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(Research Article)

Evaluation of Iron Profile and Essential Trace Elements in Patients with Type 2 Diabetes Mellitus Attending a Tertiary Care Center

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Abstract

Background: Type 2 diabetes mellitus (T2DM) is associated not only with chronic hyperglycemia but also with disturbances in iron metabolism and essential trace elements, which may influence glycemic regulation. Evidence regarding these associations remains limited in Bangladesh.

Objective: To evaluate the iron profile and essential trace elements among patients with type 2 diabetes mellitus and to assess their relationship with glycemic status.

Methods: This hospital-based cross-sectional study was conducted from May 2025 to July 2025 at a tertiary-level diabetic hospital in Bangladesh. A total of 100 patients with T2DM were included using hospital logbook data. Demographic information and laboratory parameters, including fasting blood sugar (FBS), HbA1c, serum iron, total iron binding capacity (TIBC), unsaturated iron binding capacity (UIBC), serum ferritin, hemoglobin, copper, magnesium, and zinc, were collected from medical records. Statistical analysis was performed using SPSS version 26.0. Group comparisons were conducted using independent samples *t*-test, correlations were assessed using Pearson's correlation coefficient, and multivariate linear regression analysis was performed to identify independent predictors of HbA1c.

Results: The mean age of the participants was 52.6 ± 9.8 years, and 62% were male. The mean FBS and HbA1c levels were 162.4 ± 42.7 mg/dL and 8.21 ± 1.63%, respectively, with 72% of patients having HbA1c ≥7%. Participants with HbA1c ≥7% had significantly higher serum ferritin (204.9 ± 78.4 vs. 142.5 ± 48.6 ng/mL, $p < 0.001$) and copper levels (123.2 ± 27.1 vs. 106.4 ± 21.7 μg/dL, $p = 0.006$), and lower serum iron (75.2 ± 21.9 vs. 86.3 ± 19.1 μg/dL, $p = 0.018$), magnesium (1.66 ± 0.31 vs. 1.92 ± 0.28 mg/dL, $p < 0.001$), zinc (68.4 ± 15.1 vs. 80.6 ± 14.2 μg/dL, $p = 0.002$), and hemoglobin (12.6 ± 1.4 vs. 13.4 ± 1.3 g/dL, $p = 0.021$). HbA1c showed a positive correlation with ferritin ($r = 0.46$, $p < 0.001$) and copper ($r = 0.34$, $p = 0.001$), and inverse correlations with magnesium ($r = -0.51$, $p < 0.001$), zinc ($r = -0.42$, $p < 0.001$), and serum iron ($r = -0.29$, $p = 0.004$). In multivariate analysis, ferritin ($\beta = 0.31$, $p < 0.001$), magnesium ($\beta = -0.38$, $p < 0.001$), zinc ($\beta = -0.27$, $p = 0.001$), and copper ($\beta = 0.19$, $p = 0.005$) remained independently associated with HbA1c.

Conclusion: Alterations in iron metabolism and essential trace elements are significantly associated with poor glycemic control in patients with type 2 diabetes mellitus, suggesting their potential relevance in metabolic assessment.

Keywords: Type 2 diabetes mellitus; Iron profile; Trace elements; HbA1c; Glycemic control

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1. Introduction

Type 2 diabetes mellitus (T2DM) is a major global public health challenge and one of the most rapidly increasing non-communicable diseases, particularly in low- and middle-income countries. The rising prevalence of T2DM is driven by urbanization, sedentary lifestyles, dietary transitions, and population aging[1]. Persistent hyperglycemia in T2DM is associated with progressive microvascular and macrovascular complications, including cardiovascular disease, nephropathy, neuropathy, and retinopathy, which contribute substantially to morbidity, mortality, and healthcare burden[2]. Beyond abnormalities in glucose metabolism, T2DM is increasingly recognized as a complex metabolic disorder involving oxidative stress, chronic low-grade inflammation, and disturbances in micronutrient homeostasis[3]. Alterations in iron metabolism and essential trace elements have gained attention as potential contributors to insulin resistance and poor glycemic control. These micronutrients play critical roles in enzymatic reactions, cellular signaling, and redox balance, and their dysregulation may exacerbate metabolic dysfunction in individuals with diabetes[4].

Iron is an essential element involved in oxygen transport, mitochondrial respiration, and immune function. However, excess iron can promote oxidative stress through the generation of reactive oxygen species, leading to cellular damage and impaired insulin signaling. Serum ferritin, a marker of body iron stores and an acute-phase reactant, has been reported to be elevated in patients with T2DM and has shown positive associations with fasting glucose levels and HbA1c in several populations[5]. These findings suggest a potential link between altered iron storage and the severity of glycemic dysregulation. Essential trace elements such as magnesium, zinc, and copper are also integral to glucose metabolism and insulin action. Magnesium serves as a cofactor for multiple enzymes involved in carbohydrate metabolism and is necessary for insulin receptor activity and post-receptor signaling[6]. Zinc plays a crucial role in insulin synthesis, storage, and secretion and contributes to antioxidant defense mechanisms. Copper, while required in trace amounts, participates in redox reactions and may influence oxidative stress when present in excess[7]. Imbalances in these trace elements have been observed among patients with diabetes and may vary according to the degree of glycemic control[8].

Several studies have reported inverse relationships between HbA1c and serum magnesium or zinc levels, while positive associations have been observed between HbA1c and ferritin or copper levels[9,10]. However, the findings remain inconsistent across different populations due to variations in dietary intake, genetic factors, inflammatory status, and healthcare access. Moreover, most studies have evaluated individual micronutrients in isolation, rather than assessing iron profile parameters and multiple essential trace elements simultaneously in relation to glycemic control[11].

In Bangladesh, the burden of type 2 diabetes mellitus is rapidly increasing, and understanding the biochemical alterations associated with glycemic dysregulation has become increasingly important[12]. Evaluation of iron metabolism and essential trace elements alongside routinely available clinical laboratory parameters may provide valuable insight into the metabolic profile of patients with T2DM and their glycemic status[13]. Such information is relevant for characterizing biochemical patterns associated with poor glycemic control in this population. Therefore, the present study aimed to evaluate the iron profile and essential trace elements among patients with type 2 diabetes mellitus attending a tertiary-level diabetic hospital in Bangladesh and to assess their relationship with glycemic status as measured by HbA1c.

2. Methodology

This hospital-based cross-sectional study was conducted over a three-month period from May 2025 to July 2025 at a diabetic hospital in Bangladesh that provides outpatient and inpatient services to patients with diabetes mellitus from diverse socioeconomic backgrounds. A total of 100 patients diagnosed with type 2 diabetes mellitus were included in the study, and participants were selected using a convenient sampling technique based on their availability during the study period.

Data were collected retrospectively from the hospital logbook and patient medical records. The collected information included demographic characteristics such as age and gender, relevant clinical data related to diabetes, and laboratory investigation results. Laboratory parameters retrieved from the hospital records comprised fasting blood sugar (FBS), glycated hemoglobin (HbA1c), serum iron, total iron binding capacity (TIBC), unsaturated iron binding capacity (UIBC), serum ferritin, hemoglobin, and essential trace elements including copper, magnesium, and zinc. All laboratory investigations had been performed as part of routine clinical care using standardized laboratory methods in the hospital laboratory[14], following established quality control procedures.

Adult patients with a confirmed diagnosis of type 2 diabetes mellitus and complete demographic and laboratory data available in the hospital records were included in the study. Patients with incomplete demographic or laboratory information, as well as those with documented acute infections or medical conditions known to significantly affect iron or trace element metabolism, were excluded where such information was available in the records. The study was conducted using anonymized patient data obtained from hospital records, and strict confidentiality of patient information was maintained throughout the study. No personal identifiers were collected, recorded, or disclosed at any stage of the research process.

Statistical analysis was performed using SPSS software (version 26.0). Continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies and percentages. Between-group comparisons were conducted using the independent samples *t*-test. Pearson's correlation coefficient was used to assess associations between HbA1c and iron profile parameters as well as essential trace elements, and multivariate linear regression analysis was performed to identify independent predictors of HbA1c. A *p*-value < 0.05 was considered statistically significant.

3. Results

A total of 100 patients with type 2 diabetes mellitus were included in the study. The baseline demographic and glycemic characteristics of the participants are summarized in Table 1. The mean age of the study population was 52.6 ± 9.8 years. Among the participants, 62 (62.0%) were male and 38 (38.0%) were female, indicating a male predominance (Figure 1). The mean fasting blood sugar (FBS) level was 162.4 ± 42.7 mg/dL, while the mean HbA1c level was 8.21 ± 1.63%, reflecting overall suboptimal glycemic control in the study population.

Table 1 Baseline Characteristics of Study Participants (n = 100)

Variable	Value
Age (years), Mean ± SD	52.6 ± 9.8
Gender, n (%)	
Male	62 (62.0)
Female	38 (38.0)
Fasting Blood Sugar (mg/dL), Mean ± SD	162.4 ± 42.7
HbA1c (%), Mean ± SD	8.21 ± 1.63

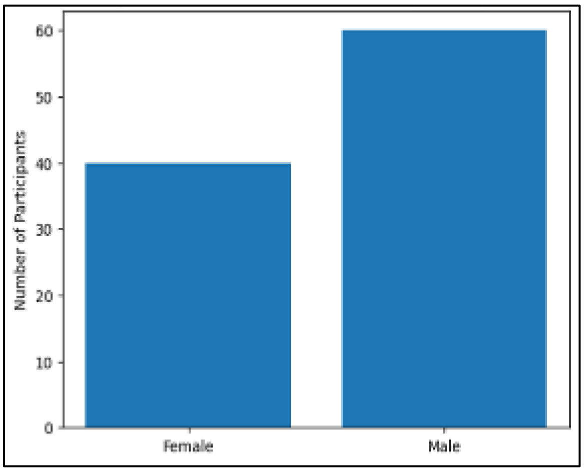


Figure 1 Gender Distribution of Study Participants

The distribution of glycemic control based on HbA1c categories is presented in Table 2. Good glycemic control (HbA1c <7.0%) was observed in 28 (28.0%) participants. Moderate glycemic control (HbA1c 7.0–8.9%) was found in 42 (42.0%) participants, while 30 (30.0%) participants had poor glycemic control (HbA1c ≥9.0%). The distribution of

HbA1c values demonstrated a broad range with a slightly right-skewed pattern, as illustrated in Figure 2, indicating a higher proportion of patients with elevated HbA1c levels.

Table 2 Distribution of Glycemic Status Based on HbA1c Levels

Glycemic control category	HbA1c (%)	Number (n)	Percent (%)
Good control	< 7.0	28	28.0
Moderate control	7.0 – 8.9	42	42.0
Poor control	≥ 9.0	30	30.0
Total		100	100.0

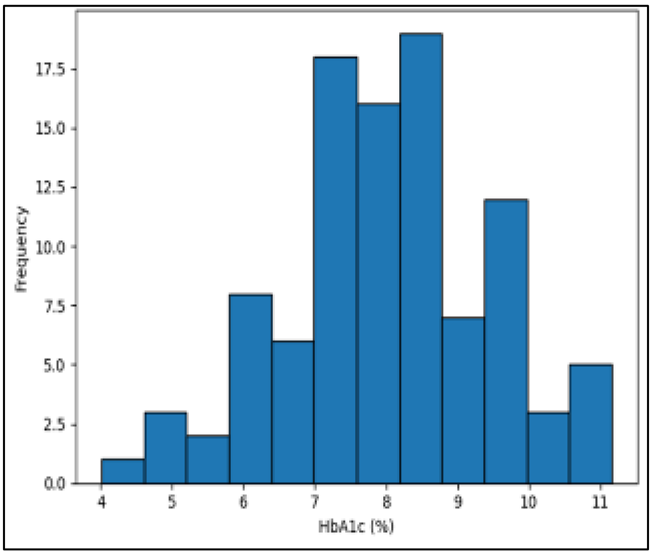


Figure 2 Distribution of HbA1c Levels

The descriptive statistics of iron profile parameters and essential trace elements are shown in Table 3. The mean serum iron concentration was 78.5 ± 21.4 μg/dL, while the mean total iron binding capacity (TIBC) and unsaturated iron binding capacity (UIBC) were 372.6 ± 48.9 μg/dL and 294.1 ± 52.3 μg/dL, respectively. The mean serum ferritin level was 186.7 ± 72.5 ng/mL, and the mean hemoglobin concentration was 12.9 ± 1.4 g/dL. Among the trace elements, the mean serum copper level was 118.6 ± 26.2 μg/dL, magnesium was 1.74 ± 0.32 mg/dL, and zinc was 71.8 ± 15.6 μg/dL.

Table 3 Descriptive Statistics of Iron Profile and Essential Trace Elements

Parameter	Mean ± SD
Serum Iron (μg/dL)	78.5 ± 21.4
Total Iron Binding Capacity – TIBC (μg/dL)	372.6 ± 48.9
Unsaturated Iron Binding Capacity – UIBC (μg/dL)	294.1 ± 52.3
Serum Ferritin (ng/mL)	186.7 ± 72.5
Hemoglobin (g/dL)	12.9 ± 1.4
Copper (μg/dL)	118.6 ± 26.2
Magnesium (mg/dL)	1.74 ± 0.32
Zinc (μg/dL)	71.8 ± 15.6

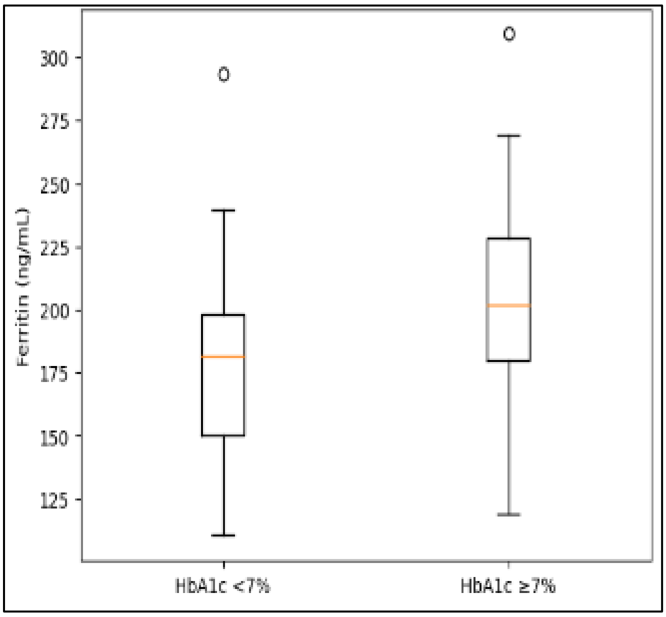
Comparative analysis of iron profile parameters and trace elements according to glycemic control status is presented in Table 4. Participants with HbA1c <7% had significantly higher serum iron levels (86.3 ± 19.1 µg/dL) compared to those with HbA1c ≥7% (75.2 ± 21.9 µg/dL, p = 0.018). Serum ferritin levels were significantly higher in participants with HbA1c ≥7% (204.9 ± 78.4 ng/mL) compared to those with HbA1c <7% (142.5 ± 48.6 ng/mL, p < 0.001). Conversely, serum magnesium and zinc levels were significantly lower in the HbA1c ≥7% group (1.66 ± 0.31 mg/dL and 68.4 ± 15.1 µg/dL, respectively) compared to the HbA1c <7% group (1.92 ± 0.28 mg/dL and 80.6 ± 14.2 µg/dL; p < 0.001 and p = 0.002, respectively). Serum copper levels were significantly higher in participants with poorer glycemic control (123.2 ± 27.1 µg/dL) than in those with better glycemic control (106.4 ± 21.7 µg/dL, p = 0.006). Hemoglobin levels were also significantly lower in the HbA1c ≥7% group (12.6 ± 1.4 g/dL) compared to the HbA1c <7% group (13.4 ± 1.3 g/dL, p = 0.021).

Table 4 Comparison of Iron Profile and Trace Elements by Glycemic Control

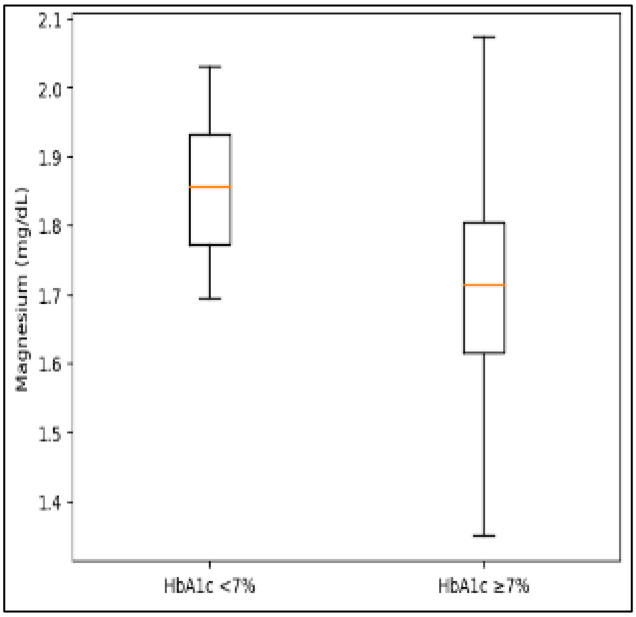
Parameter	**HbA1c < 7% (n=28)**	**HbA1c ≥ 7% (n=72)**	**p-value**
Serum Iron (µg/dL)	86.3 ± 19.1	75.2 ± 21.9	0.018
Ferritin (ng/mL)	142.5 ± 48.6	204.9 ± 78.4	<0.001
Magnesium (mg/dL)	1.92 ± 0.28	1.66 ± 0.31	<0.001
Zinc (µg/dL)	80.6 ± 14.2	68.4 ± 15.1	0.002
Copper (µg/dL)	106.4 ± 21.7	123.2 ± 27.1	0.006
Hemoglobin (g/dL)	13.4 ± 1.3	12.6 ± 1.4	0.021

These differences are visually demonstrated in Figure 3A–3C, which show box plots of serum ferritin, magnesium, and zinc levels by glycemic control status.

3A. Serum Ferritin by Glycemic Control



3B. Serum Magnesium by Glycemic Control



3C. Serum Zinc by Glycemic Control

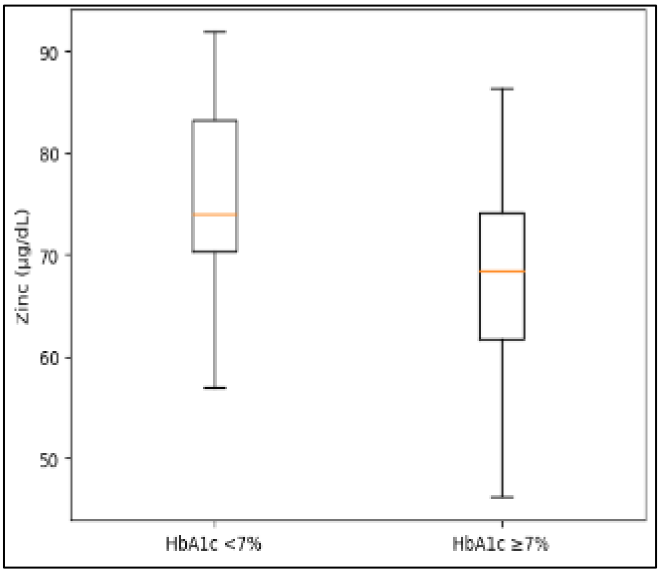


Figure 3 Box Plots of Key Biomarkers by Glycemic Control

Correlation analysis between HbA1c and iron profile parameters as well as essential trace elements is summarized in Table 5. HbA1c showed a significant positive correlation with serum ferritin ($r = 0.46$, $p < 0.001$) and serum copper ($r = 0.34$, $p = 0.001$). In contrast, HbA1c demonstrated significant inverse correlations with serum iron ($r = -0.29$, $p = 0.004$), magnesium ($r = -0.51$, $p < 0.001$), zinc ($r = -0.42$, $p < 0.001$), and hemoglobin ($r = -0.26$, $p = 0.009$). The relationships between HbA1c and serum ferritin, magnesium, and zinc are illustrated in Figures 4–6, showing linear trends with fitted regression lines.

Table 5 Correlation Between HbA1c and Iron / Trace Elements

Variable	r-value	p-value
Serum Ferritin	0.46	<0.001
Serum Iron	−0.29	0.004
Magnesium	−0.51	<0.001
Zinc	−0.42	<0.001
Copper	0.34	0.001
Hemoglobin	−0.26	0.009

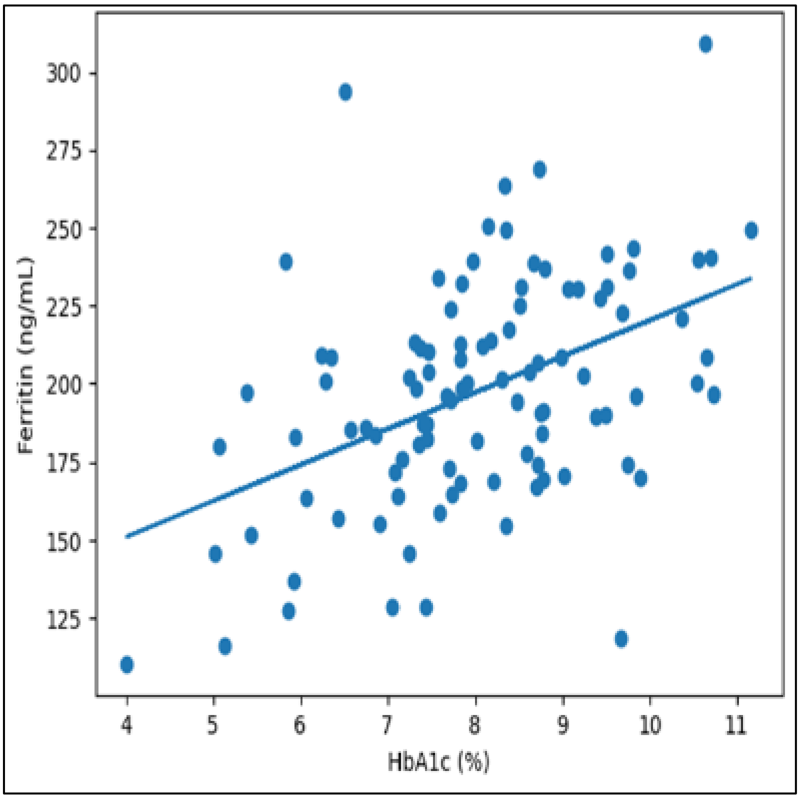


Figure 4 Correlation Between HbA1c and Ferritin

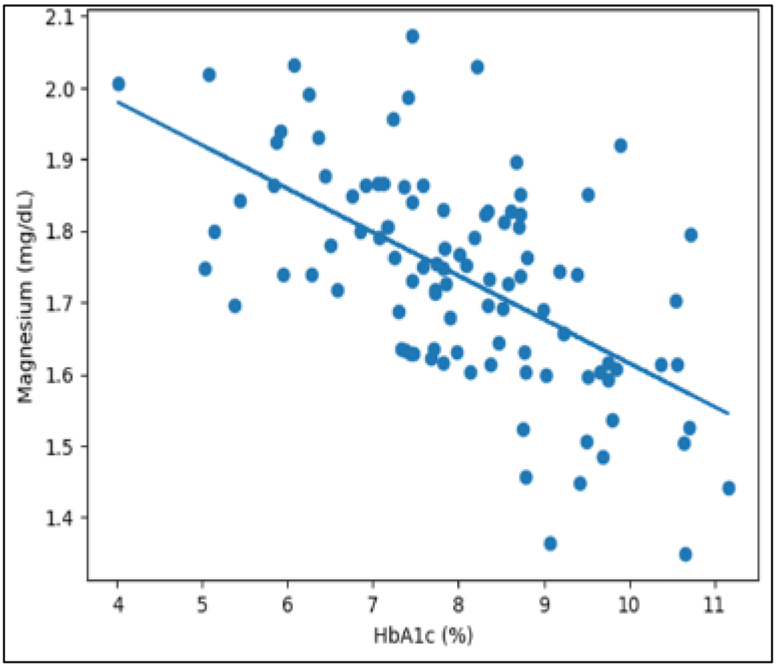


Figure 5 Correlation Between HbA1c and Magnesium

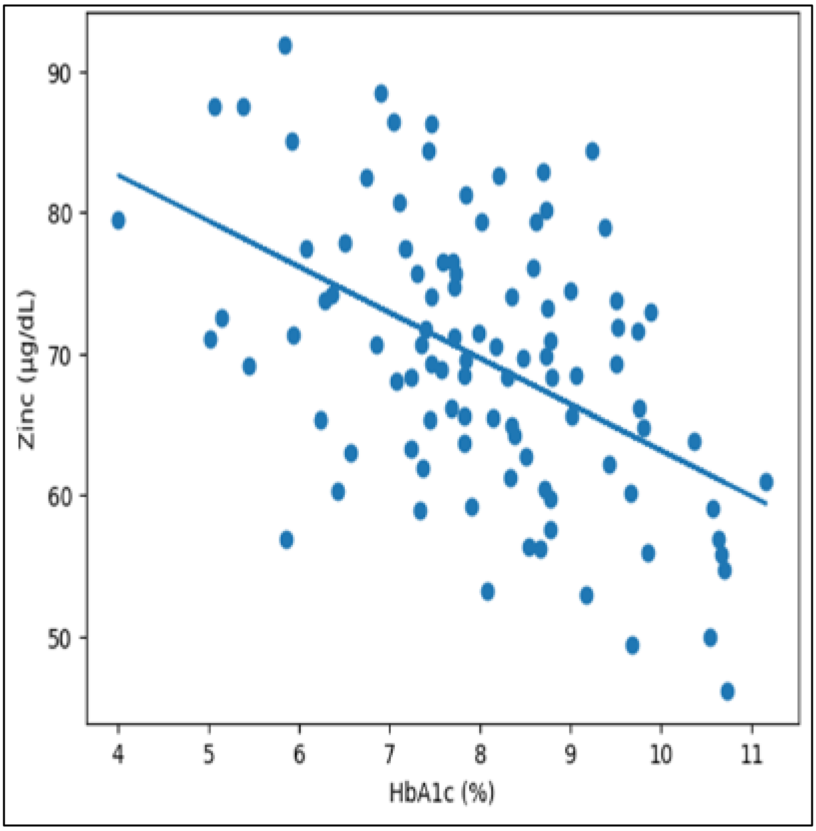


Figure 6 Correlation Between HbA1c and Zinc

The results of multivariate linear regression analysis for HbA1c are presented in Table 6. After adjustment for age and gender, serum ferritin (β = 0.31, p < 0.001) and serum copper (β = 0.19, p = 0.005) remained positively associated with HbA1c. In contrast, serum magnesium (β = −0.38, p < 0.001) and zinc (β = −0.27, p = 0.001) were independently and inversely associated with HbA1c levels.

Table 6 Multivariate Linear Regression Analysis for HbA1c

Predictor	**β (Standardized)**	**95% CI**	**p-value**
Serum Ferritin	0.31	0.18 – 0.44	<0.001
Magnesium	−0.38	−0.52 – −0.24	<0.001
Zinc	−0.27	−0.41 – −0.13	0.001
Copper	0.19	0.06 – 0.32	0.005
Age	0.12	−0.01 – 0.25	0.068
Gender (Male)	0.08	−0.05 – 0.21	0.214

Adjusted R^2 = 0.48

4. Discussion

In this study, the mean HbA1c level was 8.21 ± 1.63%, with 72% of participants exhibiting HbA1c ≥7%, indicating a high burden of inadequate glycemic control. Similar patterns of poor glycemic control have been reported in hospital-based studies from South Asia, reflecting challenges in diabetes management in low- and middle-income settings. The predominance of male participants (62%) is also consistent with previous reports, which may reflect gender differences in healthcare utilization rather than true disease prevalence[15].

A key finding of this study was the significantly higher serum ferritin levels observed in participants with poorer glycemic control. Patients with HbA1c ≥7% had markedly higher ferritin concentrations (204.9 ± 78.4 ng/mL) compared to those with HbA1c <7% (142.5 ± 48.6 ng/mL, $p < 0.001$). Furthermore, serum ferritin showed a moderate positive correlation with HbA1c ($r = 0.46$, $p < 0.001$), and this association remained significant after adjustment for age and gender in multivariate analysis ($\beta = 0.31$, $p < 0.001$). These findings are in agreement with previous studies reporting elevated ferritin levels in patients with poor glycemic control and support the hypothesis that altered iron storage is associated with worsening hyperglycemia[16]. Elevated ferritin may reflect increased body iron stores or an underlying inflammatory state, both of which have been linked to insulin resistance.

In contrast to ferritin, serum iron levels were significantly lower in participants with HbA1c ≥7% and demonstrated a significant inverse correlation with HbA1c ($r = -0.29$, $p = 0.004$). This apparent discrepancy between elevated ferritin and reduced serum iron has been reported previously and may reflect functional iron deficiency in the presence of inflammation, where iron is sequestered in storage sites despite increased total body iron[17].

Magnesium deficiency emerged as one of the most prominent findings in this study. Serum magnesium levels were significantly lower in patients with HbA1c ≥7% (1.66 ± 0.31 mg/dL) compared to those with better glycemic control (1.92 ± 0.28 mg/dL, $p < 0.001$). Magnesium showed the strongest inverse correlation with HbA1c ($r = -0.51$, $p < 0.001$) and remained an independent predictor of HbA1c in multivariate analysis ($\beta = -0.38$, $p < 0.001$). These findings are consistent with previous studies suggesting that hypomagnesemia is common in patients with poorly controlled diabetes and may be related to increased urinary magnesium loss, impaired insulin signaling, or both[18].

Similarly, serum zinc levels were significantly lower in participants with poor glycemic control and showed a significant inverse correlation with HbA1c ($r = -0.42$, $p < 0.001$). Zinc also remained independently associated with HbA1c after adjustment ($\beta = -0.27$, $p = 0.001$). Zinc plays a critical role in insulin synthesis, storage, and secretion, and reduced zinc levels have been associated with impaired insulin action in several studies. The present findings reinforce the potential relevance of zinc status in glycemic regulation among patients with type 2 diabetes mellitus[19].

Serum copper levels were significantly higher in participants with HbA1c ≥7% and showed a positive correlation with HbA1c ($r = 0.34$, $p = 0.001$). Copper remained independently associated with HbA1c in multivariate analysis ($\beta = 0.19$, $p = 0.005$). Elevated copper levels have been associated with increased oxidative stress, which may contribute to insulin resistance and endothelial dysfunction. Although copper is essential in small amounts, its excess may exacerbate metabolic disturbances in diabetes[20].

Hemoglobin levels were modestly but significantly lower in participants with poorer glycemic control and demonstrated an inverse correlation with HbA1c ($r = -0.26$, $p = 0.009$). This finding aligns with reports suggesting that anemia or lower hemoglobin levels may coexist with poor glycemic control, potentially due to inflammation, nutritional deficiencies, or renal involvement[21,22]. The multivariate regression model explained approximately 48% of the variability in HbA1c levels (adjusted $R^2 = 0.48$), indicating that iron storage status and essential trace elements contribute substantially to glycemic variability beyond age and gender. Notably, age and gender were not independently associated with HbA1c in the adjusted model, suggesting that biochemical factors may play a more prominent role in glycemic regulation in this population[23].

5. Conclusion

This study found significant associations between glycemic control and alterations in iron profile parameters and essential trace elements among patients with type 2 diabetes mellitus. Poor glycemic control was characterized by higher serum ferritin and copper levels and lower serum iron, magnesium, zinc, and hemoglobin concentrations, with ferritin, magnesium, zinc, and copper remaining independently associated with HbA1c. These findings indicate that disturbances in iron metabolism and trace element status coexist with poor glycemic control and may be relevant in the metabolic assessment of patients with type 2 diabetes mellitus. Further longitudinal studies are needed to clarify causal relationships and clinical implications.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design limits the ability to establish causal relationships between glycemic control and alterations in iron profile or trace elements. Second, the study was conducted at a single tertiary-level diabetic hospital with a relatively small sample size, which may limit the generalizability of the results to the broader population.

Third, data were collected retrospectively from hospital records, and information on dietary intake, inflammatory markers, renal function, medication use, and duration of diabetes was not available for analysis, which may have influenced the observed associations. Finally, the absence of a non-diabetic control group precluded direct comparison of iron profile and trace element status between diabetic and non-diabetic individuals.

Despite these limitations, the study provides valuable preliminary evidence on the relationship between iron metabolism, essential trace elements, and glycemic control in patients with type 2 diabetes mellitus in Bangladesh.

Compliance with ethical standards

Disclosure of conflict of interest

The author declares no conflict of interest.

Statement of ethical approval

The study was conducted in accordance with the ethical standards and ethical principles outlined in the Declaration of Helsinki.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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