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Impact of Iron Deficiency Anemia on Glycated Haemoglobin Levels in Patients with Type-2 Diabetes Mellitus: A Cross-Sectional Study

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ABSTRACT

Background: Iron deficiency anemia (IDA) is a common hematological disorder among patients with Type 2 Diabetes Mellitus (T2DM) and may influence glycated haemoglobin (HbA1c), a key marker used for assessing long-term glycaemic control. Alterations in red blood cell turnover and iron metabolism can affect HbA1c levels independent of blood glucose concentration, potentially leading to inaccurate assessment of diabetic status. This study was designed to evaluate the effect of iron deficiency anemia on HbA1c levels and to assess the relationship between hematological parameters, iron profile, and glycaemic status in patients with T2DM.

Materials and methods: This hospital-based cross-sectional study was conducted among 104 patients with T2DM attending the Department of General Medicine at Prathima Relief Institute of Medical Sciences, Hanamkonda, Telangana. Clinical evaluation and laboratory investigations including complete blood count, fasting blood glucose, HbA1c, serum iron, serum ferritin, total iron-binding capacity (TIBC), and transferrin saturation were performed. Patients were categorized into iron deficiency anemia and non-anemic groups. Statistical analyses included independent t-test, Chi-square test, correlation analysis, and multiple linear regression.

Results: Iron deficiency anemia was identified in 44.2% of participants. Patients with IDA had significantly lower haemoglobin, serum ferritin, serum iron, and transferrin saturation levels compared with non-anemic diabetic patients ($p<0.001$). Mean HbA1c was significantly higher in the IDA group (9.12±1.48%) than in the non-anemic group (8.11±1.21%) ($p<0.001$). HbA1c demonstrated significant negative correlations with haemoglobin ($r=-0.482$), serum ferritin ($r=-0.418$), serum iron ($r=-0.356$), and mean corpuscular volume ($r=-0.294$). Multiple linear regression analysis identified haemoglobin concentration and duration of diabetes as independent predictors of HbA1c levels.

Conclusion: Iron deficiency anemia significantly influences HbA1c values in patients with T2DM and may lead to overestimation of glycaemic control. Assessment of iron status should be considered when interpreting HbA1c results to ensure accurate clinical decision-making and optimal diabetes management.

***Keywords:** Type-2 diabetes mellitus, Iron deficiency anemia, HbA1c, serum ferritin, glycaemic control, hematological parameters.*

INTRODUCTION

Diabetes mellitus (DM) is one of the most prevalent chronic metabolic disorders worldwide and represents a major public health challenge. It is characterized by persistent hyperglycaemia resulting from defects in insulin secretion, insulin action, or both. The global burden of diabetes has increased substantially over recent decades, with Type 2 Diabetes Mellitus (T2DM) accounting for nearly 90–95% of all cases. According to the International Diabetes

Federation, approximately 537 million adults were living with diabetes in 2021, and this number is projected to rise significantly in the coming years owing to urbanization, sedentary lifestyles, obesity, and population aging [1].

Glycated haemoglobin (HbA1c) is widely accepted as a reliable marker for long-term glycaemic control and is commonly used for the diagnosis and monitoring of diabetes. HbA1c reflects the average blood glucose concentration over the preceding two to three months and has been strongly associated with the risk of diabetic complications such as retinopathy, nephropathy, neuropathy, and cardiovascular disease [2,3]. However, several hematological conditions may influence HbA1c levels independent of glycaemic status, thereby affecting its diagnostic accuracy [4].

Iron deficiency anemia (IDA) is the most common nutritional deficiency worldwide and remains highly prevalent in developing countries, including India [5]. The coexistence of diabetes and anemia is increasingly recognized in clinical practice. Anemia in diabetic patients may result from nutritional deficiencies, chronic inflammation, renal impairment, autonomic neuropathy, or impaired erythropoietin production [6]. Iron deficiency can alter erythrocyte lifespan and haemoglobin glycation kinetics, potentially leading to falsely elevated HbA1c levels despite stable glucose concentrations [7].

Several studies have reported an inverse relationship between haemoglobin concentration and HbA1c values, suggesting that iron deficiency may influence the interpretation of glycaemic control [8,9]. Conversely, correction of iron deficiency has been shown to reduce HbA1c levels in both diabetic and non-diabetic individuals [10]. These findings highlight the importance of understanding the interaction between iron metabolism and glycaemic markers.

Given the high prevalence of both diabetes mellitus and iron deficiency anemia in the Indian population, evaluating their interrelationship is clinically relevant. The present study was undertaken to assess the effect of iron deficiency anemia on HbA1c levels and hematological parameters among patients with Type 2 Diabetes Mellitus attending a tertiary care teaching hospital.

MATERIALS AND METHODS

The hospital-based cross-sectional observational study was carried out in the Department of General Medicine, Prathima Relief Institute of Medical Sciences, Hanamkonda, Telangana, India from April 2024 to June 2025. A total of 104 adult patients diagnosed with Type 2 Diabetes Mellitus according to the American Diabetes Association (ADA) criteria attending the General Medicine outpatient department and those admitted to the inpatient wards during the study period were screened for eligibility and enrolled after obtaining informed written consent and approval from the institutional ethics committee.

Inclusion Criteria: Patients ≥18 years of age, diagnosed with Type 2 Diabetes Mellitus according to ADA guidelines, willing to provide informed written consent and undergoing routine evaluation including complete blood count, iron profile, and HbA1c estimation.

Exclusion Criteria: Cases with type 1 Diabetes Mellitus, gestational diabetes mellitus, under iron supplementation within the preceding 3 months, known hemoglobinopathies, inherited red cell disorders, chronic kidney disease stage IV or V, chronic liver disease, acute or chronic inflammatory disorders, malignancy, history of blood transfusion within the previous 3 months, pregnancy and lactation.

A detailed demographic and clinical information were collected using a structured case record form. Anthropometric measurements and blood pressure was measured using a standardized sphygmomanometer after adequate rest. After overnight fasting of at least 8-10 hours, venous blood samples were collected under aseptic precautions for laboratory evaluation. The parameters including Complete Blood Count (CBC), glycaemic Parameters and iron profile were evaluated.

Statistical analysis

The collected data were extracted into Microsoft Excel and analyzed using SPSS v.26.0. Continuous variables were expressed as mean and standard deviation, whereas categorical variables were expressed as frequencies and percentages. Normality of data distribution was assessed using the Shapiro-Wilk test. Comparisons between groups were performed using independent Student's t-test for normally distributed continuous variables, Mann-Whitney U test for non-normally distributed variables and chi-square test for categorical variables. Correlation between HbA1c and hematological/iron profile parameters was assessed using Pearson's correlation coefficient as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

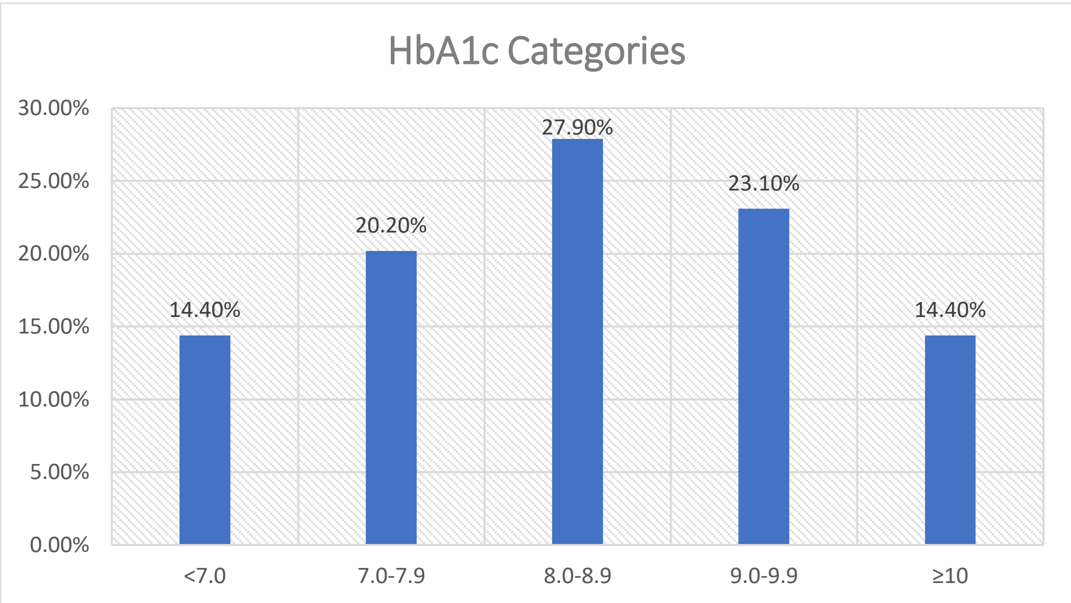
Table 1. Demographic characteristics of study participants (N=104).

Study variables	Mean ± SD / n (%)

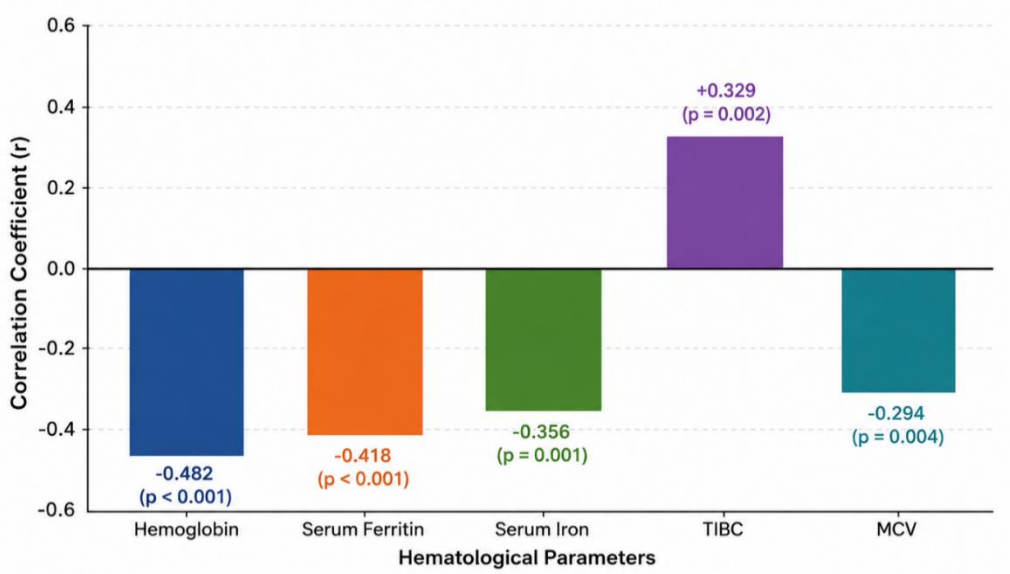
Age (In years)	56.4 ± 10.8
Gender	
Male	58 (55.8)
Female	46 (44.2)
Duration of Diabetes (years)	8.7 ± 4.9
BMI (kg/m²)	27.3 ± 3.8
Hypertension	49 (47.1)
Dyslipidaemia	41 (39.4)
Prevalence of iron deficiency anaemia	
Present	46 (44.2%)
Absent	58 (55.8%)

Table 2: Comparison of laboratory parameters between IDA and non-IDA cases.

Parameter	With IDA (n=46)	Non-IDA (n=58)	p-value
Hematological parameters			
Haemoglobin (g/dL)	10.2 ± 1.1	13.6 ± 1.2	0.001
RBC Count (million/mm³)	4.12 ± 0.58	4.78 ± 0.51	0.001
MCV (fL)	74.8 ± 6.4	86.3 ± 4.9	0.001
MCH (pg)	24.1 ± 3.0	29.2 ± 2.6	0.001
RDW (%)	16.8 ± 2.2	13.5 ± 1.4	0.001
Iron Profile			
Serum Iron (µg/dL)	42.5 ± 12.6	88.9 ± 18.4	0.001
Serum Ferritin (ng/mL)	18.7 ± 7.5	108.3 ± 39.8	0.001
TIBC (µg/dL)	418.6 ± 45.3	312.4 ± 39.1	0.001
Transferrin Saturation (%)	11.6 ± 4.2	28.4 ± 6.5	0.001
Glycaemic parameters			
FBS (mg/dL)	164.8 ± 38.7	159.6 ± 35.2	0.462
PPBS (mg/dL)	238.5 ± 54.2	229.4 ± 49.6	0.371
HbA1c (%)	9.12 ± 1.48	8.11 ± 1.21	0.001



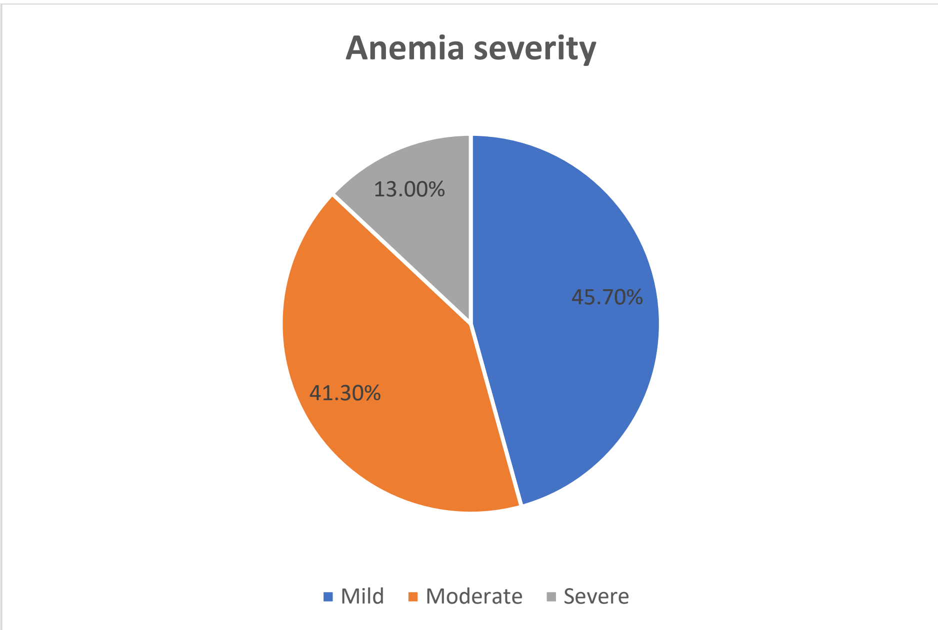
Graph 1: HbA1c categories among study participants.



Graph 2: Correlation between HbA1c and hematological parameters.

Table 3: Multiple linear regression analysis for predictors of HbA1c.

Variable	β Coefficient	95% CI	P-value
Hemoglobin	-0.29	-0.45 to -0.12	0.001
Serum Ferritin	-0.22	-0.38 to -0.08	0.004
Duration of Diabetes	0.31	0.14 to 0.47	<0.001
Age	0.08	-0.06 to 0.21	0.241



Graph 3: Distribution of anemia severity.

DISCUSSION

The iron deficiency anemia was observed in 44.2% of diabetic patients in present study. This finding is consistent with previous reports indicating that anemia is a common comorbidity among individuals with diabetes. Thomas et al. reported that approximately one-fourth of diabetic patients had previously unrecognized anemia, with prevalence increasing in the presence of diabetic complications and renal dysfunction [6]. Similarly, Bonakdaran et al. found that anemia was significantly more frequent among patients with long-standing diabetes and poor metabolic control [11]. The coexistence of diabetes and anemia may be attributed to nutritional deficiencies, chronic inflammation, autonomic neuropathy, impaired erythropoietin production, and diabetic nephropathy [12].

A major finding of the present study was the significantly higher mean HbA1c level among diabetic patients with iron deficiency anemia compared with those without anemia. This observation supports the hypothesis that iron deficiency can artificially elevate HbA1c concentrations. Coban et al. demonstrated that non-diabetic individuals with IDA had significantly elevated HbA1c levels, which decreased after iron replacement therapy, despite no change in glucose levels [10]. Similar findings were reported by Madhu et al., who observed higher HbA1c values in iron-deficient subjects and normalization following iron supplementation [8]. These studies suggest that iron deficiency prolongs erythrocyte survival and increases exposure of haemoglobin to circulating glucose, thereby enhancing glycation.

The present study also demonstrated significant negative correlations between HbA1c and hemoglobin concentration ($r = -0.482$), serum ferritin ($r = -0.418$), serum iron ($r = -0.356$), and mean corpuscular volume ($r = -0.294$). These findings are in agreement with those of Silva et al., who reported inverse relationships between HbA1c and haemoglobin, ferritin, and red cell indices among patients with iron deficiency [13]. Likewise, Rajagopal et al. found that diabetic patients with depleted iron stores exhibited significantly higher HbA1c values than those with normal iron status [14].

The pathophysiological basis of this relationship remains incompletely understood. One proposed mechanism is that iron deficiency prolongs the lifespan of circulating erythrocytes, increasing the duration of glucose exposure and consequently elevating HbA1c levels [7]. Another explanation involves structural changes in the hemoglobin molecule caused by iron depletion, making globin chains more susceptible to non-enzymatic glycation [15]. Oxidative stress associated with iron deficiency has also been suggested to enhance glycation reactions and contribute to elevated HbA1c values [16].

In the present study, serum ferritin emerged as an independent predictor of HbA1c levels. Ferritin serves as an indicator of body iron stores, and reduced ferritin concentrations have been linked with altered HbA1c measurements. English et al., in a systematic review, concluded that iron deficiency and iron deficiency anemia may significantly influence HbA1c values, potentially leading to misclassification of glycaemic status [9]. Therefore, clinicians should exercise caution when interpreting HbA1c results in patients with suspected or confirmed iron deficiency.

Duration of diabetes also emerged as a significant independent predictor of HbA1c in the multivariable regression model. This finding is expected, as progressive β-cell dysfunction and worsening insulin resistance over time often result in poorer glycaemic control [17]. Similar observations have been reported in large epidemiological studies evaluating determinants of HbA1c among diabetic populations [18].

The clinical implications of these findings are important. HbA1c is widely used for diagnosis, monitoring, and therapeutic decision-making in diabetes. However, the presence of iron deficiency anemia may result in spuriously elevated HbA1c levels, potentially leading to overestimation of glycaemic status and inappropriate treatment intensification. Screening for anemia and assessment of iron profile should therefore be considered when HbA1c values appear inconsistent with blood glucose measurements.

CONCLUSION

The iron deficiency anemia is a common comorbidity among patients with Type 2 Diabetes Mellitus and has a significant influence on HbA1c levels. Diabetic patients with iron deficiency anemia exhibited higher HbA1c values despite comparable glycaemic status, suggesting that iron deficiency may contribute to falsely elevated HbA1c measurements. Significant negative correlations were observed between HbA1c and haemoglobin, serum ferritin, serum iron, and red cell indices. These findings highlight the importance of evaluating iron status in diabetic patients before interpreting HbA1c values, thereby ensuring accurate assessment of glycaemic control and appropriate clinical management.

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