Alqalam Journal of Medical and Applied Sciences. 2026;9(11):3612-3619
https://doi.org/10.54361/ajmas.261111

Original article

Prevalence and Determinants of Vitamin D Deficiency Among Pregnant Women Attending a Private Clinic in Gharyan, Western Libya: A Cross-Sectional Study

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Abstract
Vitamin D deficiency is common among pregnant women in North Africa despite abundant sunshine, but data from western Libya are limited. This study assessed the prevalence of vitamin D deficiency and its associated factors among pregnant women attending a private clinic in Gharyan, western Libya. This cross-sectional study included 70 pregnant women attending antenatal care at the clinic between September and October 2026. A structured questionnaire collected sociodemographic, obstetric, anthropometric, sun exposure, supplement, and dietary data. Serum 25-hydroxyvitamin D [25(OH)D] was measured, and deficiency was defined as <20 ng/mL. Data were analysed using SPSS version 26. Logistic regression was used to identify factors associated with deficiency. The median age was 32.5 years (IQR 27.0–38.0). Deficiency was found in 39 of 70 women (55.7%; 95% CI 44.1–66.8%), and 81.4% had deficient or insufficient status. In multivariable analysis, an interpregnancy interval of <12 months was associated with higher odds of deficiency (adjusted OR 7.21; 95% CI 1.12–46.62; p = 0.038), whereas reported sun exposure <3 days/week was associated with lower odds (adjusted OR 0.24; 95% CI 0.08–0.73; p = 0.012). Supplement use, dairy intake, and trimester were not significantly associated with deficiency. More than half of the pregnant women in this clinic-based sample were vitamin D deficient. A short interpregnancy interval was a potential determinant, although the estimate was imprecise, and the inverse association with reported sun exposure probably reflected limitations of self-reported exposure. Larger multicentre prospective studies with objective exposure measures are needed.
Keywords: Vitamin D Deficiency; Pregnancy; Prevalence; Interpregnancy Interval; Sun Exposure; Libya.

Introduction

Vitamin D is a fat-soluble secosteroid that plays a central role in calcium and phosphorus homeostasis, bone health, and several extraskeletal functions, including immune modulation and metabolic regulation. During pregnancy, maternal vitamin D status is particularly important because 25-hydroxyvitamin D [25(OH)D] is the main circulating reservoir available to the fetus, and adequate status supports implantation, placental function, and fetal skeletal development [1].

Vitamin D deficiency during pregnancy is a widespread public health problem. A global systematic review of maternal and newborn vitamin D status reported high rates of deficiency across many regions and populations [2], and worldwide data continue to show substantial variation in 25(OH)D concentrations according to latitude, skin pigmentation, clothing, sun exposure, diet, and supplementation practices [3].

The burden of vitamin D deficiency is particularly high in the Middle East and North Africa and in the Mediterranean region, despite abundant sunshine. Regional reviews have documented a high prevalence of hypovitaminosis D among pregnant women and have highlighted cultural, behavioural, and dietary factors that limit effective sun exposure or vitamin D intake [4,5]. Libya, like other countries in this region, is affected by this “sunshine paradox,” and pregnant women are considered a particularly vulnerable group. However, contemporary pregnancy-specific data from western Libya remain limited, and local determinants of deficiency are not well characterised.

Maternal vitamin D deficiency has been associated with adverse maternal and neonatal outcomes. Systematic reviews and meta-analyses of observational studies have linked low maternal 25(OH)D levels with increased risks of preeclampsia, gestational diabetes, preterm birth, low birth weight, and other adverse pregnancy outcomes [6,7]. Experimental and clinical evidence also indicates that vitamin D deficiency may affect placental development, immune adaptation, and offspring health beyond the skeletal system [8]. These findings provide a strong rationale for identifying pregnant women at risk and for improving vitamin D status before and during pregnancy.

Vitamin D supplementation during pregnancy has been evaluated in several randomised trials and systematic reviews, with evidence suggesting benefits for some maternal and neonatal outcomes, although optimal dosing and target populations remain debated [9-11]. International guidance reflects this uncertainty: the World Health Organisation does not recommend routine vitamin D supplementation for all pregnant women within its general antenatal care recommendations [12], whereas the Endocrine Society 2024 guideline suggests empiric vitamin D supplementation during pregnancy to reduce the risk of adverse pregnancy outcomes [13]. In addition to supplementation, reproductive factors such as short interpregnancy interval may contribute to maternal nutrient depletion and adverse perinatal outcomes [14], while sun exposure, clothing practices, diet, and supplement use are key modifiable determinants of vitamin D status in sunny countries [15].

In western Libya, data on the prevalence and determinants of vitamin D deficiency among pregnant women are needed to inform local prevention and antenatal care strategies. Therefore, this cross-sectional study aimed to determine the prevalence of vitamin D deficiency among pregnant women attending a private antenatal clinic in Gharyan, western Libya,

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Received: *28-08-2026 -* ***Accepted:*** *26-10-2026 -* ***Published:*** *04-11-2026*

and to assess associated factors, including sociodemographic characteristics, obstetric history, pre-pregnancy body mass index, sun exposure, supplement use, and dietary intake. The aim of this study was to determine the prevalence of vitamin D deficiency (serum 25(OH)D <20 ng/mL) among pregnant women attending a private antenatal clinic in Gharyan, western Libya, and to identify the factors associated with vitamin D deficiency in this population, including sociodemographic characteristics, obstetric history, pre-pregnancy body mass index, sun exposure, vitamin D supplement use, and dietary intake.

Methods

Study design and setting

This was a cross-sectional study conducted among pregnant women attending antenatal care at a private clinic in Gharyan Centre, western Libya, between September and October 2026. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.

Participants

A convenience sample of pregnant women was recruited during routine antenatal visits at the clinic. Women were eligible if they were pregnant at any gestational age and had a valid serum 25-hydroxyvitamin D [25(OH)D] measurement available. Women with missing 25(OH)D results were excluded, and no eligible woman declined participation. A total of 70 pregnant women with complete data on vitamin D status were included in the final analysis. The sample size was determined by the number of eligible women recruited during the study period, and no formal sample size calculation was performed.

Data collection

Data were collected using a structured, self-administered questionnaire (an online form completed by the participants at the clinic) that covered:

- Sociodemographic characteristics: age, residence, educational level, occupation.
- Obstetric history: gestational age, trimester, gravidity, parity, type of current pregnancy, and interpregnancy interval.
- Anthropometric data: pre-pregnancy weight and height, from which pre-pregnancy body mass index (BMI) was calculated (kg/m^2) and categorised according to WHO criteria (underweight <18.5, normal weight 18.5–24.9, overweight 25–29.9, obese ≥30).
- Sun exposure: frequency of direct sun exposure and average daily time spent outdoors in daylight.
- Supplement use: current vitamin D supplement use (yes/no), dose/brand, duration, and regularity; prenatal multivitamin use; iron supplement use.
- Dietary intake: frequency of milk/dairy, oily fish, and egg consumption.
- Medical history: chronic medical conditions and other medications.

The online questionnaire responses were linked to the laboratory results using a unique anonymous study code assigned to each participant at enrolment and recorded on both the questionnaire and the laboratory request form; the matched dataset contained no names or other direct identifiers and was stored on a password-protected computer accessible only to the research team.

Laboratory assessment

Serum 25(OH)D concentrations were measured by enzyme-linked immunosorbent assay (ELISA) at the clinic's own laboratory. Vitamin D status was defined as:

- Deficiency: 25(OH)D < 20 ng/mL
- Insufficiency: 20–29.9 ng/mL
- Sufficiency: ≥ 30 ng/mL

For analysis, participants were grouped as "deficient" (<20 ng/mL) and "non-deficient" (≥20 ng/mL, i.e., insufficiency plus sufficiency).

Variables

The primary outcome was vitamin D deficiency (yes/no). Explanatory variables included age (categorised as <25, 25–34, ≥35 years), educational level, occupation (housewife vs employed/student), pre-pregnancy BMI category, trimester, gravidity, parity, interpregnancy interval, frequency of direct sun exposure (<3 vs ≥3 days/week), daily outdoor time (<15 vs ≥15 min/day), current vitamin D supplement use, regularity of supplementation, prenatal multivitamin use, dietary intake (milk/dairy, oily fish, eggs), chronic medical conditions, and other medication use.

Statistical analysis

Data were analysed using SPSS version 26 (IBM Corp., Armonk, NY, USA). Continuous variables were summarised as median with interquartile range (IQR) in both the text and the tables, consistent with the use of non-parametric tests. Categorical variables were expressed as frequencies and percentages. The prevalence of vitamin D deficiency was calculated with 95% confidence intervals (Wilson method).

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Received: *28-08-2026 -* ***Accepted:*** *26-10-2026 -* ***Published:*** *04-11-2026*

Comparisons between deficient and non-deficient groups were performed using the Mann–Whitney U test for continuous variables and the chi-square test, Fisher's exact test (for 2×2 tables with expected counts <5), or Monte Carlo exact test (for larger sparse tables) for categorical variables.

Univariable logistic regression was used to calculate crude odds ratios (ORs) with 95% confidence intervals (CIs) for factors associated with vitamin D deficiency. A multivariable logistic regression model was then fitted including five pre-specified factors: interpregnancy interval <12 months, sun exposure <3 days/week, no current vitamin D supplement use, dairy intake <3 times/week, and third trimester. Adjusted ORs with 95% CIs were reported. Model fit was assessed using the likelihood-ratio chi-square test, Nagelkerke R^2, area under the receiver operating characteristic curve (AUC), and the Hosmer–Lemeshow goodness-of-fit test. A two-sided p-value <0.05 was considered statistically significant.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the Faculty of Medicine, University of Gharyan, Libya (approval number: 25; date: 1 September 2025). The clinic management approved data collection. All participants provided informed consent before participation. Data were collected anonymously and kept confidential.

Results

Characteristics of the study participants

A total of 70 pregnant women with available serum 25(OH)D measurements were included in the analysis. The median age was 32.5 years (IQR 27.0–38.0), and the median gestational age was 24.0 weeks (IQR 11.8–36.2). The median pre-pregnancy BMI was 27.4 kg/m^2 (IQR 24.1–32.5). Most participants were university educated (47.1%) or had secondary education (40.0%), and 40.0% were housewives. According to pre-pregnancy BMI, 40.0% were normal or underweight, 27.1% were overweight, and 32.9% were obese. Nearly half of the participants (44.3%) were in the third trimester, and 45.7% had an interpregnancy interval of more than 2 years.

Regarding sun exposure, 54.3% reported direct sun exposure less than 3 days per week, and 50.0% spent less than 15 minutes outdoors daily. Current vitamin D supplement use was reported by 55.7% of women, while 88.6% were taking prenatal multivitamins. The median serum 25(OH)D concentration was 15.3 ng/mL (IQR 10.0–25.7).

Prevalence of vitamin D deficiency

Vitamin D deficiency (25(OH)D < 20 ng/mL) was present in 39 of 70 participants, corresponding to a prevalence of 55.7% (95% CI 44.1–66.8%). Insufficiency (20–29.9 ng/mL) was found in 18 women (25.7%; 95% CI 16.9–37.0%), and sufficiency (≥30 ng/mL) in 13 women (18.6%; 95% CI 11.2–29.2%). Overall, 57 women (81.4%; 95% CI 70.8–88.8%) had deficient or insufficient vitamin D status.

Characteristics according to vitamin D status:

Table 1 compares the characteristics of women with and without vitamin D deficiency. The two groups were similar in age (median 34.0 vs. 30.0 years; p = 0.434), pre-pregnancy BMI (median 27.7 vs. 27.1 kg/m^2; p = 0.497), and gestational age (median 22.0 vs. 32.0 weeks; p = 0.115). No significant differences were observed by educational level, occupation, BMI category, trimester, gravidity, parity, or interpregnancy interval (all p > 0.05).

A statistically significant difference was found for frequency of direct sun exposure: 75.0% of women reporting sun exposure ≥3 days per week were deficient, compared with 39.5% of those reporting <3 days per week (p = 0.003). The proportion of deficient women increased progressively with the frequency of sun exposure: 35.7% (10/28) among those exposed less than once per week, 50.0% (5/10) for 1–2 days/week, 70.6% (12/17) for 3–4 days/week, and 80.0% (12/15) for 5–7 days/week. Other variables, including daily outdoor time, current vitamin D supplement use, regularity of supplementation, prenatal multivitamin use, and dietary intake of milk, fish, and eggs, did not differ significantly between groups (all p > 0.05).

Vitamin D deficiency: serum 25(OH)D <20 ng/mL (prevalence 39/70, 55.7%; 95% CI 44.1–66.8). BMI, body mass index; IQR, interquartile range; 25(OH)D, 25-hydroxyvitamin D. BMI category as recorded in the questionnaire; continuous BMI calculated from reported weight and height. Vitamin D supplement use as reported by the participants (current use). Regularity among women reporting current use: regular, every day or as advised by the physician; irregular, most days or occasionally. [a] Mann–Whitney U test. [b] n is the number of women in each category; percentages show the proportion of women within that category who were deficient or non-deficient. [c] Chi-square test, Fisher's exact test (2 × 2 tables with expected counts <5) or Monte Carlo exact test (larger tables with sparse cells).

Table 1. Characteristics of the pregnant women according to vitamin D status (N = 70)

Characteristic	Total (N = 70)	Deficient (n = 39)	Non-deficient (n = 31)	p-value
Continuous variables, median (IQR)				
Age, years	32.5 (27.0–38.0)	34.0 (28.0–38.0)	30.0 (26.0–38.0)	0.434[a]
Pre-pregnancy BMI, kg/m^2	27.4 (24.1–32.5)	27.7 (24.2–33.3)	27.1 (23.7–30.4)	0.497[a]
Gestational age, weeks	24.0 (11.8–36.2)	22.0 (11.0–33.0)	32.0 (12.0–39.0)	0.115[a]

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Received: *28-08-2026 -* ***Accepted:*** *26-10-2026 -* ***Published:*** *04-11-2026*

https://doi.org/10.54361/ajmas.261111

Gravidity	4.0 (2.0–5.0)	4.0 (2.0–5.0)	4.0 (2.0–5.0)	0.684[a]
Parity	3.0 (1.0–4.0)	3.0 (1.0–4.0)	3.0 (1.0–4.0)	0.557[a]
Serum 25(OH)D, ng/mL	15.3 (10.0–25.7)	10.0 (6.0–12.0)	27.0 (21.0–33.0)	—
Categorical variables, n (%)[b]				
Age group (years)				
<25 years	7	3 (42.9)	4 (57.1)	0.833[c]
25–34 years	33	19 (57.6)	14 (42.4)	
≥35 years	30	17 (56.7)	13 (43.3)	
Educational level				
Secondary	28	16 (57.1)	12 (42.9)	0.979[c]
University	33	18 (54.5)	15 (45.5)	
Postgraduate	9	5 (55.6)	4 (44.4)	
Occupation				
Housewife	28	15 (53.6)	13 (46.4)	0.768[c]
Employed/student	42	24 (57.1)	18 (42.9)	
Pre-pregnancy BMI category				
Normal/underweight	28	15 (53.6)	13 (46.4)	0.489[c]
Overweight	19	9 (47.4)	10 (52.6)	
Obese	23	15 (65.2)	8 (34.8)	
Trimester				
First	18	10 (55.6)	8 (44.4)	0.174[c]
Second	21	15 (71.4)	6 (28.6)	
Third	31	14 (45.2)	17 (54.8)	
Gravidity				
Primigravida (1)	8	4 (50.0)	4 (50.0)	1.000[c]
2–3	20	11 (55.0)	9 (45.0)	
≥4 (grand multigravida)	42	24 (57.1)	18 (42.9)	
Parity				
Nulliparous	10	5 (50.0)	5 (50.0)	0.926[c]
1–2	23	13 (56.5)	10 (43.5)	
≥3	37	21 (56.8)	16 (43.2)	
Interpregnancy interval				
First pregnancy	7	3 (42.9)	4 (57.1)	0.067[c]
<12 months	12	10 (83.3)	2 (16.7)	
1–2 years	19	7 (36.8)	12 (63.2)	
>2 years	32	19 (59.4)	13 (40.6)	
Frequency of direct sun exposure				
<3 days/week	38	15 (39.5)	23 (60.5)	0.003[c]
≥3 days/week	32	24 (75.0)	8 (25.0)	
Daily time outdoors				
<15 min/day	35	17 (48.6)	18 (51.4)	0.229[c]
≥15 min/day	35	22 (62.9)	13 (37.1)	
Current vitamin D supplement use				
No	31	18 (58.1)	13 (41.9)	0.724[c]
Yes	39	21 (53.8)	18 (46.2)	
Regularity of vitamin D supplementation				
Not taking	31	18 (58.1)	13 (41.9)	0.766[c]
Irregular	6	4 (66.7)	2 (33.3)	
Regular	33	17 (51.5)	16 (48.5)	
Prenatal multivitamin				
No	8	4 (50.0)	4 (50.0)	1.000[c]
Yes	62	35 (56.5)	27 (43.5)	
Milk/dairy intake				
<3 times/week	36	17 (47.2)	19 (52.8)	0.141[c]
≥3 times/week	34	22 (64.7)	12 (35.3)	
Oily fish intake				
<1/week	52	31 (59.6)	21 (40.4)	0.264[c]
≥1/week	18	8 (44.4)	10 (55.6)	

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Received: *28-08-2026 -* ***Accepted:*** *26-10-2026 -* ***Published:*** *04-11-2026*

https://doi.org/10.54361/ajmas.261111

Egg intake				
<3 times/week	27	16 (59.3)	11 (40.7)	0.636[c]
≥3 times/week	43	23 (53.5)	20 (46.5)	
Chronic medical condition				
No	65	37 (56.9)	28 (43.1)	0.649[c]
Yes	5	2 (40.0)	3 (60.0)	
Other medication use				
No	62	35 (56.5)	27 (43.5)	1.000[c]
Yes	8	4 (50.0)	4 (50.0)	

Factors associated with vitamin D deficiency

Table 2 presents crude and adjusted odds ratios for factors associated with vitamin D deficiency. In univariable analysis, an interpregnancy interval of <12 months was associated with higher odds of deficiency (crude OR 5.00; 95% CI 1.01–24.84; p = 0.049), while sun exposure <3 days per week was associated with lower odds (crude OR 0.22; 95% CI 0.08–0.61; p = 0.004). No other factor reached statistical significance in univariable analysis.

In the multivariable logistic regression model including five pre-specified factors, two associations remained statistically significant. An interpregnancy interval of <12 months was associated with markedly higher odds of vitamin D deficiency (adjusted OR 7.21; 95% CI 1.12–46.62; p = 0.038), although the very wide confidence interval reflects the small number of women in this subgroup (n = 12), and sun exposure <3 days per week remained associated with lower odds of deficiency (adjusted OR 0.24; 95% CI 0.08–0.73; p = 0.012). Current vitamin D supplement use, dairy intake, and third trimester were not significantly associated with deficiency in the adjusted model (p = 0.331, p = 0.133, and p = 0.106, respectively). The model showed acceptable fit (likelihood-ratio $\chi^2(5) = 18.3$, p = 0.003; Nagelkerke $R^2 = 0.31$; AUC = 0.76; Hosmer–Lemeshow p = 0.188).

Table 2. Crude and adjusted odds ratios for vitamin D deficiency

Factor	Deficient/total, n/N	Crude OR (95% CI)	p	Adjusted OR (95% CI)	Adjusted p
Housewife (vs employed/student)	15/28	0.87 (0.33–2.26)	0.768	—	—
Age ≥35 years	17/30	1.07 (0.41–2.78)	0.890	—	—
Overweight or obese (recorded category)	24/42	1.16 (0.44–3.02)	0.768	—	—
Obese (recorded category)	15/23	1.80 (0.64–5.04)	0.265	—	—
Grand multigravida (gravidity ≥4)	24/42	1.16 (0.44–3.02)	0.768	—	—
Parity ≥3	21/37	1.09 (0.43–2.81)	0.853	—	—
Interpregnancy interval <12 months	10/12	5.00 (1.01–24.84)	0.049	7.21 (1.12–46.62)	0.038
Sun exposure <3 days/week	15/38	0.22 (0.08–0.61)	0.004	0.24 (0.08–0.73)	0.012
Outdoors <15 min/day	17/35	0.56 (0.22–1.45)	0.231	—	—
No current vitamin D supplement	18/31	1.19 (0.46–3.07)	0.724	0.50 (0.12–2.04)	0.331
Irregular or no vitamin D supplementation	22/37	1.38 (0.54–3.56)	0.505	—	—
No prenatal multivitamin	4/8	0.77 (0.18–3.37)	0.730	—	—
Dairy <3 times/week	17/36	0.49 (0.19–1.28)	0.143	0.43 (0.14–1.29)	0.133
Oily fish <1/week	31/52	1.85 (0.63–5.45)	0.267	—	—
Eggs <3 times/week	16/27	1.26 (0.48–3.35)	0.636	—	—
University or higher education	23/42	0.91 (0.35–2.38)	0.844	—	—
Third trimester (vs 1st/2nd)	14/31	0.46 (0.18–1.21)	0.115	0.32 (0.08–1.27)	0.106
Chronic condition	2/5	0.50 (0.08–3.23)	0.470	—	—

OR, odds ratio; CI, confidence interval. Crude ORs were obtained from separate univariable logistic regressions. Adjusted ORs are from a single multivariable logistic regression including the five factors shown (likelihood-ratio $\chi^2(5) = 18.3$, p = 0.003; Nagelkerke $R^2 = 0.31$; AUC = 0.76; Hosmer–Lemeshow p = 0.188).

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Received: 28-08-2026 - **Accepted:** 26-10-2026 - **Published:** 04-11-2026

Discussion

This cross-sectional study found that vitamin D deficiency (25(OH)D <20 ng/mL) affected 55.7% of pregnant women attending a private antenatal clinic in Gharyan, western Libya. A short interpregnancy interval of less than 12 months was associated with higher odds of deficiency (adjusted OR 7.21), although the estimate was imprecise, whereas the association observed for reported sun exposure was in the opposite direction to that expected. These findings add pregnancy-specific evidence to the growing body of Libyan data showing that vitamin D deficiency is highly prevalent despite abundant sunshine, and they suggest that birth spacing deserves attention as a potentially modifiable factor in local antenatal care.

The high prevalence observed occurred despite the availability of dietary supplements; a recent survey of community pharmacists in Yefren, western Libya, reported generally good self-reported knowledge regarding supplement use [16]. The prevalence observed here is broadly consistent with the Libyan literature. A nationwide systematic review and meta-analysis of 20 observational studies (7,167 participants) estimated a pooled prevalence of vitamin D deficiency of 71.1% in the general population and 80.0% among pregnant women, confirming a Libyan "Mediterranean solar paradox" in which high ambient irradiance does not translate into adequate vitamin D status [17]. In western Libya specifically, a study of pregnant women in Surman reported that 79% had 25(OH)D <10 ng/mL and a further 17% had levels between 10 and 20 ng/mL [18]. A study from Al-Marj similarly documented a high rate of deficiency among pregnant women, with older age and lack of sun exposure among the factors identified [19]. The somewhat lower prevalence in the present sample may reflect differences in sampling, assay methods, and the proportion of women already taking supplements, but the overall pattern is consistent: deficiency was common among pregnant women in this clinic-based sample, as it is elsewhere in the region. This is also consistent with the wider Middle East and North Africa literature, where the prevalence of hypovitaminosis D in pregnant women has been reported to range between 54% and 90% [4].

The finding that women reporting sun exposure on ≥3 days per week had higher odds of deficiency than those reporting less frequent exposure requires careful interpretation. The gradient was consistent across all four response categories, which makes a simple coding error unlikely. At first inspection, this appears counterintuitive, but it is unlikely to indicate a protective effect of sun avoidance. Several explanations are plausible. Women who are already known to be deficient, or who have previously been advised about their vitamin D status, may deliberately increase time outdoors, creating reverse causation. Alternatively, reported frequency of exposure may not capture the quality of exposure: in Libya, as elsewhere in the region, traditional clothing that covers most of the body, the use of sunscreen, and avoidance of peak ultraviolet-B hours can markedly reduce cutaneous synthesis even when women report going outdoors frequently. The MENA literature has consistently identified veiling, clothing practices, and low effective sun exposure as key predictors of hypovitaminosis D in pregnant women [4]. The present data therefore probably reflect the limitations of self-reported exposure rather than a genuine adverse effect of sunlight, and they underscore the need for objective measures or more detailed exposure questionnaires in future studies.

The association between an interpregnancy interval of less than 12 months and vitamin D deficiency is a notable and potentially clinically relevant finding, although its precision was limited. Short interpregnancy intervals are known to deplete maternal nutrient reserves, and a synergistic effect between short intervals and micronutrient deficiency in early pregnancy has been described, with implications for later maternal and fetal outcomes [20]. The adjusted odds ratio of 7.21 observed here was large, although the confidence interval is wide because only 12 women reported an interval below 12 months. This finding should therefore be interpreted as hypothesis-generating, but it is biologically coherent: repeated pregnancies in close succession increase the cumulative metabolic demand for vitamin D and leave little time for repletion of maternal stores. If replicated, this would support the inclusion of interpregnancy interval in risk stratification for vitamin D deficiency and would reinforce the importance of preconception and postpartum supplementation, particularly in settings where short birth spacing is common.

In contrast to the interpregnancy interval, current vitamin D supplement use, dairy intake, and trimester were not significantly associated with deficiency in the adjusted model. The absence of a protective association for supplementation was not entirely surprising in the Libyan context. In the present study, 55.7% of women reported current vitamin D supplement use, but dose and duration were not analysed, and 6 of the 39 users (15.4%) reported irregular use. Previous Libyan work has suggested that standard supplementation practices may be insufficient to correct deficiency in pregnancy: in pregnant diabetic women in western Libya, routine supplementation with 400 IU/day did not ameliorate the severity of deficiency [21]. Moreover, trials using substantially higher doses (2,000–4,000 IU/day) have been required to achieve adequacy in pregnancy [22]. In addition, a cross-sectional analysis in Tobruk found that supplement use was associated with educational level, household income, and guidance from health professionals, factors that may be unevenly distributed across antenatal settings [23]. The lack of a clear trimester effect may reflect the small sample size and the cross-sectional design rather than a true absence of biological variation.

These findings must be interpreted within the limitations of the study. First, the sample size of 70 women is modest, which limits statistical precision and the power to detect modest associations. This is reflected in the wide confidence intervals around several estimates, including the prevalence itself (55.7%; 95% CI 44.1–66.8%). The non-significant associations for supplement use, dairy intake, and trimester should therefore be regarded as inconclusive rather than as evidence of no association, because the study was probably underpowered to detect them. Second, the subgroup analysis for short interpregnancy intervals is particularly vulnerable to this limitation: only 12 women reported an interval of less than 12

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Received: *28-08-2026 -* ***Accepted:*** *26-10-2026 -* ***Published:*** *04-11-2026*

months (10 deficient and 2 non-deficient), and the adjusted odds ratio of 7.21 had a 95% confidence interval of 1.12–46.62, with a lower limit close to the null value. With so few women in this subgroup, the estimate is unstable and may be inflated, and its statistical significance (p = 0.038) may not be robust to small changes in the data. In addition, the comparison group combined women with longer intervals and women in their first pregnancy, and the multivariable model included five factors for 31 women in the smaller outcome group (about six events per variable), which is below the commonly recommended minimum of ten and increases the risk of overfitting and sparse-data bias. Many factors were also examined without adjustment for multiple comparisons, so chance findings cannot be excluded. The interpregnancy-interval finding should therefore be considered exploratory and hypothesis-generating, and it requires confirmation in larger studies before any clinical or programmatic conclusions are drawn. Third, the convenience sampling strategy and the use of a self-administered questionnaire may have introduced selection and reporting bias. In addition, women attending a private clinic may differ in socioeconomic status and access to supplements from those using public antenatal services. Sun exposure and supplement use were self-reported and not validated against objective measures such as UV dosimetry or prescription records. The cross-sectional design precludes causal inference, and reverse causation cannot be excluded for the sun-exposure finding. Clothing style, sunscreen use, and skin type were not recorded, so residual confounding is possible. Finally, the study was conducted at a single private clinic in Gharyan over two months (September–October), and the findings cannot be generalised to other regions, to women attending public antenatal services, or to other seasons.

Notwithstanding these limitations, the study has several implications. It indicates that vitamin D deficiency was highly prevalent among pregnant women attending this clinic in Gharyan and that it coexisted with reported supplement use, suggesting that current preventive strategies may not be achieving adequate status. The signal for short interpregnancy intervals, if confirmed in larger prospective studies, would justify incorporating birth spacing into vitamin D risk assessment and counselling. The paradoxical sun-exposure finding highlights the need for qualitative and quantitative research on clothing practices, sunscreen use, and effective outdoor exposure in this population. From a programmatic perspective, the Libyan “solar paradox” is unlikely to be resolved by advice to “get more sun” alone; the national evidence base already points to food fortification, antenatal supplementation with adequate doses, and standardised diagnostic assays as priorities [17], and the present data are consistent with this multidimensional approach.

Conclusion

Vitamin D deficiency affected more than half of the pregnant women attending a private antenatal clinic in Gharyan, western Libya. A short pregnancy interval was associated with higher odds of deficiency, although the estimate was imprecise, whereas self-reported sun exposure showed an unexpected inverse association that probably reflected the limitations of self-reported exposure (clothing practices and timing of exposure were not recorded). Current vitamin D supplementation, as practised in this sample, did not appear sufficient to ensure adequacy. These findings call for larger multicenter prospective studies with objective exposure and adherence measures, and for antenatal strategies that combine appropriate supplementation, attention to birth spacing, and context-specific approaches to improving effective sun exposure or dietary intake.

Acknowledgements

The authors would like to thank the pregnant women who generously participated in this study, as well as the staff of the private clinic in Gharyan for their cooperation and assistance during data collection. The authors are also grateful to the Faculty of Medicine, University of Gharyan, for its support of this research.

Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

All authors contributed to the study conception and design, data collection, data analysis, and drafting of the manuscript. All authors read and approved the final manuscript.

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Received: *28-08-2026 -* ***Accepted:*** *26-10-2026 -* ***Published:*** *04-11-2026*

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Received*: 28-08-2026 -* ***Accepted****: 26-10-2026 -* ***Published****: 04-11-2026*