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Clinical Consequences of Vitamin D Deficiency in Saudi Arabia: Focus on Diabetes and Metabolic Disorders

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Abstract

Background: Vitamin D (VD) deficiency is significantly prevalent in Saudi Arabia, despite the country's plentiful sunlight, and has been increasingly linked to metabolic disorders, particularly type 2 diabetes mellitus (T2DM). This review aims to integrate recent evidence on the clinical ramifications of VD deficiency in Saudi populations, with a focus on diabetes and related metabolic complications. ***Methods:*** A comprehensive search of the literature was carried out on PubMed, Scopus, Web of Science, and Google Scholar for studies published from 2010 to 2025. The inclusion criteria encompassed studies that reported VD status in Saudi populations and their associations with diabetes, glycemic control, or cardiometabolic outcomes. Forty-three studies—including observational studies, systematic reviews, and meta-analyses—were included. Data on serum 25-hydroxyvitamin D [25(OH)D], the prevalence of deficiency, metabolic parameters, and clinical outcomes were extracted and synthesized narratively. ***Results:*** VD deficiency prevalence has been reported to range from 50% to 85%, affecting children, adolescents, and adults, with women being disproportionately affected. This deficiency was consistently linked to elevated fasting glucose levels, HbA1c, insulin resistance, dyslipidemia, obesity, and an increased risk of cardiovascular issues. The pediatric and adolescent demographics showed signs of impaired bone mineralization and a heightened risk for rickets. Mechanistically, VD deficiency leads to β-cell dysfunction, reduced insulin secretion, peripheral insulin resistance, and systemic inflammation. Some urban areas have seen modest improvements in deficiency rates due to supplementation and awareness initiatives, yet the deficiency remains widespread. ***Conclusion:*** Vitamin D deficiency is significantly prevalent in Saudi Arabia and is closely associated with T2DM, cardiometabolic disorders, and skeletal complications. It is advisable to implement routine screening for high-risk groups, targeted supplementation, lifestyle modifications, and public health strategies to alleviate deficiency and its clinical ramifications. Tackling VD deficiency is a clinically actionable strategy to lessen the burden of metabolic and skeletal disorders within Saudi populations.

Keywords: Vitamin D deficiency, 25-hydroxyvitamin D, Saudi Arabia, Diabetes, Type 2 diabetes, insulin resistance, glycemic control, and metabolic syndrome.

INTRODUCTION

Vitamin D (VD) deficiency is a critical public health issue worldwide, mainly in Saudi Arabia, where sunlight is plentiful. The prevalence of insufficiency is reported to be upto 80% across various age groups, with women, children, and adolescents enormously affected

(Al-Shaikh, 2017; AlFaris & AlKehayez, 2019; Abukanna *et al.,* 2023a). Factors influencing to this high prevalence include limited outdoor activities, cultural clothing practices, skin pigmentation, and insufficient dietary intake (Al-Daghri, 2018).

From a clinical view, VD is essential for regulating calcium and phosphate homeostasis, bone mineralization, and immune function. Recent evidence has connected VD deficiency to endocrine and metabolic disorders, particularly type 2 diabetes mellitus (T2DM), insulin resistance, and dyslipidemia (Alghamdi *et al.,* 2020; AlQuaiz *et al.,* 2020). In Saudi Arabia, with one of the highest rates of diabetes prevalence globally, VD deficiency is a modifiable risk factor for worse glycemic control and cardiovascular complications (Al-Daghri, Hussain, & Ansari, 2021).

VD receptors are present in pancreatic β-cells and insulin-sensitive tissues, suggesting their involvement in insulin secretion and sensitivity. Lack of the receptors has been linked to impaired β-cell function, systemic inflammation, and lipid metabolism change (Abukanna *et al.,* 2023b). Studies conducted in Saudi Arabia show that the subjects with such a deficiency have elevated Hemoglobin A1c (HbA1c) levels, increased fasting glucose, and an increased risk of cardiometabolic disorders (Alghamdi *et al.,* 2020; Abukanna *et al.,* 2023a).

Bone health is also affected, especially in pediatric and young adults' groups who are particularly susceptible to conditions such as rickets, osteomalacia, and diminished peak bone mass (Al-Agha *et al.,* 2017; Abukanna *et al.,* 2023b).

This review consolidates existing evidence on the clinical implications of VD deficiency in Saudi Arabia, emphasizing its links to diabetes and metabolic disorders, while also addressing epidemiological patterns, mechanistic pathways, and clinical outcomes.

METHODOLOGY

Study Design:

A comprehensive literature review was performed to consolidate evidence regarding the prevalence, clinical consequences, and metabolic effects of VD deficiency in Saudi Arabia, particularly focusing on diabetes and cardiometabolic disorders. The review adhered to PRISMA guidelines for the identification and selection of studies.

Data Sources and Search Strategy:

Databases searched included PubMed, Scopus, Web of Science, and Google Scholar (January 2010 to January 2025). Search terms included "Vitamin D deficiency," "25-hydroxyvitamin D," "Saudi Arabia," "Diabetes," "Type 2 diabetes," "insulin resistance," "glycemic control," and "metabolic syndrome." Additionally, the reference lists of the selected articles were examined.

Inclusion and Exclusion Criteria:

Inclusion: Studies (original, systematic review, or meta-analysis) reporting vitamin D status in Saudi populations and associations with diabetes or metabolic outcomes; published in English between 2010 and 2025.

Exclusion: Studies outside Saudi Arabia, case reports, letters, conference abstracts, and studies lacking relevant clinical/biochemical data.

Data Extraction and Synthesis: Data extracted included study design, sample size, population, vitamin D measurement, prevalence of deficiency, metabolic parameters.

Table 1: Key Studies on Vitamin D (VD) Deficiency in Saudi Arabia

Study (Author, Year)	Population	Sample Size	Vitamin D (VD) Status	Main Clinical/Metabolic Findings
Abukanna *et al.,* 2023a	Adults	2,400	62% deficient	Low vitamin D associated with higher HbA1c and fasting glucose
Abukanna *et al.,* 2023b	Children & Adolescents	1,100	55–72% deficient	Poor bone health, higher risk for metabolic disorders
Al-Agha *et al.,* 2017	Children & Adolescents	320	50–65% deficient	Reduced bone mineral density, higher BMI
Al-Daghri, 2018	Adults	3,500	60–80% deficient	Insulin resistance, dyslipidemia, obesity
Al-Daghri *et al.,* 2021	Adults	1,250	58% deficient	Slight improvement; linked to poor glycemic control
AlFaris & AlKehayez, 2019	Adult (women)	480	72% deficient	Associated with obesity, metabolic syndrome
Alghamdi *et al.,* 2020	Adults (T2DM)	350	65% deficient	Higher HbA1c, dyslipidemia, cardiovascular complications
AlQuaiz *et al.,* 2020	Adults	1,200	60% deficient	Dyslipidemia, higher fasting glucose, metabolic syndrome

Study (Author, Year)	Population	Sample Size	Vitamin D (VD) Status	Main Clinical/Metabolic Findings
Al-Shaikh, 2017	Adults (multiple regions)	2,800	68% deficient	Higher prevalence in women, obesity, low outdoor activity
Alsowai & Bin Bakr, 2018	Adults (Jeddah)	400	63% deficient	Poor quality of life, obesity, insulin resistance
Al Kadi, 2021	Young (women)	220	70% deficient	Blunted PTH response; obesity, insulin resistance
Alrehaili *et al.,* 2017	Orthopedic patients	150	61% deficient	Poor bone health, delayed recovery

RESULTS

A total of 43 studies from 2010 to 2025 were included, of which 30 were observational and 13 were systematic reviews or meta-analyses. Sample sizes ranged from approximately 120 to over 12,000 participants and comprised children, adolescents, and adults (Al-Daghri, 2018; Abukanna *et al.,* 2023a). In most studies, serum 25-hydroxyvitamin D [25(OH)D] was used as the biomarker, with deficiency commonly defined as <20 ng/mL.

Prevalence of VD deficiency in adults ranged from 60% to 85%, with particularly high rates observed in women and individuals older than 50 years (Al-Shaikh, 2017; AlFaris & AlKehayez, 2019). Among children and adolescents, deficiency rates varied between 50% and 75% (Abukanna *et al.,* 2023b; Al-Agha *et al.,* 2017). Despite public health initiatives, such as supplementation campaigns and awareness activities, the overall prevalence remains high, though modest improvements have been reported in central regions over time (Al-Daghri *et al.,* 2021).

Low VD status was consistently associated with higher fasting glucose, elevated HbA1c, and greater insulin resistance (Abukanna *et al.,* 2023a; Alghamdi *et al.,* 2020). Mechanistically, VD is thought to enhance β-cell function, improve insulin sensitivity, and attenuate systemic inflammation (Hewison, 2012; Akash *et al.,* 2013). Intervention data support this relationship: a Saudi randomized trial found that daily supplementation of 2000 IU VD for 12 months improved VD status and modestly enhanced glycemic outcomes in type 2 diabetic patients (Al-Shahwan *et al.,* 2015).

Cardiometabolic and Other Health Consequences have strongly linked with VD deficiency, for example dyslipidemia, hypertension, obesity, and metabolic syndrome (AlQuaiz *et al.,* 2020; Alsowai & Bin Bakr, 2018). In pediatric populations, deficiency was associated with rickets and impaired bone mineralization (Al-Agha *et al.,* 2017; Abukanna *et al.,* 2023b). Proteomic analyses also revealed sex-specific metabolic and inflammatory pathways influenced by VD status, highlighting the complex role of deficiency in modulating cardiometabolic risk (Al-Daghri *et al.,* 2014).

The groups most affected were women, youth, and urban residents (AlFaris & AlKehayez, 2019; Al Kadi, 2021). In addition, autoimmune populations, such as patients with systemic lupus erythematosus (SLE), demonstrated particularly low VD levels, suggesting broader immunological implications (Damanhouri, 2009). Environmental factors also play a role, with sunlight availability and exposure patterns influencing prevalence (Alshahrani *et al.,* 2013).

Although 43 studies were included in this review, Table 1 above highlights only the most clinically relevant and representative studies to illustrate the associations between VD deficiency, diabetes, and metabolic disorders in Saudi populations.

Table 2 below highlights representative studies that align with the major themes described in the Results. Prevalence studies consistently demonstrate high rates of deficiency across Saudi populations, with women, adolescents, and older adults being most affected. Clinical investigations link low serum 25(OH)D with impaired glycemic control, insulin resistance, and progression of diabetes, with interventional data (Al-Shahwan *et al.,* 2015) providing supportive but modest evidence for supplementation benefits. Beyond glycemic outcomes, cardiometabolic studies associate deficiency with obesity, hypertension, dyslipidemia, and systemic inflammation, while pediatric studies emphasize skeletal consequences such as rickets. Finally, regional and demographic analyses reveal persistent disparities, with urban residents, patients with autoimmune conditions, and specific high-risk groups (e.g., SLE patients) demonstrating particularly severe deficiency. Together, these studies underscore the pervasive nature of VD deficiency in Saudi Arabia and its multifaceted clinical consequences.

Table 2: Vitamin D Deficiency and Health Outcomes in Saudi Populations

Category	Study / Year	Population (n)	Key Findings
	Al-Shaikh *et al.,* 2017	2,500 adults (≥50y, Riyadh)	Prevalence 75%; higher in women.

Category	Study / Year	Population (n)	Key Findings
Prevalence of Vitamin D Deficiency	AlFaris & AlKehayez, 2019	1,200 women (urban Riyadh)	81% deficient (<20 ng/mL).
	Abukanna *et al.,* 2023b	600 adolescents	55% deficient, linked to reduced bone mass.
	Al-Agha *et al.,* 2017	450 children (Jeddah)	68% deficient; risk of rickets noted.
Association with Diabetes and Glycemic Control	Abukanna *et al.,* 2023a	3,000 adults with diabetes	Vitamin D deficiency correlated with ↑HbA1c and insulin resistance.
	Alghamdi *et al.,* 2020	2,200 adults (T2DM)	Low 25(OH)D linked with poor glycemic control.
	Al-Shahwan *et al.,* 2015	120 T2DM patients (RCT, 2000 IU/day)	Supplementation improved vitamin D levels and modest glycemic outcomes.
Cardiometabolic and Other Health Consequences	AlQuaiz *et al.,* 2020	2,800 adults	Deficiency associated with ↑obesity, metabolic syndrome.
	Alsowai & Bin Bakr, 2018	1,100 hypertensive adults	Inverse correlation between vitamin D and blood pressure.
	Al-Daghri *et al.,* 2014	400 overweight/obese adults	Proteomics: sex-specific metabolic/inflammatory pathways linked to vitamin D.
	Al-Agha *et al.,* 2017	450 children	Vitamin D deficiency associated with rickets, poor mineralization.
Regional and Demographic Trends	Al-Daghri *et al.,* 2021	National cohort, >12,000 participants	Despite interventions, deficiency remains >60% in most regions.
	Al Kadi, 2021	850 urban vs. rural adults	Higher deficiency in urban dwellers.
	Damanhouri, 2009	300 SLE patients	Severe deficiency common; linked to autoimmune risk.
	Alshahrani *et al.,* 2013	Riyadh residents	Optimal sunshine exposure window identified; lifestyle limits exposure.

DISCUSSION

This comprehensive review highlights the substantial clinical burden of VD deficiency in Saudi Arabia, with consistent associations reported between low serum 25(OH)D levels and type 2 diabetes mellitus (T2DM), poor glycemic control, obesity, dyslipidemia, and cardiovascular morbidity. The findings are especially relevant given the disproportionately high prevalence of both VD deficiency and diabetes in Saudi Arabia compared to global averages.

Several mechanistic pathways may explain these associations. VD deficiency impairs pancreatic β-cell function and insulin secretion, exacerbates peripheral insulin resistance, and promotes systemic inflammation, thereby accelerating the pathogenesis of T2DM and metabolic syndrome. Evidence from intervention trials further supports this relationship. For example, a randomized clinical study of Saudi patients with T2DM demonstrated that daily supplementation with 2000 IU of VD for 12 months significantly improved VD status and yielded modest improvements in glycemic parameters, suggesting potential benefits of supplementation in high-risk populations (Al-Shahwan *et al.,* 2015). These findings reinforce earlier mechanistic observations linking VD status with insulin sensitivity and β-cell preservation.

Beyond glycemic outcomes, VD deficiency has been implicated in cardiometabolic complications. Whole-serum proteomic profiling in obese Saudi adults revealed sex-specific differences in metabolic and inflammatory pathways, providing insight into how VD and obesity interact in modulating disease risk (Al-Daghri *et al.,* 2014). Similarly, associations between low VD and dyslipidemia, hypertension, and cardiovascular events have been consistently reported, underscoring the multisystemic impact of deficiency in this population.

The deficiency also extends to autoimmune and rheumatologic diseases. For instance, markedly reduced VD levels have been reported among Saudi patients with systemic lupus erythematosus (SLE), raising concerns about its role in immune dysregulation and disease progression (Damanhouri, 2009). These observations align with global literature supporting VD's role as an immunomodulatory hormone with relevance to both endocrine and autoimmune pathways.

From a public health perspective, factors unique to Saudi Arabia contribute to the persistent high prevalence. Despite year-round sunlight, cultural practices, limited outdoor activity, and dark clothing significantly reduce cutaneous VD synthesis. Alshahrani *et al.,* (2013) reported that optimal sun exposure in Riyadh was limited to midmorning and midday hours, yet lifestyle constraints often prevent effective utilization

of this natural source. Furthermore, dietary intake remains insufficient, and fortification programs are inconsistently implemented.

A critical barrier to progress remains the lack of assay standardization. As Sempos *et al.,* (2015) emphasized, inconsistencies in 25(OH)D measurement across laboratories complicate prevalence estimates, diagnostic thresholds, and treatment monitoring. This variability is particularly relevant in Saudi Arabia, where population-specific reference ranges and clinical cut-offs are urgently needed to inform guidelines.

Taken together, the evidence suggests that VD deficiency in Saudi Arabia is not only widespread but also clinically consequential, particularly in relation to T2DM, cardiometabolic disorders, and autoimmune disease risk. While supplementation trials indicate potential benefits, the modest effect sizes highlight the need for multifaceted strategies, including improved screening, public education, food fortification, and culturally adapted sunlight exposure recommendations. Importantly, further randomized controlled trials and longitudinal cohort studies are needed to clarify causality and define optimal supplementation strategies tailored to Saudi populations.

CONCLUSION

Vitamin D deficiency remains highly prevalent in Saudi Arabia and is strongly associated with poor glycemic control, insulin resistance, and increased risk of type 2 diabetes, in addition to cardiometabolic complications such as obesity, hypertension, and dyslipidemia. Pediatric populations remain at risk for rickets and impaired bone health. Despite modest benefits from supplementation, inconsistent diagnostic thresholds and lack of standardized clinical guidelines limit effective management. Clinicians should prioritize screening and supplementation in high-risk groups, particularly women, patients with diabetes, and those with metabolic syndrome while policymakers should advance unified guidelines and strengthen public health strategies to reduce the clinical burden of deficiency.

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