Retrospective Evaluation of the Association Between Vitamin D Status and Blood Pressure Among Saudi Adolescents: A Five-Year Cohort Study

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Abstract

Background: Vitamin D deficiency is prevalent among adolescents and may contribute to cardiometabolic risk factors, including elevated blood pressure. Limited evidence exists regarding this association in Saudi adolescents.

Objective: To evaluate the association between vitamin D status and blood pressure in a retrospective cohort of Saudi adolescents.

Methods: We reviewed electronic health records of 1,960 adolescents (12–18 years) attending King Faisal University-affiliated medical centers from January 2019–September 2024. Serum 25(OH)D levels, anthropometrics, blood pressure readings, and metabolic parameters were extracted. Adolescents were categorized as vitamin D deficient (<30 nmol/L), insufficient (30–49 nmol/L), or sufficient (≥50 nmol/L). Multivariable linear and logistic regression analyses examined the relationship between vitamin D categories and blood pressure status, adjusting for age, sex, BMI, and metabolic factors.

Results: Vitamin D deficiency was observed in 42.4% of participants. Deficient adolescents had higher mean systolic and diastolic blood pressure and a greater prevalence of prehypertension/hypertension (27.1%) compared to sufficient peers (15.2%; p<0.001). Adjusted analyses revealed that vitamin D deficiency was associated with increased odds of elevated blood pressure (OR=1.58, 95% CI: 1.29–1.93, p<0.001). Sensitivity analyses stratified by BMI and sex produced consistent findings.

Conclusions: Vitamin D deficiency was independently associated with elevated blood pressure in Saudi adolescents. Addressing vitamin D deficiency may serve as an early preventive measure against the development of hypertension and its sequelae. Further prospective and interventional studies are warranted to guide clinical practice.

Keywords: Vitamin D deficiency, Blood pressure, Adolescents, Saudi Arabia, Retrospective Cohort, Cardiometabolic risk

Introduction

Vitamin D deficiency is recognized as a global public health problem that disproportionately affects children and adolescents, including those in sun-rich regions such as the Middle East [1–4]. Hypovitaminosis D in youth is associated not only with skeletal issues but also with a spectrum of cardiometabolic disturbances, including obesity, insulin resistance, and, increasingly, elevated blood pressure [2,3,9,16]. Adolescence is a critical window for establishing long-term cardiometabolic health trajectories. Early-life risk factors, such as vitamin D deficiency, may predispose individuals to hypertension and cardiovascular disease in adulthood [1,4,16].

Despite abundant sunlight, Saudi adolescents exhibit a high prevalence of vitamin D deficiency, influenced by lifestyle factors, limited sun exposure, dietary insufficiencies, and cultural attire [5–7]. While the associations between vitamin D status and cardiometabolic markers have been reported in various populations [2,9,14,15], data focusing on Saudi adolescents, particularly the link between vitamin D levels and blood pressure, remain limited.

The complex mechanisms underlying the vitamin D–blood pressure relationship are not fully elucidated, but proposed pathways include the modulation of the renin-angiotensin system, endothelial function, and inflammatory processes [18–22]. Understanding these relationships in Saudi adolescents is clinically significant, given the region's high burden of vitamin D deficiency and emerging pediatric hypertension trends [1,16].

This retrospective cohort study aimed to investigate whether vitamin D deficiency is associated with elevated blood pressure among Saudi adolescents. We hypothesized that adolescents with lower vitamin D levels would have higher blood pressure readings and an increased prevalence of prehypertension and hypertension compared to those with sufficient vitamin D status. The findings may inform future screening, preventive strategies, and targeted interventions to reduce early cardiovascular risk in this vulnerable population.

Methods

This retrospective study was conducted according to the STROBE guidelines and approved by the Institutional Review Board of King Faisal University (Ref No: KFU-IRB-2023-076). The requirement for individual informed consent was waived due to the use of de-identified medical records.

Study Design and Setting

We reviewed electronic health records (EHRs) from King Faisal University-affiliated medical centers located in the Eastern Province of Saudi Arabia. The data included clinical visits between January 2019 and September 2024.

Study Population

Adolescents aged 12–18 years at their first visit during the study period were eligible for inclusion. We included participants with at least one measurement of serum 25(OH)D and recorded blood pressure. Exclusion criteria included chronic kidney disease, endocrine disorders affecting vitamin D metabolism, long-term steroid use, and incomplete data on key variables (height, weight, blood pressure, and vitamin D level).

Sample Size and Sampling

We identified 2,150 eligible adolescents, of whom 1,960 had complete data for the primary outcomes. This sample provided ≥80% power to detect a moderate association between vitamin D status and elevated blood pressure at a 5% significance level based on previous estimates of vitamin D deficiency and hypertension prevalence in similar populations [1,2,16].

Data Collection

Demographic data (age, sex), anthropometrics (height, weight, BMI), and lifestyle factors

(recorded where available) were extracted. Serum 25(OH)D levels were measured by liquid chromatography-tandem mass spectrometry. We categorized vitamin D status as:

- Deficient: <30 nmol/L
- Insufficient: 30–49 nmol/L
- Sufficient: ≥50 nmol/L [3,4,9].

Blood pressure was measured using standard pediatric protocols [1,3]. Systolic (SBP) and diastolic (DBP) readings were averaged from two recordings. Blood pressure categories followed established pediatric guidelines: normal, prehypertension, and hypertension [1].

Variables

The primary exposure was vitamin D status. The main outcome was blood pressure category (normal vs. elevated [prehypertension/hypertension]). Covariates included age, sex, BMI (converted to age- and sex-adjusted percentiles), and metabolic factors (fasting glucose, lipid profile where available).

Ethical Considerations

The study adhered to the Declaration of Helsinki and local regulatory standards. Data were anonymized, and no patient identifiers were retained.

Statistical Analysis

Data were analyzed using SPSS v28.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ± SD or median (IQR) if skewed. Categorical variables were reported as frequencies and percentages. Between-group comparisons employed t-tests, ANOVA, or chi-square tests as appropriate.

Multivariable linear regression examined associations between vitamin D categories and SBP/DBP. Logistic regression assessed the odds of elevated blood pressure by vitamin D status, adjusting for age, sex, BMI, and metabolic variables. Missing data were <5% and addressed using multiple imputation. Sensitivity analyses stratified by sex and BMI category were performed.

Results

A total of 1,960 adolescents were included in the final analysis. Mean age was 15.1 ± 1.7 years, and 51.4% were female. Table 1 presents baseline characteristics by vitamin D status.

Table 1. Baseline Characteristics Stratified by Vitamin D Status

Characteristic	Deficient (<30 nmol/L) N=832	Insufficient (30–49 nmol/L) N=640	Sufficient (≥50 nmol/L) N=488	p-value*
Age (years), mean ±SD	15.0 ±1.8	15.2 ±1.7	15.3 ±1.7	0.112
Female, n (%)	435 (52.3)	331 (51.7)	240 (49.2)	0.360
BMI (kg/m²), mean ±SD	24.2 ±4.1	23.5 ±3.9	22.9 ±3.7	<0.001
Overweight/Obese, n (%)	245 (29.4)	159 (24.8)	99 (20.3)	<0.001
25(OH)D (nmol/L), mean ±SD	24.1 ±4.5	38.2 ±5.1	59.8 ±8.2	<0.001
Fasting Glucose (mmol/L), mean ±SD	5.0 ±0.5	4.9 ±0.4	4.9 ±0.4	0.028

Characteristic	Deficient (<30 nmol/L) N=832	Insufficient (30–49 nmol/L) N=640	Sufficient (≥50 nmol/L) N=488	p-value*
HDL-C (mmol/L), mean ±SD	1.1 ±0.3	1.2 ±0.3	1.3 ±0.3	<0.001
LDL-C (mmol/L), mean ±SD	2.8 ±0.7	2.7 ±0.6	2.5 ±0.6	<0.001

*p-value from ANOVA or chi-square test. Abbreviations: BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

Vitamin D deficiency was noted in 42.4% of the sample. Deficient adolescents had higher BMI, lower HDL-C, and higher LDL-C compared to their sufficient peers (p<0.001). Table 2 details blood pressure parameters across vitamin D status groups.

Table 2. Blood Pressure Measures by Vitamin D Status

Variable	Deficient (<30 nmol/L) N=832	Insufficient (30–49 nmol/L) N=640	Sufficient (≥50 nmol/L) N=488	p-value*
SBP (mmHg), mean ±SD	119.6 ±9.8	116.1 ±9.2	114.9 ±9.0	<0.001
DBP (mmHg), mean ±SD	77.8 ±7.1	75.6 ±6.9	74.8 ±6.7	<0.001
Prehypertension/Hypertension, n (%)	225 (27.1)	127 (19.8)	74 (15.2)	<0.001

*p-value from ANOVA or chi-square test.

Deficient adolescents had significantly higher mean SBP and DBP than those with sufficient vitamin D (p<0.001). The prevalence of prehypertension/hypertension was notably greater in the deficient group.

Table 3 presents multivariable logistic regression results. After adjusting for age, sex, BMI, and metabolic factors, vitamin D deficiency remained significantly associated with elevated blood pressure.

Table 3. Adjusted Odds Ratios (OR) for Elevated Blood Pressure by Vitamin D Status

Variable	OR (95% CI)	p-value
Vitamin D Deficient vs. Sufficient	1.58 (1.29–1.93)	<0.001
Vitamin D Insufficient vs. Sufficient	1.27 (1.01–1.59)	0.043
Age (per year)	1.03 (0.98–1.08)	0.197
Male Sex	1.12 (0.93–1.35)	0.221
BMI (per kg/m²)	1.05 (1.03–1.07)	<0.001
LDL-C (per mmol/L)	1.16 (1.07–1.26)	0.001

Deficient and insufficient vitamin D levels increased the odds of elevated blood pressure compared to sufficient levels. BMI and LDL-C were also significant covariates.

To explore potential effect modification, we conducted stratified analyses by sex and BMI category (normal-weight vs. overweight/obese). Results in Table 4 demonstrate consistent

associations across subgroups, suggesting the vitamin D–blood pressure relationship was robust.

Table 4. Stratified Analyses: Association of Vitamin D Deficiency with Elevated Blood Pressure

Subgroup	OR (95% CI) for Deficient vs. Sufficient	p-value
Males (N=953)	1.60 (1.21–2.10)	0.001
Females (N=1,007)	1.55 (1.18–2.04)	0.002
Normal Weight (N=1,414)	1.53 (1.18–1.98)	0.001
Overweight/Obese (N=546)	1.64 (1.24–2.18)	<0.001

The relationship persisted irrespective of sex or weight category.

Discussion

This retrospective study demonstrated a significant inverse association between vitamin D status and blood pressure levels in Saudi adolescents. Those with deficient vitamin D levels had notably higher SBP and DBP and were more likely to present with prehypertension or hypertension compared to adolescents with sufficient vitamin D. These findings align with accumulating evidence linking hypovitaminosis D to cardiometabolic disturbances in pediatric populations [1–4,16,24].

Our results are particularly relevant in the Saudi context, where adolescents have high rates of vitamin D deficiency despite abundant sunlight [5–7]. Previous research has highlighted those cultural practices, limited outdoor activity, and dietary inadequacies contribute to inadequate vitamin D levels [6,7]. The current study expands on these findings by showing that vitamin D deficiency may also predispose adolescents to early elevations in blood pressure, a key cardiometabolic risk factor.

Several potential mechanisms may explain the vitamin D–blood pressure relationship. Vitamin D may modulate the renin-angiotensin-aldosterone system (RAAS), improve endothelial function, and exert anti-inflammatory effects [18–22]. Deficiency states could dysregulate RAAS, leading to elevated blood pressure. Our adjusted models accounted for key metabolic factors, suggesting that the association is not solely due to confounding by obesity or dyslipidemia. Instead, low vitamin D status appears to be an independent contributor to elevated blood pressure risk.

The findings are consistent with global literature. For instance, Abboud et al. and Hauger et al. highlight that vitamin D supplementation or adequate status correlates with improved cardiometabolic profiles, including blood pressure control [24,128]. Similarly, meta-analyses have suggested that improving vitamin D status may beneficially influence blood pressure in pediatric and adult populations [129–132]. Given that adolescence is a formative period for establishing long-term cardiovascular health, early identification and correction of vitamin D deficiency could mitigate the progression to persistent hypertension and its associated morbidity [1,16].

Our study contributes to the existing body of knowledge by providing region-specific insights. Although numerous international studies have examined vitamin D and cardiometabolic outcomes, research focusing on Saudi adolescents remains limited. By leveraging a large retrospective cohort and adjusting for pertinent confounders, we offer compelling evidence that vitamin D deficiency is linked to higher blood pressure in this unique population.

The study's strengths include the sizable sample, adjustment for multiple confounders, and comprehensive assessment of anthropometric and metabolic factors. We also employed rigorous statistical methods and sensitivity analyses, confirming the robustness of the findings

across subgroups. However, limitations must be acknowledged. The retrospective design precludes causality inference. We lacked data on dietary vitamin D intake, physical activity, and sunlight exposure patterns, which could further explain variations in vitamin D status. Additionally, our categorization of vitamin D thresholds, although widely utilized, may not fully capture the complexity of vitamin D's optimal levels for cardiometabolic health [3,4,9].

In the future, prospective interventional studies or randomized controlled trials involving vitamin D supplementation could elucidate whether correcting deficiency lowers blood pressure and improves cardiometabolic outcomes. Understanding dose-response relationships and identifying subpopulations that derive the greatest benefit from supplementation would enhance clinical and public health strategies. Integrating vitamin D screening into routine adolescent health checks, especially in regions prone to deficiency, may be a cost-effective measure to prevent early cardiovascular risks.

Regarding our tables, Table 1 demonstrated that vitamin D deficiency was associated with unfavorable anthropometric and metabolic profiles, including higher BMI and LDL-C. Table 2 revealed a stepwise increase in blood pressure indices and prevalence of elevated blood pressure across worsening vitamin D categories. Table 3 confirmed the independent relationship between vitamin D deficiency and elevated blood pressure after adjusting for key covariates, while Table 4 showed consistency of this association across sex and BMI subgroups. These patterns collectively suggest that vitamin D sufficiency could have protective cardiometabolic implications during adolescence.

Conclusion

Our findings underscore the clinical importance of addressing vitamin D deficiency in Saudi adolescents. Deficient vitamin D status was independently associated with elevated blood pressure, suggesting that hypovitaminosis D might be an overlooked factor contributing to early hypertension risk. Improving vitamin D levels through dietary interventions, supplementation, or lifestyle modifications could represent a strategic approach to safeguarding future cardiovascular health in this population. Prospective studies are needed to confirm these results and guide evidence-based recommendations for vitamin D optimization in adolescence.

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