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# Predictive Value of Random Blood Sugar, Hemoglobin A1c, and Zinc Deficiency for Insulin Resistance in Patients with Type 2 Diabetes Mellitus

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## ABSTRACT

This study was conducted to explore the relationship between glycemic indicators, zinc deficiency, and insulin resistance in individuals with type 2 diabetes. The study took place at the Leila Qasm Diagnostic Center in Erbil, Iraq, between November, 2024 and March, 2025. It included 200 patients diagnosed with type 2 diabetes and 200 healthy individuals as controls. Blood samples were collected and analyzed for serum markers using the Cobas Integra system. Compared to the healthy controls, patients with type 2 diabetes showed significantly lower serum zinc levels and higher levels of random blood glucose, HbA1c, and HOMA-IR. Correlation analysis revealed a negative association between serum zinc and insulin resistance, while both random blood glucose and HbA1c were positively correlated with insulin resistance. Multiple linear regression analysis identified zinc deficiency and elevated HbA1c as significant predictors of increased HOMA-IR in diabetic patients.

In conclusion, type 2 diabetes, reduced serum zinc along with elevated random blood glucose and HbA1c levels are strong predictors of increased insulin resistance.

**Keywords:** *D printing, Interim restorations,*

## INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by consistently elevated blood glucose levels, insulin resistance, and diminished insulin secretion (Mohammed Merza, (2025)). The global number of people living with diabetes surged from 200 million to 830 million, with low- and middle-income countries seeing a more rapid increase than high-income regions (WHO, 2024). Due to insulin resistance, individuals with T2DM are at a higher risk for cardiovascular diseases and other health complications (Qader Idrees B, 2024). Gaining a deeper understanding of the factors that contribute to insulin resistance is key to improving T2DM management and preventing complications.

Atef et al., highlighted zinc's essential role in insulin dynamics, including its storage, release, and action. Their studies suggest that zinc deficiency may impair glucose metabolism and contribute to insulin resistance (Atef et al., 2025). Although maintaining sufficient zinc levels may enhance insulin sensitivity and glucose control, further clinical trials are needed to determine its therapeutic value.

A meta-analysis by Jansen et al. (2009) reported a notable inverse relationship between serum zinc levels and insulin resistance, measured by the HOMA-IR index. With a correlation coefficient of $r = -0.215$ (95% CI: -0.157 to -0.268; $p < 0.001$), the findings indicate that lower zinc levels are linked to increased insulin resistance (Tan et al., 2024).

In addition to zinc deficiency, glycemic markers such as random blood sugar (RBS) and glycated hemoglobin (HbA1c) have been associated with reduced insulin sensitivity. Elevated levels of RBS and HbA1c are known to contribute to worsening insulin resistance and progression of T2DM (Ali et al., 2024).

Given the potential connections among zinc levels, glycemic control, and insulin resistance, this case-control study aims to examine how serum zinc deficiency and glycemic markers relate to insulin resistance in patients with T2DM.

### Materials and Methods

### Study Design

This case-control study was carried out at the Leila Qasm Diagnostic Center for Diabetic Care in Erbil, Iraq, over a six-month period from November,2024 to March 2025. A total of 400 participants were enrolled, including 206 individuals diagnosed with type 2 diabetes mellitus (T2DM) (120 males, 80 females; mean age: 43.04 ± 1.02 years) and 200 healthy controls (HCs) (130 males, 70 females; mean age: 40.24 ± 1.044 years).

T2DM diagnosis was confirmed by a specialist endocrinologist based on clinical signs—such as polyuria, polydipsia, and polyphagia—along with laboratory criteria: fasting plasma glucose ≥126 mg/dL (7.0 mmol/L), 2-hour plasma glucose ≥200 mg/dL after an oral glucose tolerance test, or random blood sugar (RBS) ≥200 mg/dL with classic hyperglycemic symptoms (Smushkin & Vella, 2010). An HbA1c level ≥6.5% was also considered diagnostic for T2DM.

Eligibility for the T2DM group required participants to be aged between 20 and 79 years and to meet at least one of the above diagnostic criteria. Exclusion criteria included the presence of type 1, gestational, or secondary diabetes, as well as other coexisting medical conditions.

**Data Collection**

The average age of T2DM participants was 43.04 ± 1.02 years. Blood samples were allowed to clot for 30 minutes in SST tubes before serum was separated and stored at -70°C. Patient data, including demographic details, medical history, and laboratory test results, were retrieved from the diagnostic center's database and documented through a standardized questionnaire.

**Analysis Data**

Serum levels of zinc, RBS, fasting blood glucose (FBG), HbA1c, and insulin were analyzed using the Cobas Integra analyzer (Fleming, 2007). Insulin resistance was calculated using the HOMA2 Calculator (version 2.2.3), based on insulin and fasting glucose values.

**Statistical Analysis**

To evaluate data distribution, normality tests—including Shapiro-Wilk, Kolmogorov-Smirnov, and D'Agostino—were performed using GraphPad Prism 9 (GraphPad Software, USA). As the data met normality assumptions, parametric tests were used. Results were expressed as mean ± standard error of the mean (SEM).

Group comparisons were conducted using independent Student's t-tests. Pearson correlation analysis was used to examine relationships between variables. Multiple linear regression was performed using SPSS version 29 (IBM, USA) to explore associations between independent variables (age, gender, serum zinc, RBS, HbA1c) and insulin resistance (HOMA-IR). Tolerance and variance inflation factor (VIF) were used for collinearity diagnostics. A p-value less than 0.05 was considered statistically significant.

**Results**

Comparison of Demographics and Serum Biomarkers Between Healthy Controls and T2DM Patients. Table 1 presents data from 200 individuals with type 2 diabetes mellitus (T2DM) and 200 healthy controls (HCs). The mean age of the T2DM group was 43.04 ± 1.02 years, while that of the HCs was 40.24 ± 1.024 years, with no statistically significant difference observed ($p = 0.125$). Both groups showed a similar male-to-female ratio of approximately 2:1, and no significant association between gender and T2DM susceptibility was identified ($p = 0.641$).

T2DM patients had significantly lower serum zinc levels (44.52 ± 1.2 µg/dL) compared to the control group (82.15 ± 0.14 µg/dL), with a highly significant difference ($p < 0.001$). Additionally, patients with T2DM exhibited significantly elevated levels of random blood sugar (RBS), glycated hemoglobin (HbA1c), and insulin resistance (HOMA-IR) in comparison to healthy individuals ($p < 0.001$), as shown in Table 1.

Table 1: Comparison of clinical and biochemical parameters between healthy controls and individuals with type 2 diabetes mellitus

| Group | | Mean (or N) | SEM | p-value |
|---|---|---|---|---|
| **Age** | HC | 45.02 | 1.094 | 0.179 |
| | T2DM | 42.98 | 1.053 | |
| **Gender (Male /Female)** | HC | 202 (140/62) | - | 0.831 |
| | T2DM | 206 (140/66) | - | |
| **Serum zinc (µg/dL)** | HC | 82.15 | 0.211 | <0.001 |
| | T2DM | 44.52 | 1.2 | |
| **RBS (mg/dL)** | HC | 1243 | 4.93 | <0.001 |
| | T2DM | 213.2 | 6.567 | |
| **HbA1c** | HC | 4.300 | 0.046 | <0.001 |
| | T2DM | 7.87 | 0.124 | |
| **HOMA-IR** | HC | 1.83 | 0.024 | <0.001 |
| | T2DM | 3.04 | 0.041 | |

Table 2: Assessment of correlations among various factors in type 2 diabetes mellitus

| Variables | Correlation indexes | Serum zinc | RBS | HbA1c | HOMA-IR |
|---|---|---|---|---|---|
| **Serum zinc** | R | 1 | -0.210** | -0.400** | -0.354** |
| | P-value | - | <0.001 | <0.001 | <0.001 |
| **RBS** | R | -0.315** | 1 | 0.366** | 0.318** |
| | P-value | <0.001 | - | <0.001 | <0.001 |
| **HbA1c** | R | -0.422** | 0.386** | 1 | 0.450** |
| | P-value | <0.001 | <0.001 | - | <0.001 |
| **HOMA-IR** | R | -0.404** | 0.304** | 0-.421** | 1 |
| | P-value | <0.001 | <0.001 | <0.001 | - |

**Multiple Linear Regression Analysis: Predictors of Insulin Resistance in T2DM**

To identify significant predictors of insulin resistance in patients with T2DM, multiple linear regression analysis was conducted using age, gender, serum zinc, random blood sugar (RBS), and HbA1c as independent variables, with HOMA-IR as the dependent variable.

As shown in Table 4, serum zinc deficiency, elevated RBS, and increased HbA1c levels emerged as significant predictors of higher HOMA-IR values, indicating greater insulin resistance. Collinearity diagnostics—including tolerance and variance inflation factor (VIF)—were assessed to confirm the validity of the regression model, and the results are presented in Table 3.

**Table 3:** Multivariate Regression Analysis of Parameters Associated with HOMA-IR in T2DM Patients

| | B | p-value | Tolerance | VIF |
|---|---|---|---|---|
| **Age** | -0.013 | 0.146 | 0.912 | 1.126 |
| **Gender** | 0.010 | 0.910 | 0.960 | 1.210 |
| **Serum zinc** | -0.008 | <0.001 | 0.626 | 1.422 |
| **RBS** | 0.0021 | <0.001 | 0.633 | 1.403 |
| **HbA1C** | 0.012 | 0.168 | 0.612 | 1.256 |

**Discussion**

Managing type 2 diabetes mellitus (T2DM) presents ongoing challenges due to the broad spectrum of clinical symptoms. Evaluating specific biomarkers can provide critical insights into insulin resistance, aiding in the disease's diagnosis and management and damaging of pancreatic cells having role in insulin resistance (Merza Mohammed 2024; Mohammed Merza, 2025; Mohammed Merza, 2024). This study explored how demographic factors and serum biomarkers relate to insulin resistance, offering valuable evidence to support personalized treatment approaches.

Although the age distribution between T2DM patients and healthy controls (HCs) differed, the analysis indicated no significant association, suggesting that age alone might not substantially increase T2DM risk. Similarly, gender was not significantly correlated with disease susceptibility, a finding that aligns with earlier research by Merza et al. (2025) and supports the notion that other unidentified variables may contribute to ethnic and racial disparities in T2DM development (Merza M, 2025).

Consistent with previous studies, our findings revealed significantly lower serum zinc levels in T2DM patients compared to healthy controls. Zinc is known to play an essential role in insulin synthesis, storage, and secretion; thus, its deficiency is closely tied to impaired glucose metabolism and increased insulin resistance (Ceballos-Rasgado et al., 2025). Evidence from randomized controlled trials further supports zinc supplementation as a potential strategy for enhancing insulin secretion, improving glycemic control, and reducing oxidative stress (Hsu et al., 2024). A meta-analysis by Huang et al. (2024) reinforced this relationship, showing a clear inverse correlation between serum zinc levels and insulin resistance as measured by HOMA-IR (Huang et al., 2024).

These findings complement numerous studies across various populations. This study observed significantly lower serum zinc in individuals with prediabetes, linking this deficiency to impaired β-cell function and higher insulin resistance. Similar trends have been reported, a lower zinc levels were associated with disrupted glucose metabolism and insulin sensitivity (Zong et al., 2024). These studies highlight the importance of routine zinc level assessments in T2DM management.

In addition to zinc, this study found that elevated random blood sugar (RBS) was a strong predictor of insulin resistance. High RBS levels are a hallmark of T2DM and reflect diminished glucose uptake due to insulin resistance (Mba et al., 2023). Research has demonstrated a strong correlation between elevated glucose and decreased insulin sensitivity, although this relationship can vary depending on factors such as obesity, physical activity, and genetic predisposition .

Likewise, HbA1c—a long-term indicator of glycemic control—was also significantly associated with HOMA-IR. A study by Aydemir et al. (2016) support the use of HbA1c as a reliable marker for assessing insulin resistance (Aydemir et al., 2016). Further showed that interventions reducing HbA1c levels improved insulin sensitivity. Nevertheless, a study noted inter-individual variability, suggesting that HbA1c alone may not fully explain insulin resistance and that other metabolic or genetic factors may be involved (Harder et al., 2020).

While this study contributes meaningful insights into T2DM pathophysiology, certain limitations should be acknowledged. The relatively small sample size and cross-sectional design limit causal inference. Future longitudinal studies with larger and more diverse cohorts are essential to validate these results. Additionally, assessing confounding factors such as comorbid conditions and medication use will provide a more comprehensive understanding of disease mechanisms and treatment outcomes.

**Conclusion**

This study highlights the critical role of serum biomarkers—specifically zinc levels, RBS, and HbA1c—in predicting insulin resistance in T2DM patients. These findings reinforce the potential utility of incorporating biomarker monitoring into standard diabetes management protocols. Addressing zinc deficiency and glycemic dysregulation may offer new opportunities for targeted, individualized interventions aimed at mitigating insulin resistance and improving overall metabolic health in individuals with T2DM.

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