Association between vitamin D deficiency and metabolic syndrome among adults in Arab countries

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Abstract

Background: The association between vitamin D deficiency and metabolic syndrome among adults in Arab countries has not been systematically synthesised.

Aim: To assess the association between vitamin D deficiency and metabolic syndrome among adults in Arab countries.

Methods: Using guidelines from the Joanna Briggs Institute manual for evidence synthesis, meta-analysis of observational studies in epidemiology, and preferred reporting items for systematic reviews and meta-analyses, we reviewed studies published between January 2015 and January 2025 on vitamin D deficiency and metabolic syndrome among adults aged ≥ 18 years in Arab countries. Statistical analyses were conducted using R version 4.5.0; mean serum vitamin D concentrations were compared using unpaired t-tests, and the prevalence of vitamin D deficiency was compared using chi-square tests. Statistical significance was set at $P \leq 0.05$.

Results: Twelve studies involving 4399 participants from 6 Arab countries were analysed. Vitamin D deficiency was more prevalent among adults with metabolic syndrome and was associated with higher odds of metabolic syndrome (pooled odds ratio 1.84; 95% confidence interval 1.15–2.94), with substantial heterogeneity. The association remained significant after sensitivity analysis.

Conclusion: Given the high prevalence of vitamin D deficiency and metabolic syndrome, there is a need for preventive strategies in the Arab countries. Well-designed interventional studies are needed to clarify causality, assess the effectiveness of vitamin D interventions and determine whether there is a threshold beyond which additional increases in vitamin D provide limited metabolic benefit.

Keywords: vitamin D deficiency, vitamin D concentration, metabolic syndrome, Arab countries

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Introduction

Vitamin D deficiency is a widespread global public health concern and one of the most extensively studied micronutrient deficiencies (*1*). Vitamin D is synthesised in the skin following exposure to sunlight or obtained from dietary sources, and undergoes hepatic and renal hydroxylation to form its biologically active metabolite (*2*). Several factors contribute to vitamin D deficiency, including increased skin pigmentation, sunscreen use, ageing and obesity (*3*). Lifestyle and cultural practices, such as limited outdoor activity and clothing that reduces sun exposure, may further contribute to this deficiency.

A high prevalence of vitamin D deficiency has been reported across Arab countries, with consistently high rates in Gulf Cooperation Council (GCC) countries, North Africa and the Levant (*3,4,7–9*). Deficiency is generally more prevalent among women, particularly those who are veiled. Most studies define vitamin D deficiency using a serum 25-hydroxyvitamin (OH) D concentration of ≤ 20 ng/mL (50 nmol/L), consistent with regional expert consensus (*3*).

Traditionally, vitamin D deficiency has been associated with rickets and osteomalacia among children (*10,11*). However, increasing evidence suggests associations with chronic conditions, including metabolic syndrome. Metabolic syndrome is also highly prevalent across Arab countries and is defined as a cluster of interrelated cardiometabolic risk factors, including central obesity, dyslipidaemia, hypertension, and dysglycaemia (*12–17*). The International Diabetes Federation (IDF), Adult Treatment Panel III (ATP III), and WHO definitions of metabolic syndrome are the most widely used diagnostic criteria, with studies in this review primarily applying the IDF or ATP III definitions (*18–20*).

Although associations between vitamin D deficiency and metabolic syndrome have been reported among Western populations, evidence from studies conducted in Arab countries has not been systematically synthesised. Therefore, this systematic review assessed the association between vitamin D deficiency and metabolic syndrome among Arab adults.

Methods

This systematic review and meta-analysis followed the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis and was reported in accordance with the Meta-analysis of Observational Studies in Epidemiology (MOOSE) and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statements (*21,22*). A protocol was developed a priori but not registered on PROSPERO because it was not an institutional requirement at the time.

Eligibility criteria

Eligible studies included adults (≥18 years) from Arab countries examining vitamin D deficiency and metabolic syndrome as a defined condition. Studies focusing solely on individual components of metabolic syndrome (dyslipidaemia, hypertension or insulin resistance) were excluded. Eligible study designs included observational studies (cohort, case–control, and cross-sectional) and intervention studies (randomised controlled trials). Studies conducted outside the Arab region, research lacking specific vitamin D data, non-English publications, animal studies, and studies involving paediatric populations were excluded.

Information sources and search strategy

A comprehensive literature search was conducted in PubMed, Web of Science, Embase and the Cochrane Library for studies published between January 2015 and January 2025. The search strategy used medical subject headings and relevant keywords related to vitamin D deficiency, metabolic syndrome, and Arab countries, combined using Boolean operators (AND/OR). Searches were limited to studies conducted among adults. Reference lists of included studies were manually screened to identify additional eligible publications. The search was completed on 10 February 2025. Grey literature was not included.

Study selection

All identified records were imported into Rayyan software (*23*). Two independent reviewers screened titles and abstracts for eligibility. Full texts of potentially relevant studies were retrieved and assessed independently by the same reviewers. Disagreements were resolved through discussion. The study selection process was documented using a PRISMA flow diagram (*22*).

Data extraction

Data were extracted independently by 2 reviewers using a structured Excel form. Extracted information included study characteristics (author, year, country), participant characteristics (sample size, sex distribution, age), and metabolic syndrome classification. Vitamin D-related data included cutoff values for deficiency, insufficiency, and sufficiency, as well as prevalence estimates by metabolic syndrome status. Mean serum 25(OH)D concentrations with standard deviations were extracted where available. Effect estimates, including odds ratios with 95% confidence intervals, multivariate-adjusted ratios by menopausal status, and relative risks per ng/mL 25(OH)D were recorded. Study authors were not contacted. All data were cross-checked prior to analysis.

Risk of bias assessment

Study quality was assessed using the JBI critical appraisal checklists for cross-sectional and case-control studies, evaluating sample representativeness, validity of exposure and outcome measurements, and confounder adjustment. Two reviewers conducted the assessment independently, with disagreements resolved through discussion.

Data synthesis and analysis

Statistical analyses were conducted using R (version 4.5.0). Mean serum vitamin D concentrations were compared between participants with and without metabolic syndrome using unpaired t-tests, and the prevalence of vitamin D deficiency was compared using chi-square tests. Meta-analysis was performed using a random-effects model to estimate pooled odds ratios with 95% confidence intervals. Statistical heterogeneity was assessed using the I^2 statistic. Sensitivity analyses were conducted to assess the influence of individual studies. Statistical significance was set at $P \leq 0.05$.

Quality of evidence assessment

The certainty of evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach, which evaluates risk of bias, inconsistency, indirectness, imprecision, and publication bias. Assessments were conducted independently by 2 reviewers, with disagreements resolved through discussion.

Results

Database searches identified 318 records. After removal of duplicates, 98 full-text articles were assessed for eligibility and 12 met the inclusion criteria (*13,24–34*). Reasons for exclusion are presented in the PRISMA flow diagram (*22*).

The 12 included studies, published between 2015 and 2023, enrolled a total of 4399 participants from 6 Arab countries: Saudi Arabia and Jordan (3 studies each), Qatar and Lebanon (2 studies each), and Iraq and Algeria (one study each). Six studies included only females, one included only males, and 5 included both sexes (3 304 female, 1086 male participants). The mean age across studies was 47.1 years.

Metabolic syndrome prevalence was 37.2% (range: 12.0%–57.0%), with 1634 participants with Metabolic syndrome and 2756 without metabolic syndrome. Mean serum 25(OH)D concentrations were lower among participants with metabolic syndrome (19.97 ng/mL, range: 11.96–41.30) than among those without Metabolic syndrome (24.39 ng/mL, range: 12.44–42.50). Vitamin D deficiency was more prevalent among participants with

metabolic syndrome (69.9%) than among those without metabolic syndrome (57.2%).

Most studies defined vitamin D deficiency as a serum 25(OH)D concentration < 20 ng/mL (< 50 nmol/L), with insufficiency defined as 21–29 ng/mL (or 52.5–72.5 nmol/L) and sufficiency as ≥ 30 ng/mL (or ≥ 75 nmol/L) (*35*). Study characteristics are summarised in Table 1.

Risk of bias assessment

Of the 12 included studies, 10 were cross-sectional and 2 were case-control studies. Six cross-sectional studies were assessed as having a low risk of bias and 4 a moderate risk, while both case-control studies had a moderate risk of bias. Inadequate identification and adjustment for confounding factors was the main reason for classification as moderate risk.

Comparative findings

Two studies reported significantly lower mean vitamin D concentrations among participants with metabolic syndrome than those without metabolic syndrome ($P < 0.001$) (Table 2) (*29,32*). One study with complete data across all vitamin D categories showed a significant association between vitamin D status and metabolic syndrome ($P < 0.05$) (Table 3) (*28*). Another study reported a significantly higher prevalence of vitamin D deficiency among participants with metabolic syndrome ($P = 0.01$) and a higher prevalence of vitamin D sufficiency among participants without metabolic syndrome ($P = 0.01$) (*31*).

Overall, most studies demonstrated lower vitamin D concentrations among participants with Metabolic syndrome, although this finding was not consistent across all included studies.

Meta-analysis

Five studies contributed to the meta-analysis. A random-effects model was applied to account for between-study heterogeneity. The pooled odds ratio (OR) was 1.84, indicating higher odds of metabolic syndrome among individuals with vitamin D deficiency. Substantial heterogeneity was observed ($I^2 = 71.8\%$) (Figure 1).

Sensitivity analysis identified one influential study reporting a stronger association (OR = 4.48). After its exclusion, the pooled OR decreased to 1.46 (95% CI: 1.14–1.87, $P = 0.003$) and heterogeneity was eliminated ($I^2 = 0\%$) (*28*).

Visual inspection of the funnel plot showed asymmetry, with one study appearing as an outlier. However, Egger's test was not statistically significant ($P = 0.64$), indicating no evidence of publication bias (Figure 2).

Table 1 Characteristics of studies on vitamin D deficiency and metabolic syndrome among adults in Arab countries

Characteristic	Value
No. of studies	12
No. of participants	4399
Country, *n* (%)	
Saudi Arabia	3 (25.0)
Qatar	2 (16.7)
Jordan	3 (25.0)
Lebanon	2 (16.7)
Iraq	1 (8.3)
Algeria	1 (8.3)
Sex, *n* (%)	
Female	3304 (75.3)
Male	1086 (24.7)
Age, years, mean ± SD	47.1 ± 9.7
Metabolic syndrome prevalence, *n* (%)	1634 (37.2)
Vitamin D levels	
Participants with metabolic syndrome (ng/mL, mean ± SD)	19.97 ± 9.45
Participants without metabolic syndrome (ng/mL, mean ± SD)	24.39 ± 10.04
Vitamin D deficiency prevalence, %	
Participants with metabolic syndrome (%)	69.9
Participants without metabolic syndrome (%)	57.2

SD = standard deviation; ng/mL = nanograms per milliliter

Table 2 Mean serum 25(OH)D concentrations among participants with and without metabolic syndrome

Author, year	Participants with metabolic syndrome, mean ± SD (ng/mL)	Participants without metabolic syndrome, mean ± SD (ng/mL)	Mean difference	*P*	Significant (α = 0.05)
Alissa et al, 2015	12.48 ± 0.64	12.44 ± 0.84	0.04	0.65	No
Qahwaji et al, 2022	24.75 ± 12.26	24.58 ± 12.02	0.17	0.92	No
Begga et al, 2023	14.33 ± 0.69	20.08 ± 1.23	-5.75	< 0.001	Yes
Yasein et al, 2015	41.30 ± 31.30	42.50 ± 29.70	-1.20	0.73	No
Mohammed et al, 2022	20.40 ± 1.80	40.3 ± 2.40	-19.90	< 0.001	Yes
Abboud et al, 2023	17.74 ± 10.01	17.36 ± 14.05	0.38	0.81	No

Values are mean ± SD; P values are from unpaired t-tests; P < 0.05 = statistical significance

Additional findings

Two studies were excluded from comparative and meta-analyses due to insufficient data or absence of a control group. A study from Qatar (*n* = 1205) reported a relative risk (RR) of 0.92 (95% CI: 0.86–0.98) per 1 ng/mL increase in 25(OH)D, indicating a lower risk of metabolic syndrome with higher vitamin D levels. Although not eligible for inclusion in the meta-analysis, this finding supports an inverse association between vitamin D status and metabolic syndrome (*24*).

Another study from Jordan included only participants with metabolic syndrome (n = 124, 62% female) and reported vitamin D deficiency in 59.7%, insufficiency in 27.4%, and sufficiency in 12.9% of participants, with a mean serum 25(OH)D concentration of 16.8 ng/mL (*26*).

Quality of evidence assessment

Using GRADE, the overall certainty of evidence was rated as low. Evidence was downgraded due to risk of bias related to observational study designs and inadequate control for confounding, and because of inconsistency due to substantial heterogeneity (I^2=71.8%) that resolved after exclusion of one outlying study (I^2 = 0%). No concerns were identified for indirectness or imprecision, and publication bias was not detected (*P* = 0.64).

Discussion

This systematic review and meta-analysis synthesised evidence from Arab countries to assess the association between vitamin D deficiency and metabolic syndrome. The pooled analysis of 5 studies involving 1836 participants showed a significant association between vitamin D deficiency and increased risk of metabolic syndrome, with a pooled odds ratio of 1.84 (95% confidence interval [CI]: 1.15–2.94). Substantial heterogeneity was observed (I^2 = 71.8%), largely driven by one outlying study that reported a stronger association than the others (*28*). After exclusion of this study, the association remained statistically significant but more modest (pooled odds ratio = 1.46; 95% CI: 1.14–1.87), with elimination of heterogeneity (I^2 = 0%), indicating a more modest and consistent relationship across the remaining studies.

This heterogeneity likely reflects methodological differences, including variation in metabolic syndrome diagnostic criteria and vitamin D assay methods, as well as population characteristics such as age, sex and occupation. Geographic factors across Arab countries and differences in the seasonal timing of data collection may have further contributed to variability in effect estimates. Descriptive comparison suggested a stronger association in studies conducted in the Levant (OR = 2.18) than in

Table 3 Prevalence of vitamin D among participants with and without metabolic syndrome

Author, year	Vitamin D status	Participants with metabolic syndrome (%)	Participants without metabolic syndrome (%)	Difference	*P*	Significant (α = 0.05)
Alissa et al, 2015	Deficiency	82.0	77.0	5.0	0.34	No
Alzaim et al, 2022	Deficiency	86.4	85.2	1.2	1	No
Ghadieh et al, 2018	Deficiency	52.3	33.5	18.8	0.01	Yes
Ghadieh et al, 2018	Sufficiency	47.7	66.5	-18.8	0.01	Yes
Atoum et al, 2023	Deficiency	69.0	33.0	36.0	< 0.001	Yes
Atoum et al, 2023	Insufficiency	25.0	42.0	-17.0	0.02	Yes
Atoum et al, 2023	Sufficiency	6.0	25.0	-19.0	< 0.001	Yes

Percentages represent prevalence within each group; Group differences were assessed using Chi-square tests with Yates' correction or Fisher's exact test where appropriate; P < 0.05 = statistical significance

Figure 1 Forest plot of vitamin D deficiency and metabolic syndrome

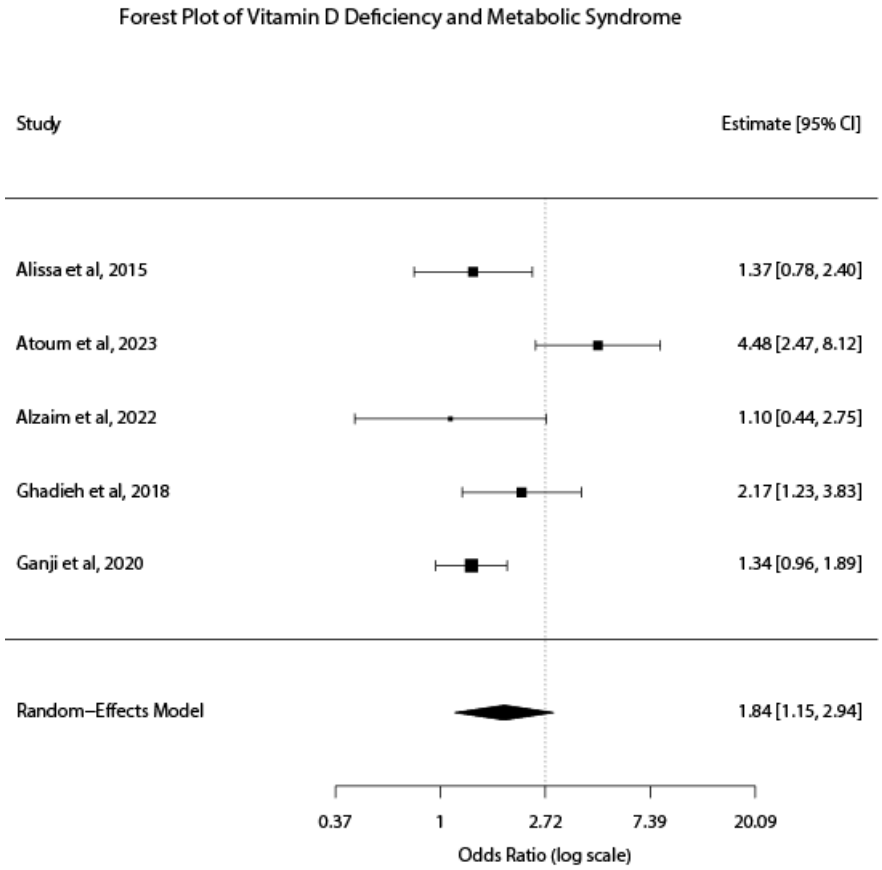
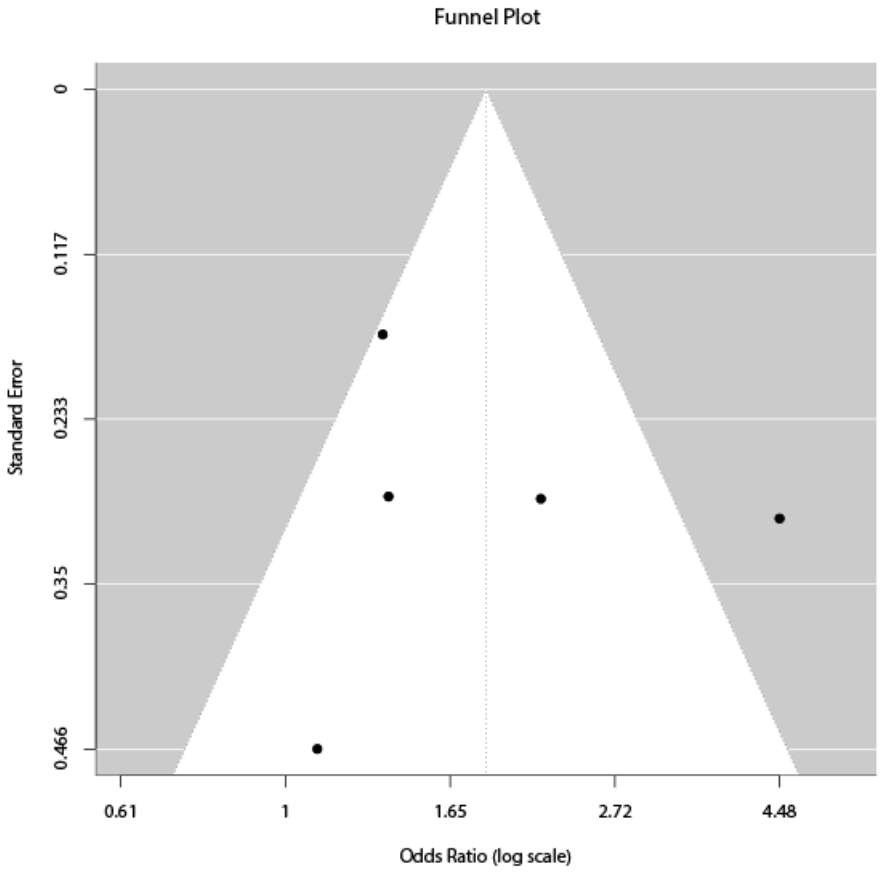


Figure 2 Funnel plot of vitamin D deficiency and metabolic syndrome



those from Gulf Cooperation Council countries (ORs 1.10–1.34), although the limited number of studies precludes firm conclusions regarding regional differences (*31*).

Our findings are consistent with evidence from other populations. A large cohort study conducted in China involving 23 810 reported significantly lower odds of metabolic syndrome among individuals in the highest vitamin D quartile [mean 25(OH)D concentration 28.0 ± 6.6 ng/mL] than those in the lowest quartile (11.9 ± 3.1 ng/mL), with an odds ratio of 0.43 (95% CI: 0.35–0.52). This inverse association is comparable in magnitude, though opposite in direction, to the increased odds observed with vitamin D deficiency in our meta-analysis. Similarly, a large cross-sectional study from the United States reported higher odds of metabolic syndrome among individuals in the lowest vitamin D tertile (≤ 56 nmol/L or ≤ 22.4 ng/mL), with an odds ratio of 1.89 (95% CI: 1.55–2.31) (37). The similarity between this estimate and our pooled odds ratio (1.84) suggests a consistent association between vitamin D status and metabolic syndrome across diverse populations.

Evidence from individual studies included in this review also suggests a dose-response relationship. One large study from Qatar reported a relative risk of 0.92 (95% CI: 0.86–0.98) for metabolic syndrome per 1 ng/mL increase in serum 25(OH)D concentration, indicating a lower risk of metabolic syndrome with higher vitamin D levels. This finding is consistent with international studies reporting 15–20% risk reductions in Metabolic syndrome risk per 10 ng/mL increment (24,38,39).

The potential modifiability of vitamin D deficiency has important public health relevance in regions where both vitamin D deficiency and metabolic syndrome are highly prevalent. Although the included studies were observational and do not allow causal inference, the consistent association observed across most studies suggests that vitamin D status may represent a relevant target for preventive strategies. However, evidence from well-designed longitudinal and interventional studies is required before specific supplementation or population-level interventions can be recommended.

Study limitations

Most of the studies included were cross-sectional, which limits inference on temporality and precludes causal interpretation. The limited number of available studies from Arab countries reduced statistical power, limited subgroup analyses, and increased susceptibility to the influence of individual studies, as evidenced by the substantial change in the pooled odds ratio and heterogeneity after exclusion of a single outlier. Inconsistent reporting of adjusted effect estimates further constrained the ability to account for confounding. Although no evidence of publication bias was detected using Egger's test, interpretation is limited by the small number of included studies. Exclusion of grey literature may have contributed to publication bias despite the comprehensive search strategy.

Conclusion

This meta-analysis adds to the increasing evidence indicating an association between vitamin D deficiency and metabolic syndrome among adults in Arab countries. Given the high prevalence of both conditions in the region, these findings underscore the potential public health relevance of vitamin D status within broader preventive strategies. However, because the available evidence is largely observational, findings should be interpreted with caution. Well-designed interventional studies are needed to clarify causality, assess the effectiveness of vitamin D interventions, and determine whether there is a threshold beyond which additional increases in vitamin D provide limited metabolic benefit.

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Conflict of interests: None declared.

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