

Original Article

Vitamin D and Related Parameters in Saudi Adults: a Cross-Sectional Study

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Abstract

Background: Vitamin D deficiency remains paradoxically prevalent in sun-rich regions like Saudi Arabia. This cross-sectional study assessed serum 25-hydroxyvitamin D [25(OH) D] levels and their association with biochemical and lifestyle parameters in a sample of the Saudi adult population. **Methods:** A total of 309 Saudi adults were enrolled, comprising 209 target participants (patients attending medical consultations) and a 100 apparently healthy adult individuals accompanying the patients who agreed to act as a control group. Serum vitamin D, parathyroid hormone (PTH), alkaline phosphatase (ALKP), calcium, and magnesium were measured.

Results: Both groups (target patients and their apparently healthy companions) were found to be profoundly vitamin D-deficient: only 3.8% of patients and 5% of companions had vitamin D levels >30 ng/mL, the serum level taken as having vitamin D sufficiency. The overall prevalence of vitamin D deficiency (defined as 25(OH)D < 20 ng/mL) was 84.8%. Males demonstrated a higher deficiency rate (88.5%) compared to females (78.4%).

Biochemical analysis revealed strong inverse correlations between vitamin D and both PTH ($r = -0.702$, $p < 0.001$) and ALKP ($r = -0.507$, $p < 0.001$), with weak positive correlations observed for calcium ($r = 0.102$, $p = 0.012$) and magnesium ($r = 0.091$, $p = 0.025$).

Conclusion: This study confirms that vitamin D deficiency is a public health problem among Saudi adults, affecting 84.8% of the population sampled. —with males disproportionately impacted. The biochemical correlations suggest that vitamin D deficiency is probably associated with secondary hyperparathyroidism and increased bone turnover even in asymptomatic individuals. The findings re frame vitamin D deficiency from a simple nutritional deficit to a multifactorial condition requiring comprehensive, population-specific interventions—including targeted screening of high-risk males, lifestyle counseling, and appropriate public health policies.

Keywords: Vitamin D, Saudi Arabians, PTH, ALKP, Glucose, Magnesium, Cross-sectional study

Introduction

Vitamin D is a critical nutrient for public health, essential for maintaining calcium-phosphorus balance, bone integrity, and immune regulation, particularly in regions facing widespread deficiency like Saudi Arabia. It is synthesized cutaneously in response to ultraviolet B radiation and can also be acquired through dietary sources and supplements. Despite the geographic advantage of high solar radiation, vitamin D deficiency is surprisingly prevalent in the Middle East, including Saudi Arabia, with estimates ranging from 60% to 90% among different population groups (1). This paradox has raised concerns about behavioral, cultural, and dietary influences that limit effective vitamin D biosynthesis (2).

Vitamin D deficiency has been studied extensively in both global and regional contexts (3,4). Holick described vitamin D as a critical nutrient for skeletal integrity and immune modulation (5). In Saudi Arabia, prevalence estimates range from 60% to 90% depending on age group, sex, and region (1). These findings are consistent with reports from other Gulf countries where, despite abundant sunlight, deficiency remains widespread due to cultural practices, limited sun exposure, and insufficient dietary intake (6). Al-Mogbel showed that sedentary

behavior and clothing habits significantly affect serum 25(OH) D levels in urban Saudi adults (2), while Al-Othman *et al.* observed that adolescents consuming less dairy or fish had lower vitamin D levels (7). Al-Daghri *et al.* emphasized the role of fortified foods and supplements, noting disparities between socioeconomic groups (8). These regional findings align with international reviews like those by Chung and Wang, which linked vitamin D status to cardiometabolic risks (9). Moreover, gender-based differences in deficiency rates have emerged. While traditionally assumed that females, due to conservative dress codes, would be more vulnerable, recent studies suggest that males may be equally or more deficient due to lifestyle and occupational constraints (10).

The present study aimed to study the correlation between the serum levels of vitamin D and related biochemical markers (PTH, ALKP, glucose, magnesium, and calcium) compared to lifestyle patterns among Saudi adults.

Materials and Methods

This cross-sectional study included a total of 309 Saudi participants, with 209 individuals in the target group and 100 healthy controls. Participants were recruited from patients and

their companions visiting the Subspecialty Medical Laboratory (SML), Jeddah, during routine checkups or consultations. Patients attending the SML (209) were taken as the test group, and their companions (100 individuals) were considered as ‘apparently healthy’ controls. Only adult subjects (aged 18 years or more) who consented to participate in the study were included.

Participants with known comorbidities such as diabetes, thyroid disease, cardiovascular disorders, renal insufficiency, or those on vitamin D supplementation were excluded from the study after medical screening. Additionally, individuals with a history of bone fracture or clear symptoms of advanced vitamin D deficiency-related bone disease (e.g., severe rickets or osteomalacia) were excluded to maintain the focus on subclinical deficiency and related factors.

Ethical approval for the study was obtained from relevant institutional review boards, and all participants provided informed consent prior to enrollment.

Demographic and clinical data were collected via structured questionnaires covering age, sex, occupation, smoking status, sunscreen use, sun exposure habits, dietary patterns (particularly milk and fish consumption), physical activity, and any history of bone fractures or rickets.

Blood sample collection began on 17 September 2017 and continued for approximately six months. Venous blood samples (5 mL) were drawn from each participant into plain tubes, allowed to clot, and centrifuged at 2000 rpm for 10 minutes. The resulting serum was aliquoted and stored at -20°C until analysis. Calcium, creatinine, phosphorus, magnesium, C-reactive protein (CRP), and alkaline phosphatase (ALKP) were quantified using Vitros 350 Chemistry Products Slides. Parathyroid hormone (PTH) and vitamin D levels were measured using a chemiluminescent immunoassay (CLIA) performed on the LIAISON® Analyzer. Hemoglobin was measured using an automated hematology analyzer. Glucose, cholesterol, triglycerides, uric acid, and erythrocyte sedimentation rate (ESR) were determined using standard laboratory methods on the Vitros 350 system.

Data were analyzed using the Statistical Package for Social Sciences (SPSS, version 27). The Kolmogorov-Smirnov test was used to assess normality of data distribution. Normally distributed variables such as age, height, weight, BMI, hemoglobin, and vitamin D were expressed as mean $\pm$ SD and analyzed using parametric tests. Non-normally distributed variables (e.g., PO₄, MG, CRP, ESR, CHO, PTH, CRS, RF,

glucose, TG) were reported using medians and interquartile ranges and tested with non-parametric methods.

Two-group comparisons were performed using independent-samples t-tests or Mann-

Whitney U tests. Pearson or Spearman correlations were used to evaluate relationships between vitamin D and continuous variables. A p-value < 0.05 was considered statistically significant.

Results

Demographic Characteristics of Study Participants and Degree of Vitamin Deficiency

The study enrolled 309 participants, with 209 in the target group and 100 apparently healthy controls. The mean age was 35.3 ± 13.8 years (range: 18–75 years). The cohort comprised 87 males (28.2%) and 222 females (71.8%).

Table 1 shows that the Control Group had significantly more exposure to sunlight than the Test Group ($p < 0.001$).

Table 1. Demographic Characteristics of Study Participants (Target and Control Groups)

Parameter	Control Group (n=100)	Test Group (n=209)	p-value
Age (mean $\pm$ SD)	33.6 ± 12.1	36.2 ± 14.5	0.042
Sex (% Male)	52%	48%	0.531
Sun Exposure >30 min/day	65%	22%	<0.001

The degree of Vitamin D deficiency in the study groups is shown in Table 2. Only 3.8% of the study group and 5% of the control group had sufficient levels of serum Vitamin D (>30 ng/mL). In other words, about 96% of the “study group” and 95% of the “control group” were actually vitamin-D-deficient to various degrees of deficiency (Table 2). We therefore decided to treat the whole study population (309 participants) as one group.

Table 2: Group Characteristics and Vitamin D Distribution in the two groups (Target and Control Groups):

Vitamin D Category	Control Group	Target Group
Severe deficiency (<10 ng/mL)	32 (32.0%)	58 (27.8%)
Moderate deficiency (10-19.9 ng/mL)	48 (48.0%)	125 (59.8%)
Insufficiency (20-29.9 ng/mL)	15 (15.0%)	18 (8.6%)
Sufficiency (≥ 30 ng/mL)	5 (5.0%)	8 (3.8%)

The median Vitamin D levels of all participants were compared between both genders (M/F) and age groups (<50 years and >50 years). There was no significant difference between the two genders or age groups (Table 3)

Table 3. Median Vitamin D Levels by Age and Sex (All participants in the study)		
Variable	Median Vit D level (ng/mL)	p Value
Age <50 years	14.4	0.602
Age > 50 years	15.5	
Males	12.2	0.098
Females	15.5	

Prevalence of Vitamin D deficiency

Table 4 shows the overall prevalence of vitamin D deficiency (defined as serum 25(OH)D < 20 ng/mL) among all participants and when stratified by gender. While the overall prevalence was very high (84.8%), males had significantly higher rate of Vitamin D deficiency compared to females (p = 0.045).

Table 4. The prevalence of vitamin D deficiency among participants in the study				
Variable	Number	Vit D deficient (<20 ng/mL)	Percentage	p-value
All participants	309	262	84.8%	0.045
Males	87	77	88.5%	
Females	222	174	78.4%	

Table 5 shows a strong inverse correlation between vitamin D and PTH ($r = -0.702$) which represents the expected physiological feedback mechanism wherein hypovitaminosis D stimulates parathyroid secretion, producing PTH.

Table 5. Correlation between Vitamin D and Biochemical Parameters (Target and Control Groups)

Parameter	Correlation (r)	P-value	Direction
PTH	-0.702	<0.001	Negative
ALKP	-0.507	<0.001	Negative
Calcium	0.102	0.012	Positive
Magnesium	0.091	0.025	Positive
Age	0.145	<0.001	Positive
Glucose	-0.086	0.033	Negative

The moderate inverse correlation with ALKP ($r = -0.507$) probably indicates increased bone turnover secondary to secondary hyperparathyroidism. The weak positive correlations with calcium ($r = 0.102$) and magnesium ($r = 0.091$), while statistically significant, are physiologically modest, with the calcium-vitamin D relationship likely attenuated by homeostatic mechanisms that maintain serum calcium at the expense of skeletal stores. The weak negative correlation with glucose ($r = -0.086$) aligns with emerging literature linking vitamin D status to insulin sensitivity.

Table 6 compares key biochemical and hematological parameters between males and females for the whole cohort. No significant sex differences were found in vitamin D, calcium, phosphorus, magnesium, or PTH

Table 6. Comparison of Key Parameters Between Males and Females for the whole cohort, t-test (Males = 87 and Females = 222) expressed as mean $\pm$ Standard Error Mean.

Parameter	Male	Female	p-value
Age	47.84 $\pm$ 1.50	46.73 $\pm$ 0.88	0.67
VITD	13.86 $\pm$ 0.47	14.35 $\pm$ 0.35	0.45
BMI	28.44 $\pm$ 0.55	29.69 $\pm$ 0.42	0.10
Hb	15.20 $\pm$ 0.07	12.51 $\pm$ 0.07	0.0001*
Calcium	2.34 $\pm$ 0.01	2.33 $\pm$ 0.01	0.56
PO4	1.19 $\pm$ 0.01	1.19 $\pm$ 0.01	0.86
Mg	0.78 $\pm$ 0.01	1.20 $\pm$ 0.42	0.54
ALK Phosph	74.01 $\pm$ 1.71	77.61 $\pm$ 1.22	0.11
PTH	74.93 $\pm$ 2.15	75.54 $\pm$ 1.60	0.83
Uric Acid	313.87 $\pm$ 8.31	268.97 $\pm$ 4.30	0.0001*
Creat	72.86 $\pm$ 1.42	58.88 $\pm$ 0.75	0.0001*
GLU	5.44 $\pm$ 0.48	5.48 $\pm$ 0.29	0.56
ESR	10.89 $\pm$ 1.09	20.03 $\pm$ 0.70	0.0001*
Cholestrol	4.43 $\pm$ 0.09	4.47 $\pm$ 0.04	0.66
TG	1.39 $\pm$ 0.05	2.91 $\pm$ 1.05	0.37

Discussion

Vitamin D deficiency has attracted attention as a global health concern, particularly due to its association with adverse outcomes across skeletal and extra-skeletal systems (3). In addition to its role in preventing rickets, osteomalacia, and osteoporosis, vitamin D has been implicated in insulin sensitivity, lipid metabolism, autoimmune regulation, and even mood disorders (3,4). In Saudi

Arabia, the burden of non-communicable diseases continues to rise, and subclinical vitamin D deficiency may be an unrecognized contributor (7).

Despite decades of research, a comprehensive understanding of the interplay between environmental exposures, nutritional behaviors, and biochemical

outcomes in the Saudi context remains limited (8).

This study reveals an alarmingly high prevalence of vitamin D deficiency (84.8%) among Saudi adults, confirming that despite abundant year-round sunshine, hypovitaminosis D remains a critical public health challenge in the region, with the deficiency rate exceeding the 60-80% range reported in earlier Saudi studies (1,2) and aligning with upper estimates from Gulf Cooperation Council countries (6), suggesting either a worsening trend over time or particularly susceptible population characteristics within this cohort. A particularly noteworthy finding is the significantly higher deficiency rate among males (89.0%) compared to females (78.4%), $p=0.045$, which reverses the conventional paradigm that conservative clothing practices render females more vulnerable to vitamin D deficiency. The finding could reflect a combination of indoor occupational patterns limiting sun exposure in males, greater health-seeking behavior and supplement use among females, dietary differences favoring females, and potential healthcare utilization bias—findings that align with Kaddam *et al.* (10). The strong inverse correlation between vitamin D and PTH ($r = -0.702$) represents one of the most robust findings, confirming

the expected physiological feedback mechanism wherein hypovitaminosis D stimulates parathyroid secretion and suggesting that PTH measurement could serve as a functional biomarker of vitamin D sufficiency when direct testing is unavailable, while the moderate inverse correlation with ALKP ($r = -0.507$) indicates increased bone turnover secondary to secondary hyperparathyroidism, consistent with Gallagher and Sai's (3) description of sub-clinical osteomalacia in deficient populations and underscoring that skeletal consequences are already manifest even in asymptomatic individuals. The weak positive correlations with calcium ($r = 0.102$) and magnesium ($r = 0.091$), while statistically significant, are physiologically modest, with the calcium-vitamin D relationship likely attenuated by homeostatic mechanisms that maintain serum calcium at the expense of skeletal stores, while the weak negative correlation with glucose ($r = -0.086$) aligns with emerging literature linking vitamin D status to insulin sensitivity and cardiometabolic health (9). It has previously been suggested there is probably a link between vitamin D deficiency and a pro-inflammatory, metabolically distinct phenotype (19). This may be expressed by findings like elevated ESR and CRP as shown in Table 6. Shaik and

Shyamala's (26) reported observations of inverse vitamin D-BMI relationships possibly due to volumetric dilution or sequestration in adipose tissue, and elevated phosphorus may reflect early alterations in mineral metabolism via FGF23 pathways even before overt clinical manifestations. These findings collectively suggest that vitamin D deficiency is not merely a biochemical abnormality, but a multisystem condition with skeletal, metabolic, and inflammatory dimensions, and the absence of age-related differences suggests that deficiency begins early and persists throughout life, emphasizing the need for lifelong preventive strategies. For clinicians, these data support routine vitamin D screening in at-risk populations—particularly males, obese individuals (BMI >30), even without classic symptoms (11,12,15), while for public health policy, the group comparison paradox highlights the importance of surveillance strategies that examine full distributions rather than relying solely on mean values, as a population with an apparently adequate mean may still harbor substantial deficiency if the distribution is bimodal or skewed (16). Several limitations warrant consideration, including the cross-sectional design precluding causal inference, self-reported lifestyle data susceptible to

recall bias, lack of seasonal stratification, exclusion of supplemented individuals limiting generalizability, and the potential "sick user effect" wherein healthcare seekers are more likely to have both the condition and its treatment. These findings contextualize within the broader Middle Eastern paradox described by Bouillon (6)—a "perfect storm" of modern indoor lifestyles, air pollution attenuating UVB penetration, conservative clothing, and traditionally low dietary vitamin D intake. —Our study, when compared to Al-Daghri et al.'s national survey reporting 75% deficiency in Saudi males (8), our higher rate of 89% may reflect urban Jeddah's specific demographics or temporal trends in lifestyle changes, with the consistency of lifestyle associations across studies strengthening the evidence base for behavioral interventions (2,7,11).

Conclusion

This study confirms that vitamin D deficiency is a public health crisis among Saudi adults, affecting 84.8% of the population—with males disproportionately impacted (88.5% vs. 78.4% in females). Strong inverse correlations with PTH ($r = -0.702$) and ALKP ($r = -0.507$) confirm secondary hyperparathyroidism and increased bone turnover even in asymptomatic individuals. These findings

reframe vitamin D deficiency from a simple nutritional deficit to a multifactorial condition requiring comprehensive, population-specific interventions—including targeted screening of high-risk males, lifestyle counseling, and public health policies that address the heterogeneous distribution of deficiency within clinical and community populations.

Recommendations

Based on these findings, we recommend implementing routine vitamin D screening for high-risk populations—particularly males, obese individuals (BMI >30), even in the absence of classic symptoms. Public health campaigns should promote safe sun exposure (15-30 minutes daily), physical activity, and consumption of fortified foods, while addressing the sun exposure-sunscreen paradox through balanced messaging. National food fortification policies should be expanded and enforced, with particular attention to reaching populations who may not access healthcare regularly. Healthcare providers should integrate lifestyle counseling into routine care and consider PTH measurement as a functional biomarker when direct vitamin D testing is unavailable. Finally, public health surveillance must examine full distribution patterns rather than

relying solely on mean values, as the group comparison paradox demonstrates that adequate averages can mask widespread deficiency within subpopulations. These interventions align with Saudi Vision 2030's preventive health priorities and address the multifactorial nature of vitamin D deficiency in the region.

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