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Insulin Resistance and Vitamin D Deficiency in Relation to Body Mass Index

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A B S T R A C T

Background: Vitamin D deficiency and obesity are worldwide health issues associated with metabolic diseases. Aims: This study examined the association between vitamin D insufficiency and insulin resistance (IR) and body mass index (BMI) in Zliten, Libya, to assess whether BMI modulates the association between vitamin D and IR. Methods: A cross-sectional study of 60 individuals (18-60 years) was conducted. Serum 25(OH)D, fasting glucose, and insulin were measured using automated chemiluminescence. IR was calculated via HOMA-IR. Results: Participants showed a mean BMI of 40.28 (morbid obesity), vitamin D of 21.04 ng/mL (deficiency), and HOMA-IR of 4.97. While regression analysis showed weak overall predictors, Spearman's correlation analysis revealed a significant negative correlation between vitamin D and HOMA-IR (p=0.031). Conclusion: Vitamin D and BMI were not strong sole predictors of IR in this morbidly obese cohort, although a significant inverse association between vitamin D and IR was observed.

Keywords: Vitamin D deficiency, Insulin resistance, Body mass index, HOMA-IR, Obesity

. Introduction1

Vitamin D, previously known for its role in bone and mineral metabolism, has emerged as a key regulator of metabolic health. Growing evidence suggests that vitamin D deficiency is linked to an increased risk of metabolic disorders, including polycystic ovarian syndrome (PCOS), metabolic syndrome, and type 2 diabetes mellitus (T2DM) [1]. Clinical and epidemiological studies have shown an inverse relationship between serum 25-hydroxyvitamin D [25(OH)D] levels and insulin resistance. Insulin resistance (HOMA-IR) is assessed using the Homeostatic Model Assessment, suggesting that adequate vitamin D levels may improve insulin sensitivity and glucose homeostasis [2]. The proposed biological mechanisms underlying this relationship are multifaceted. Vitamin D is thought to influence metabolic function by modulating pro-inflammatory cytokine production [3]. Furthermore, the vitamin D receptor (VDR) is expressed in pancreatic β-cells, suggesting a direct role in regulating insulin secretion and cellular survival. Research shows that VDR overexpression in β-cells ameliorates diabetes, while vitamin D enhances insulin secretion by increasing calcium influx and upregulating voltage-gated calcium channels [4]. Vitamin D also promotes the insulin signaling cascade in skeletal muscle, the liver, and adipose tissue, notably by reducing oxidative stress and upregulating the SIRT1/AMPK/GLUT4 pathway [5].

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Obesity adds a layer of complexity to this metabolic interplay. It is widely acknowledged that excessive adiposity predisposes individuals to vitamin D deficiency. This is primarily due to vitamin D being partitioned into fat stores, which reduces the fraction available for metabolic processes [6]. Additionally, the chronic low-grade inflammation associated with obesity ,characterized by complex interactions among proinflammatory cytokines, chemokines, and adipokines, exacerbates insulin resistance (IR), especially in people with a high body mass index (BMI) [7,9].

Despite these global insights, localized data from Libyan populations, particularly regarding the specific metabolic trends in the Zliten region, remain scarce. This study aims to evaluate the association between vitamin D status, BMI, and IR among adults in Zliten, Libya, to provide essential clinical insights and support evidence-based metabolic interventions in the region.

2. Materials and Methods

2.1 Study Design and Participants

The current study was conducted as a cross-sectional observational study in the clinical setting of Alpha Medical Laboratory in Zliten, Libya. The study included 60 participants aged between 12 and 60 years. Exclusion criteria included individuals with known chronic diseases affecting vitamin D metabolism (such as severe renal or liver disease), those using vitamin D supplements, and patients on medications that alter insulin sensitivity.

2.2 Ethical Consideration

The study followed the ethical guidelines outlined in the Declaration of Helsinki. The Faculty of Pharmacy's Institutional Review Board granted ethical approval (Alasmarya Islamic University, Ref. No. PH14:2024). All participants provided informed consent before their inclusion in the study.

2.3 Anthropometric Measurements

The BMI was calculated for all participants using the standard formula: Weight (kg) / Height (m)². To ensure a rigorous analysis of the metabolic trends, participants were categorized based on the World Health Organization (WHO) guidelines into the following four distinct groups: underweight BMI < 18.5 kg/m²; normal weight BMI 18.5-24.9 kg/m²; overweight BMI 25.0-29.9 kg/m²; and obese BMI ≥ 30.0 kg/m².

2.4 Laboratory Procedures

Fasting blood samples were collected from all participants after an 8–12-hour overnight fast. Serum 25-hydroxyvitamin D [25(OH)D] concentrations were measured in nanograms per milliliter (ng/mL) using the Mindray CL-1200i automated chemiluminescence immunoassay (CLIA) analyzer.

Fasting serum insulin levels were quantified in micro-international units per milliliter (µIU/mL), and fasting glucose levels were measured in milligrams per deciliter (mg/dL), both using the Mindray CL-900i system.

2.5 Calculation of IR

The HOMA-IR index, calculated as the product of fasting insulin (µU/mL) and fasting glucose (mg/dL) divided by 405, was used to assess insulin resistance [10]. This constant ensures the appropriate conversion for the clinical units used in the analysis.

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2.6 Statistical Analysis

For the statistical framework of this study, IBM SPSS Statistics v. 26.0 was used. The distributional characteristics of the variables were scrutinized for normality using the Shapiro-Wilk test, ensuring the validity of subsequent parametric or nonparametric analyses. Because the data did not follow a normal distribution (Shapiro-Wilk $p < 0.05$), the median and interquartile range (IQR; 25th-75th percentiles) were used to report continuous variables. To further describe the distribution, skewness and kurtosis were calculated from the standardized third and fourth central moments, respectively. The threshold for statistical significance was set at $p < 0.05$, using two-tailed tests for all comparative analyses.

3. Results

3.1. Descriptive Characteristics

Table 1 shows the baseline clinical and biochemical parameters of all 60 participants. In strict adherence to the distributional diagnostics, all parameters are expressed as median (IQR).

The cohort exhibited a high prevalence of obesity, with a median BMI of 36.3 kg/m² (IQR: 30.1–44.8). Biochemical analysis of vitamin D status revealed a significant deficiency burden, as indicated by a median serum 25(OH)D level of 18.0 ng/mL (IQR: 12.0–26.0). Consistent with these findings, the median HOMA-IR was 5.0 (IQR: 3.0–7.0), markedly exceeding the clinical cut-off of 2.5, confirming the presence of established IR in the study population.

Notably, distributional diagnostics confirmed a pronounced positive skewness for serum Vitamin D (Skewness = 4.12; Kurtosis = 21.3). These coefficients, calculated using the standardized moment method in SPSS, indicate pronounced clustering of values within the deficient range, further supporting the superiority of the median over the mean for providing a more robust representative value for this metabolic cohort.

Table (1): Descriptive Characteristics of the Study Population (N=60)

Variable	*Median (IQR)*	*Range (Min – Max)*	*Skewness*	*Kurtosis*
BMI (kg/m²)	36.3 (30.1- 44.8)	16.0 – 96.0	1.34	*2.51*
Vitamin D (ng/mL)	18.0 (12.0-26.0)	4.0 – 96.1	4.12	*21.3*
HOMA-IR	5.0 (3.0-7.0)	1.6 – 15.0	1.48	*1.83*

3.2. Correlation and Regression Analysis

The Shapiro-Wilk test indicated a non-normal distribution ($p < 0.05$). The correlations between the variables were evaluated using Spearman's rank correlation coefficient (rho). (**Table 2**).

A statistically significant negative correlation was identified between serum Vitamin D levels and HOMA-IR (rho = -0.278, p = 0.031), suggesting that lower Vitamin D levels were linked with increased IR. In contrast, the relationship between BMI and HOMA-IR (rho = 0.231,

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p = 0.076) and the association between BMI and Vitamin D (rho = 0.053, p = 0.688) did not reach statistical significance. Additionally, multiple linear regression analysis revealed that the combination of BMI and Vitamin D accounted for only 6.9% of the variance in IR(R^2 = 0.069, p > 0.05).

Table (2): Summary of Correlation Analysis (Spearman's rho)

Variable Pair	*Spearman (ρ)*	*P-value*	*Significance*
Vitamin D vs. HOMA-IR	-0.278	0.031*	*Significance*
BMI vs. HOMA-IR	0.231	0.076	*Non-significant*
BMI vs. Vitamin D	0.053	0.688	*Non-significant*

** Correlation is significant at the 0.05 level (2-tailed).*

4. Discussion

The present study investigated the relationship among vitamin D status, obesity, and IR in a specific Libyan population. Our findings demonstrate a significant inverse correlation between serum Vitamin D levels and HOMA-IR (r = -0.278, p = 0.031). This supports the concept that Vitamin D insufficiency is a major contributor to impaired glucose metabolism. This negative association aligns with global research suggesting that Vitamin D serves a diverse function in regulating systemic insulin sensitivity [1, 2, 13].

A notable finding in this study was that despite the high prevalence of obesity (Median BMI = 36.3 kg/m²), BMI was not a statistically significant predictor of IR (p = 0.076). This observation underscores the limitations of BMI as a metabolic marker, as it fails to differentiate between subcutaneous fat and visceral adiposity. Visceral fat is more immunologically active, secreting pro-inflammatory cytokines like Tumor Necrosis Factor- and Interleukin-6, which directly impair insulin signaling pathways [7- 9]. In this cross-sectional study, the lack of significant correlation suggests that Vitamin D status might serve as a more sensitive and independent indicator of metabolic risk than total body mass alone.

The high variability and severe vitamin D deficiency (Median = 18.0 ng/mL, Skewness = 4.12) observed in this study could be attributed to several physiological factors. In obese individuals, Vitamin D, being a lipophilic molecule, is often sequestered within the expanded adipose tissue volume, significantly reducing its bioavailability in the systemic circulation [4]. Additionally, the inverse relationship between serum Vitamin D and markers of adiposity suggests that metabolic dysfunction is compounded by chronic low-grade inflammation, further exacerbating the deficiency state [3, 7].

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The results have major clinical and public health implications for Zliten and the wider Libyan region. They suggest that routine Vitamin D screening and targeted supplementation could serve as a cost-effective strategy to reduce IR and lower the risk of Type 2 Diabetes Mellitus. This is particularly relevant for individuals for whom achieving sustainable weight loss is clinically challenging.

5. Conclusion

In conclusion, this study shows a significant inverse association between serum Vitamin D levels and IR among our sample. Although the study population had a high prevalence of morbid obesity, BMI alone was not a statistically significant predictor of IR. These findings suggest that Vitamin D status may play a more pivotal role in glucose homeostasis than total body mass index in this specific population.

The clinical implications of these results are substantial, highlighting the importance of Vitamin D screening as an essential component of metabolic health evaluation. Given the widespread shortage reported, vitamin D supplementation may provide a cost-effective and accessible strategy to increase insulin sensitivity and reduce the incidence of Type 2 Diabetes Mellitus in the region, particularly when weight control is difficult.

Future recommendations: Further longitudinal studies with larger sample sizes are needed to clarify causal relationships and to account for confounding factors such as dietary habits, seasonal sun exposure, and genetic variation in the vitamin D receptor in the Libyan population.

ETHICAL STATEMENT

The Ethics Committee of the Faculty of Pharmacy at Alasmarya Islamic University authorized the study protocol (Approval No. **PH14:2025).**

CONFLICT OF INTEREST

The writers disclose no conflict of interest.

AUTHORS' CONTRIBUTIONS

N.A.A: Supervision and design. A.M.A, A.S.S, H.M.A, S.A.A: Data collection and analysis. M.S.A: Writing and formatting.

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