzed using the Mann-Whitney U test or the Kruskal-Wallis test. Post hoc analyses were performed to further explore significant findings. Tukey test was applied for normally-distributed data, while Dunn's test was used for non-parametric data.

RESULTS

Overall status of the study population

The present study included 5,014 participants from various regions of Iraq, with a mean age of 40.7 ± 17.9 years (range: 4 - 88 years). Out of these, 63.6% were female and 36.4% male. The overall status revealed a wide range of 25(OH)D3 levels spanning from 3 to 110 ng/mL, with a mean of 26.5 ± 15.7 ng/mL and a median of 23.3 ng/mL. Notably, 39% of participants in this study exhibited VITD deficiency (< 20 ng/mL), with 11% classified as severely deficient (levels < 10 ng/mL). Further, 28% of participants fell within the insufficient range (20 - 30 ng/mL), while 33% exhibited sufficient levels exceeding 30 ng/mL (Table 1).

The calcium levels ranged from 6.2 to 11.9 mg/dL, with a mean concentration of 9.33 ± 0.7 mg/dL. A significant positive correlation was observed between calcium and VITD levels ($p < 0.001$). When participants were categorized based on their VITD levels, those classified as deficient exhibited a significantly lower mean calcium concentration in comparison to the individuals categorized as insufficient ($p < 0.005$) and sufficient ($p < 0.001$) in VITD levels. However, no statistically significant difference was observed between the insufficient and sufficient VITD groups in terms of calcium concentration ($p > 0.05$) (Table 1). A significant difference in mean VITD levels was observed between genders ($p < 0.05$). Females exhibited significantly higher levels of VITD as compared to the male participants. However, no significant difference was observed between female and male subgroups regarding calcium levels ($p > 0.05$) (Table 1).

When participants were stratified by age, significant differences in VITD levels were observed. Adolescents (< 15 years) and young adults (16 - 30 years) exhibited significantly lower VITD concentrations compared to older age groups (31 - 45, 46 - 60, and > 60 years; $p < 0.001$), with these groups (< 15 and 16 - 30 years) also demonstrating the highest deficiency rates among the age groups, at 54.3% and 53.2%, respectively. The highest concentrations of VITD were observed in the senior adult (> 60 years), with more than 53% having levels exceeding 30 ng/mL (Table 2). Calcium levels across age groups showed a more homogeneous pattern, with fewer differences observed. Individuals aged 16 - 30 and 31 - 45 years had significantly lower Ca levels compared to those in the 46 - 60 and > 60 years age group ($p < 0.05$) (Table 2).

Seasonal variation of VITD levels

The participants from the Middle region of Iraq were recruited over a period of one year, resulting in a total of 3,277 participants. These participants were categorized into four groups based on the season of sample collection. Participant characteristics and measurements are shown in Table 3.

A clear seasonal fluctuation was observed in VITD levels. The participants recruited during the winter season had significantly lower 25(OH)D3 levels as compared to those collected in other seasons ($p < 0.001$). Conversely, the autumn season yielded the highest 25(OH)D3 concentration among all seasons ($p < 0.001$). The spring and summer samples were not significantly different from each other ($p > 0.05$); both seasons exhibited higher VITD levels than winter ($p < 0.001$) and lower levels than autumn ($p < 0.001$) (Table 3; Figure 1). The percentage of individuals with sufficient, insufficient, and deficient VITD levels across the seasons is illustrated in Figure 2. During the winter season, only 28% of participants showed sufficient VITD levels (> 30 ng/mL), while 43% were deficient (< 20 ng/mL). As the seasons progressed, the proportion of participants with sufficient VITD levels gradually increased, reaching 38% in spring, 39% in summer, and a peak of 43% in autumn. Notably, the percentage of individuals with VITD deficiency mirrored this trend, decreasing to 32% in spring and summer, and further diminishing to 27% in autumn (Figure 2).

Further analysis revealed a clear age-related trend in VITD deficiency across the seasons. Individuals in the youngest age group (< 15 years) exhibited the highest prevalence of VITD deficiency throughout the year, with deficiency rates of approximately 70% in winter, 55% in spring, 36% in summer, and 59% in autumn. The prevalence of deficiency decreased across older age groups (Figure 3).

The observed seasonal fluctuations in VITD levels significantly influenced the calcium levels. Participants recruited during the winter season exhibited the lowest mean calcium level (9.3 ± 0.6 mg/dL), which was significantly different from both the summer ($p < 0.001$) and autumn ($p < 0.005$) seasons. Conversely, the samples collected in summer showed the highest mean calcium level as compared to all other seasons ($p < 0.001$) (Table 3; Figure 4).

Table 1. VITD and calcium levels (mean ± SD) of Iraqi participants.

	n (%)	Age (years) mean ± SD	25(OH)D3 (ng/mL)		Calcium (mg/dL) mean ± SD (n)
			mean ± SD	median (IQR)	
Total	5,014 (100)	40.7 ± 17.9	26.5 ± 15.7	23.3 (19.5)	9.33 ± 0.7 (954)
Gender					
Female	3,191 (63.6)	41.2 ± 17.9	27.2 ± 15.9	24.7 (20.0)	9.35 ± 0.6 (623)
Male	1,823 (36.4)	39.8 ± 18	25.3 ± 15.2	21.6 (17.3)	9.36 ± 0.6 (331)
VITD level (ng/mL)					
Deficient (< 20)	1,970 (39.3)	35.1 ± 16.6	12.9 ± 4.4	13.1 (7.6)	9.22 ± 0.6 (347)
Insufficient (20 - 30)	1,383 (27.6)	42.3 ± 17.1	24.6 ± 2.7	24.4 (5.0)	9.41 ± 0.6 (218)
Sufficient (> 30)	1,661 (33.1)	46.1 ± 18.2	44.3 ± 13.2	40.8 (15.6)	9.45 ± 0.6 (389)

Table 2. VITD, calcium levels, and VITD distribution among the Iraqi population stratified by age.

Age group	25(OH)D3 (ng/mL)		VITD distribution			Calcium (mg/dL)	
	n	mean ± SD	deficient	insufficient	sufficient	n	mean ± SD
< 15	422	22.8 ± 15.6	54.3%	22.3%	23.4%	101	9.36 ± 0.6
16 - 30	1,084	22.3 ± 13.8	53.2%	24.4%	22.4%	184	9.23 ± 0.7
31 - 45	1,527	26.1 ± 15.6 [a, b]	39.6%	30.3%	30.1%	231	9.25 ± 0.6
46 - 60	1,181	28 ± 15.6 [a, b, c]	33.3%	30.0%	36.7%	249	9.41 ± 0.6 [c, b]
> 60	800	32.9 ± 16 [a, b, c, d]	20.8%	26.0%	53.2%	189	9.52 ± 0.6 [c, b]
p-value		< 0.001					< 0.001

Significance levels denoted by letters a, b, c, and d represent post hoc comparisons following Kruskal-Wallis Test for VITD and ANOVA for calcium comparisons: [a] significance with the < 15 age group, [b] significance with 16 - 30, [c] significance with 31 - 45, [d] significance with 46 - 60 age group.

Table 3. Characteristics of the middle region population stratified by season.

Season	Participant n (%)	Gender F/M	Age (year) mean ± SD	25(OH)D3 (ng/mL) mean ± SD, median (IQR)	Calcium (mg/dL) mean ± SD (n)
Winter	807 (25%)	518/289	43.3 ± 17.7	24.8 ± 14.3, 21.9 (16.8)	9.3 ± 0.6 (177)
Spring	740 (23%)	483/257	44.5 ± 18.2	28.3 ± 14.6, 25.4 (17.9)	9.4 ± 0.4 (181)
Summer	938 (28%)	647/291	42 ± 18.2	28.5 ± 15.5, 26 (19.2)	9.8 ± 0.5 (178)
Autumn	792 (24%)	531/261	43 ± 18.7	31.3 ± 16.4, 28.6 (22)	9.5 ± 0.6 (176)
Total	3,277 (100%)	2,195/1,082	43.1 ± 18.2	28.3 ± 15.5, 25.5 (19.3)	9.5 ± 0.6 (712)

Regional variation of VITD levels

The study samples were collected from three distinct geographical regions of Iraq (North, Middle, and South), and the participants were categorized accordingly. Samples from North and South regions were collected during the winter season. To maintain consistency in comparisons across the regions, only winter season samples were considered for the Middle region, despite year-round data availability. This winter-specific sampling strategy minimized the influence of seasonal variations on VITD concentrations, enabling a more accurate assessment of potential regional differences. The characteristics of participants from each region are presented in Table 4.

The participants recruited from North region of Iraq had significantly lower VITD levels (21.7 ± 17 ng/mL) as

Table 4. Characteristics of the study population stratified by region.

Region	n (%)	Gender F/M	Age (year) mean ± SD	25(OH)D3 (ng/mL)	
				mean ± SD	median (IQR)
Middle	**807 (31.7)**	**518/289**	**43.3 ± 17.7**	**24.8 ± 14.3**	**21.9 (16.8)**
South	**825 (32.4)**	**534/291**	**33.4 ± 16.2**	**25.1 ± 14.2**	**22.0 (18)**
North	**912 (35.9)**	**462/450**	**38.8 ± 16.6**	**21.7 ± 17**	**18.1 (16.7)**
Total	**2,544 (100)**	**1,514/1,030**	**38.5 ± 17.3**	**23.8 ± 15.3**	**20.5 (17.7)**

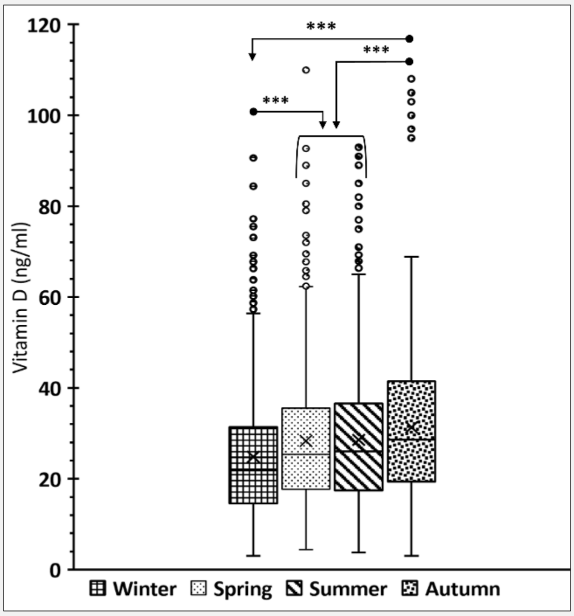

Figure 1. Box plots of 25(OH)D3 levels (ng/mL) in Iraq's middle region population (N: 3,277), stratified by season of sample collection.

The box represents the interquartile range, the line through the box indicates the median level, and × represents the mean. Whiskers extend up to 1.5 times the interquartile range, with (•) denoting outliers above this limit. The significance level (p < 0.001) is indicated by asterisks (***).

compared to those from Middle (24.8 ± 14.3 ng/mL) and South regions (25.1 ± 14.2 ng/mL, $p < 0.001$). However, no significant difference was observed between the Middle and South regions ($p > 0.05$) (Table 4; Figure 5).

Consistent with these differences in VITD levels, the prevalence of VITD deficiency (< 20 ng/mL) also varied significantly across the regions. Participants from the North region suffered from VITD deficiency at a significantly higher rate (58%) in comparison to the Middle (43%) and South (42%) regions ($p < 0.001$) (Figure 6).

Further analysis revealed that the youngest age group (< 15 years) was most affected by VITD deficiency throughout the country. In the Middle region, 70% of participants aged < 15 years were VITD deficient, with 55 and 57% of participants deficient in the South and North regions, respectively. Notably, the 16 - 30 age group also suffered significantly, especially in the North, where 74% was deficient, compared to 60% and 49% in the Middle and South regions, respectively (Figure 7).

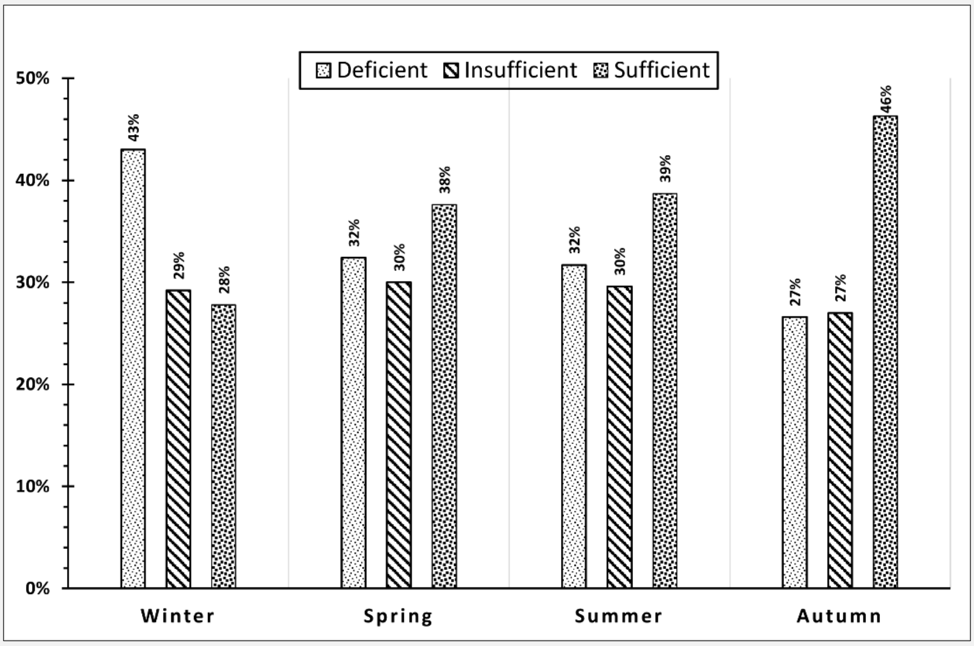

Figure 2. The percentage of individuals with sufficient, insufficient, and deficient VITD levels across the seasons.

The y-axis denotes the percentage of populations. Each set of 3 bars corresponds to a specific season reflecting deficient, insufficient, and sufficient population percentage.

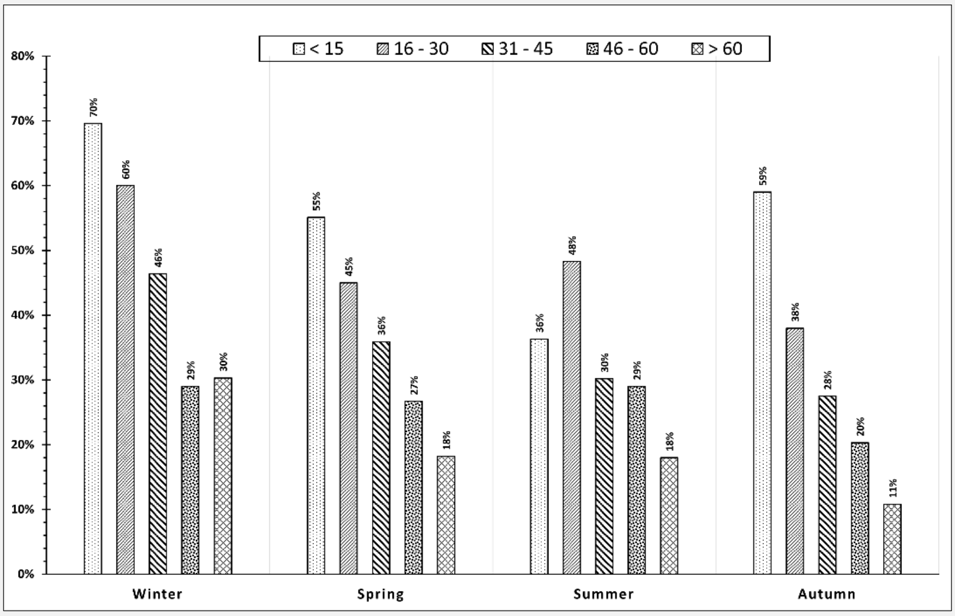

Figure 3. Seasonal distribution of VITD deficiency (< 20 ng/mL) across different age groups.

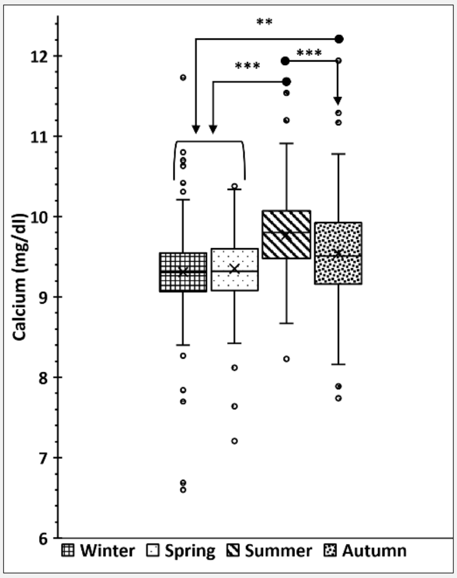

Figure 4. Box plots of calcium levels (mg/dL) in the middle region population (N: 712), stratified by season of sample collection.

The box represents the interquartile range, the line through the box indicates the median level, and × represents the mean. Whiskers extend up to 1.5 times the interquartile range, with (•) denoting outliers above this limit. The significance levels (p < 0.001) and (p < 0.005) are indicated by (***) and (**), respectively.

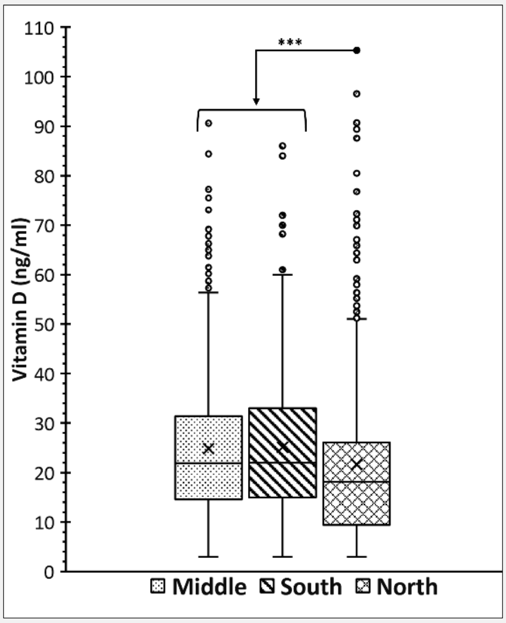

Figure 5. Box plots of 25(OH)D3 levels (ng/mL) in the study population (n: 2,544), stratified by region of sample collection.

The box represents the interquartile range, the line through the box indicates the median level, and × represents the mean. Whiskers extend up to 1.5 times the interquartile range, with (•) denoting outliers above this limit. The significance level (p < 0.001) is indicated by (***).

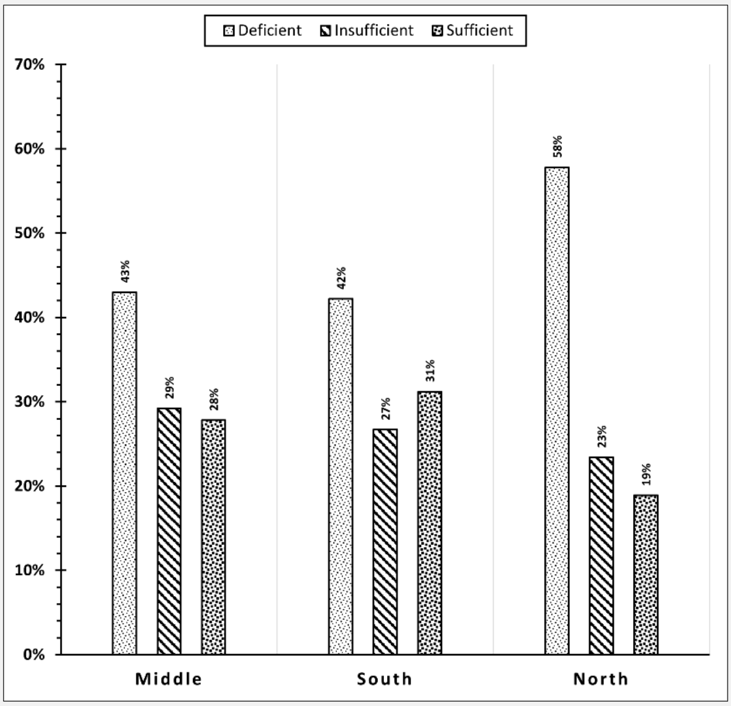

Figure 6. Percentage of individuals with sufficient, insufficient, and deficient VITD levels across the regions of Iraq.

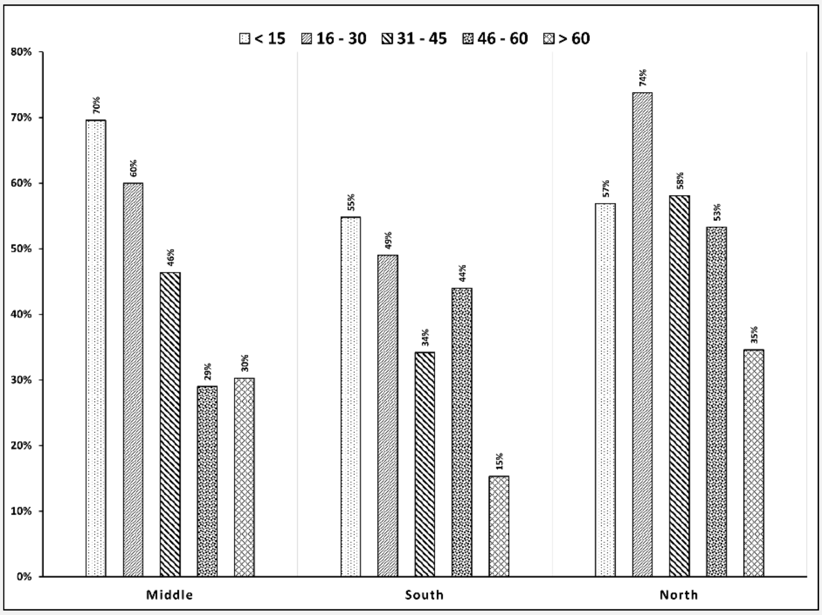

Figure 7. Regional distribution of VITD deficiency (< 20 ng/mL) across different age groups.

DISCUSSION

The results of the present study reveal a wide fluctuation in the VITD levels based on age, gender, seasonal, and regional measures. Deficient VITD levels were found in more than one-third of the study population (39% assigned at < 20 ng/mL), consistent with numerous studies highlighting the frequent incidence of VITD deficiency worldwide [6,8]. Interestingly, the mean VITD level was significantly higher in females compared to males, contradicting the general concept supported by several studies that VITD levels are usually lower in females [11-13]. However, this finding agrees with other research, including a U.S. study by Kestenbaum et al. (15,804 participants), a Chilean study by Vallejo et al. (1,329 participants), and a Saudi study by AlQuaiz et al. (2,835 participants), all of which reported higher VITD levels in females compared to males [14-16]. Gender-related variations in vitamin D levels have been correlated with several factors, including body fat percentage and hormonal differences [17,18]. Females commonly receive medical advice to take vitamin D for bone health, pregnancy, or osteoporosis and tend to be more proactive in managing their health, including more frequent clinic visits compared to men [16,19]. Although current supplement users were excluded from our study, the fat-soluble nature of vitamin D suggest that prior supplementation could be the reason behind the elevated levels in women.

In the current study, more than 50% of participants in both the (< 15) and (16 - 30) age groups were VITD deficient (< 20 ng/mL), while just over 20% in each group maintained sufficient VITD levels. This indicates that children, adolescents, and young adults are particularly vulnerable to VITD deficiency. These findings are consistent with existing literature regarding the prevalence of VITD deficiency in children and adolescents. For instance, a cross-sectional survey in Pakistan found that 56% of children and adolescents (aged 6 - 18 years) were VITD deficient (< 20 ng/mL), while only 24% had sufficient VITD levels [13]. Similarly, a study conducted in Ankara, Turkey, reported a 40% deficiency rate among children and adolescents under the age of 16 years [20]. Additionally, a study by Nadeem et al. reported an even higher deficiency rate of up to 89% among Pakistani medical students aged 19 - 25 years [21]. Collectively, these findings highlight the widespread prevalence of VITD deficiency among younger populations.

Participants aged 30 years and above demonstrated better VITD status compared to those under 30, with deficiency rates progressively decreasing to around 20% in seniors aged > 60 years. These findings highlight a lower prevalence of VITD deficiency in older age groups, particularly the elderly, compared to children and adolescents. Studies on VITD status in older populations show controversial findings. Haitchi et al. reported a 22% deficiency rate among 478 seniors over 65 years, consistent with the current findings of a 20% deficiency rate in this age group [22]. However, higher deficiency rates were observed by Schlögl et al. (58% in seniors above the age of 70 in Switzerland) and Kmieć et al. (> 50% in adults above 40 years in Northern Poland) [23,24]. AlQuaiz et al. also supported our finding, noting lower VITD deficiency rates in older compared to younger participants, likely due to the frequent use of VITD supplementation among older individuals, which may contribute to their improved VITD status [16].This aligns with the possibility that prior supplementation, despite exclusion at sampling, could have influenced the vitamin D levels in this age group.

The high deficiency rates observed in children and adolescents may be attributed to poor control and monitoring within these age groups. Modern lifestyle changes, with children and adolescents spending more time indoors, significantly reduce their exposure to sunlight, adversely impacting their VITD status. On the other hand, the lower percentage of deficiency in adults and seniors is mainly related to the increased use of VITD supplementation among these age groups.

The current results for calcium support the findings related to VITD, revealing a significant difference between the deficient group and both the insufficient and sufficient groups. Moreover, the calcium findings were associated with age in a manner consistent with the age-related VITD findings. Although calcium levels may not effectively predict VITD levels, their correlation with VITD in metabolism and absorption makes them valuable evidence for the measured VITD status. The positive correlation between calcium ions and VITD has been indicated in certain studies, highlighting the value of this marker as an assistive measure in reflecting VITD status [19,21].

In our attempt to investigate the seasonal impact on VITD status while limiting regional differences, we focused on the middle region of Iraq to reflect multi-seasonal changes within a single region. The middle region was represented by Baghdad, a multi-ethnic city in the center of Iraq. Such a regional population is a good reflection of how multiple seasons can cast their influence on VITD status. The observed lowest levels of VITD during the winter season, compared to other seasons, are consistent with the well-established understanding that reduced daylight, lower UV radiation, and heavier clothing during winter collectively limit skin exposure to sunlight, thereby reducing VITD synthesis [3,25]. Even more, the reduced activity and sedentary lifestyle in winter could adversely lower the metabolic rate in general, including VITD metabolism [26]. This seasonal trend has been similarly observed in studies worldwide [27,28].

In spring and summer, VITD levels improved significantly compared to winter, likely due to increased sunlight intensity and outdoor activities [29]. While VITD levels remained elevated in summer, they showed no significant increase compared to spring. In Iraq, spring begins early in March with moderate temperatures, encouraging outdoor activities and greater sun exposure.

By late spring, temperatures exceed extreme levels (up to 50°C), reducing outdoor activity and sun exposure, potentially explaining the plateau in VITD levels during summer. The elevated VITD levels in both spring and summer align with established literature, and often, the VITD levels in these two seasons are close to each other. [28,30].

While VITD levels in spring and summer were significantly higher than in winter, autumn recorded the highest mean value across all seasons. Deficiency rates decreased from 43% in winter to 27% in autumn, with sufficiency levels reaching 46%, the highest among all seasons. This finding contrasts with studies reporting a decline in VITD during autumn due to colder weather and reduced sunlight intensity [9,12]. However, latitude and geographical location influence seasonal characteristics, UV radiation intensity, and individual activities, thus, the VITD status [29]. In Iraq, the extreme summer hotness often extends into mid-September, after which temperatures gradually drop to the mid-20s (°C) by October [31]. This shift encourages increased outdoor activities, similar to patterns seen in spring, enhancing sunlight exposure and VITD synthesis. Additionally, VITD stores accumulated during the summer likely contribute to the higher levels observed in autumn. This seasonal pattern is consistent with findings from central China and Nepal, which also report higher VITD levels in autumn, highlighting the role of sunlight exposure, geographical factors, and outdoor time on seasonal VITD variations [32,33]. A recent study in Baghdad confirmed high UV radiation levels throughout most of the year, including autumn, and noted that extreme summer heat reduces outdoor activity, limiting sun exposure [34]. These findings support our assumption linking the fluctuations in VITD levels and outdoor activities across the different seasons in Iraq.

Interestingly, children and adolescents consistently exhibit high rates of VITD deficiency across all seasons. These results underscore our previous declaration that current changes in lifestyle mainly affect children and adolescents as they spend more time on digital activities such as watching TV, spending time on electronics, and using smart devices [35]. As such, there will be less exposure rate to the sun in these younger age groups, who are supposed to be engaged in plenty of outdoor activities, which is a crucial factor in supporting healthy vitamin levels [35]. In contrast, older participants showed the lowest deficiency rates, likely due to the widespread use of VITD supplements among the elderly.

Seasonal changes in VITD status also influence calcium levels, with significantly higher levels observed in summer and autumn compared to other seasons. This could prove how VITD fluctuations may impact calcium status in individuals. VITD plays a crucial role in maintaining calcium levels, which are essential for normal bodily functions, including proper neural activity and bone mineralization [19,36]. Several studies confirmed a correlation between VITD and calcium levels, supporting the current findings [1,2].

The observed regional variations in VITD levels highlight the influence of latitude and geographical location on VITD status. Higher deficiency rates were mostly found in areas at higher latitudes, likely due to reduced UV radiation intensity [25,37]. This may help to explain the significant differences in VITD levels between the Northern (lat. 36) and Southern (lat. 30) regions of Iraq. Additionally, socioeconomic factors and dietary habits play a role. Populations in Southern and, to some extent, those in the middle regions of Iraq tend to consume more seafood, which is a richer source of VITD, compared to residents in the Northern regions [2]. A study by Yeşiltepe-Mutlu et al. in Turkey found higher VITD deficiency rates in the Northern region (42%) compared to the central (24%) and Southern regions (26%); although these findings agree with our current results, the study highlighted additional factors that may affect VITD levels in some regions, including economic conditions and specific VITD supplementation protocols [38].

The youngest age groups (< 15 and 16 - 30 years) consistently showed the highest VITD deficiency rates across all regions, while older groups (> 30 years) had the lowest. This age-related trend was observed both among all participants and when grouped by season. Deficiency rates in different age groups were generally highest in the North, followed by the Middle, and lowest in the South. However, exceptions existed: the < 15 age group had the highest deficiency rate in the Middle region (70%), while the 16 - 30 group peaked in the North (74%) instead of the < 15 age group. Additionally, the 46 - 60 group had the lowest deficiency in the Middle, unlike other regions where the > 60 group scored the lowest. These variations suggest that factors such as nutrition, socioeconomic status, and VITD supplementation may play a more significant role than sun exposure in influencing VITD levels [39]. In agreement with our results, a study conducted in Korea found higher VITD deficiency rates among younger age groups across 13 cities, with the highest prevalence in the Northern regions [40].

The current study may have some limitations that we wanted to outline here. The study is missing data such as the body mass index (BMI), nutritional information, and occupations, which are essential additives that may support the findings when addressing the deficiency status. However, in our study, we focused on VITD concentration in different locations in Iraq and through variable seasons to highlight the deficiency status at a nationwide level. Our study was unique in the way that it involved a large sample size from all around the country and across several regions and seasons and provided valuable data to be considered for future assessment of VITD status.

CONCLUSION

The deficiency state of VITD in Iraq reached a high level, reflected by almost one-third of the population. The deficiency was highest in the youngest age participants. Seasons affected VITD status, fluctuating from low in winter to high in other seasons. Regional differences also impacted the levels of VITD, with increased deficiency in Northern Iraq and comparatively lesser deficiency in the Middle and Southern regions of the country. Children and adolescents had the highest VITD deficiency in multiple latitudes of Iraq and all seasons. Based on the current results, certain factors like season and geographical location need to be considered while measuring VITD levels. The findings reveal critical VITD levels in children and adolescents of Iraq. We recommend monitoring and follow-up of VITD, specifically in these age groups. Proper supplementation of VITD tracked by medical professionals is necessary to obtain stable levels.

Declaration of Interest:
The authors declare no conflict of interest concerning the authorship or publication of this article.

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