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Comparative Analysis of Glycemic Control and Iron-Related Anemia Parameters in Diabetic and Non-Diabetic Women in Bangladesh

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Abstract

Background: Type 2 diabetes mellitus (T2DM) is increasingly prevalent among women in South Asia and is associated not only with metabolic complications but also with hematological and nutritional abnormalities. Anemia and disturbances in iron metabolism may coexist with poor glycemic control, potentially worsening clinical outcomes, particularly in resource-limited settings such as Bangladesh.

Objective: To compare glycemic control and iron-related anemia parameters between diabetic and non-diabetic women in Bangladesh and to examine the association between glycemic status and hematological as well as iron indices.

Methods: This hospital-based comparative cross-sectional study was conducted at a tertiary care diabetic center in Bangladesh from January to April 2025. A total of 120 adult women were included, comprising 60 diabetic and 60 non-diabetic participants. Data were collected from hospital record books and laboratory reports. Fasting blood glucose (FBS), HbA1c, lipid profile, complete blood count, serum iron, ferritin, and total iron-binding capacity (TIBC) were analyzed. Group comparisons, correlation analyses, and multivariable linear and logistic regression analyses were performed using SPSS version 26.0.

Results: Diabetic women had significantly higher FBS (8.6 ± 2.1 vs 5.1 ± 0.6 mmol/L; $p < 0.001$) and HbA1c levels (8.1 ± 1.3% vs 5.4 ± 0.4%; $p < 0.001$) than non-diabetic women. Mean hemoglobin concentration was significantly lower in diabetic women (10.9 ± 1.4 g/dL) compared with non-diabetic women (12.1 ± 1.3 g/dL; $p < 0.001$), and anemia prevalence was markedly higher (56.7% vs 30.0%; $p = 0.003$). Diabetic women also showed lower serum ferritin [48 ng/mL (IQR 32–86) vs 62 ng/mL (IQR 41–102); $p = 0.02$] and serum iron levels (62 ± 18 vs 74 ± 20 µg/dL; $p = 0.004$), along with higher TIBC (418 ± 52 vs 392 ± 47 µg/dL; $p = 0.01$). HbA1c was negatively correlated with hemoglobin ($r = −0.41$), serum ferritin ($r = −0.29$), and serum iron ($r = −0.33$), and positively correlated with TIBC ($r = 0.27$) (all $p < 0.01$). In multivariable analysis, diabetic status ($\beta = −0.38$; $p < 0.001$) and HbA1c ($\beta = −0.29$; $p < 0.001$) were independently associated with lower hemoglobin levels, while low ferritin was the strongest predictor of anemia (adjusted OR = 3.02; 95% CI: 1.48–6.18).

Conclusion: Diabetic women in Bangladesh experience a significantly higher burden of anemia and adverse iron-related alterations compared with non-diabetic women. Poor glycemic control is independently associated with reduced hemoglobin levels and depleted iron stores.

Keywords: Diabetes mellitus; Anemia; Iron status; HbA1c; Women

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1. Introduction

Diabetes mellitus represents one of the most significant public health challenges worldwide, with a rapidly increasing burden in low- and middle-income countries. Type 2 diabetes mellitus (T2DM) is characterized by chronic hyperglycemia resulting from insulin resistance and impaired insulin secretion, leading to a wide range of metabolic and vascular complications[1]. In South Asian populations, including Bangladesh, the prevalence of T2DM has risen sharply due to urbanization[2], dietary transitions, physical inactivity, and genetic susceptibility[3], disproportionately affecting adult women and contributing to substantial morbidity and healthcare costs[4].

Beyond classical microvascular and macrovascular complications, T2DM is increasingly recognized to influence hematological and nutritional status. Chronic hyperglycemia induces oxidative stress, systemic inflammation, and renal dysfunction, all of which can adversely affect erythropoiesis and iron metabolism[5]. Anemia is therefore frequently observed among individuals with diabetes and has been associated with reduced quality of life, accelerated progression of diabetic complications, and increased cardiovascular risk[6]. Women are particularly vulnerable to anemia due to menstrual blood loss, nutritional deficiencies, and socioeconomic factors, making this interaction clinically relevant in female populations[7].

Iron metabolism plays a pivotal role in erythropoiesis and cellular oxygen transport, and its dysregulation has important implications in diabetes[8]. Alterations in serum iron, ferritin, and total iron-binding capacity (TIBC) have been reported among patients with poor glycemic control, suggesting a bidirectional relationship between glucose homeostasis and iron status[9]. While iron deficiency may exacerbate fatigue and functional impairment, abnormal iron handling may also influence insulin sensitivity and glycation processes, further complicating metabolic control. Hemoglobin concentration and red cell indices may therefore serve as indirect markers of both nutritional status and metabolic dysregulation in diabetic individuals[10].

In Bangladesh, anemia remains a major public health concern among women of reproductive and middle age, driven by dietary inadequacy, micronutrient deficiencies, and chronic disease burden[11]. The coexistence of diabetes and anemia in this setting poses a dual challenge, potentially amplifying adverse health outcomes. However, comparative clinical data examining glycemic status alongside iron-related anemia parameters among diabetic and non-diabetic women using standardized laboratory measures remain limited[12]. Understanding these associations is essential for integrated metabolic and nutritional management strategies, particularly in resource-constrained healthcare systems. Therefore, the aim of the present study was to comparatively evaluate glycemic control and iron-related anemia parameters among diabetic and non-diabetic women in Bangladesh.

2. Materials and methods

This hospital-based comparative cross-sectional study was conducted at a tertiary care diabetic center in Bangladesh over a four-month period from January to April 2025. A total of 120 adult women were enrolled, including 60 women with diabetes mellitus and 60 non-diabetic women. Participants were selected using a convenience sampling technique. Women aged 18 years or older were eligible for inclusion. The diabetic group consisted of women with a confirmed diagnosis of diabetes mellitus based on hospital medical records and documented glycemic measurements, whereas the non-diabetic group included women without a prior history of diabetes and with normal fasting blood glucose and HbA1c levels as recorded in hospital reports. Participants with known hematological disorders other than anemia, chronic kidney or liver disease, malignancy, acute infection, recent blood transfusion or iron supplementation, and those who were pregnant or lactating were excluded to minimize potential confounding effects on hematological and iron parameters.

Sociodemographic and clinical information, including age, residence, marital status, and diabetic status, were obtained retrospectively from hospital record books and patient files, supplemented by review of laboratory investigation reports. All extracted data were cross-checked for completeness and recorded using standardized data collection formats to ensure consistency and accuracy. Laboratory data were obtained from existing hospital laboratory reports. Fasting blood glucose had been measured using the enzymatic glucose oxidase method, while glycated hemoglobin was analyzed using standardized automated techniques aligned with international reference standards. Serum creatinine and lipid profile parameters, including total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triglycerides, were measured using automated biochemical analyzers following routine laboratory protocols and internal quality control procedures.

Hematological parameters, including hemoglobin concentration, red blood cell count, total white blood cell count, platelet count, mean corpuscular volume, and mean corpuscular hemoglobin, were retrieved from complete blood count reports generated by automated hematology analyzers. Anemia was defined according to standard hemoglobin cut-off values for adult women. Serum iron, ferritin, and total iron-binding capacity values were extracted from laboratory records and had been measured using validated immunochemical and colorimetric methods. Due to non-normal distribution, ferritin values were expressed as median with interquartile range.

Statistical analysis was performed using SPSS version 26.0. Data were expressed as mean ± SD, median (IQR), or frequencies and percentages. Group comparisons were conducted using appropriate parametric or nonparametric tests, and chi-square tests for categorical variables. Correlations were assessed using Pearson's coefficient, and multivariable regression analyses were performed to identify predictors of hemoglobin levels and anemia. A p-value < 0.05 was considered statistically significant.

3. Results

The study included a total of 120 women, comprising 60 diabetic and 60 non-diabetic participants. The mean age of diabetic women was 45.2 ± 8.1 years, which was slightly higher than that of non-diabetic women (42.6 ± 7.4 years), although the difference was not statistically significant (p = 0.08).Age group distribution did not differ significantly between groups (p = 0.41). The majority of participants in both groups were aged 35–49 years (51.7% in diabetic vs 46.7% in non-diabetic women). Urban residence was more common among diabetic women (63.3%) compared with non-diabetic women (56.7%), but this difference was not statistically significant (p = 0.46). Most participants were married in both groups, with no significant difference in marital status distribution (86.7% vs 81.7%; p = 0.45) (Table 1).

Table 1 Demographic Characteristics of Study Participants (n = 120)

Variable	Diabetic Women (n = 60)	Non-Diabetic Women (n = 60)	p-value
Age (years), mean ± SD	45.2 ± 8.1	42.6 ± 7.4	0.08
Age group (years), n (%)			
18–34	12 (20.0)	18 (30.0)	
35–49	31 (51.7)	28 (46.7)	
≥50	17 (28.3)	14 (23.3)	0.41
Residence, n (%)			
Urban	38 (63.3)	34 (56.7)	
Rural	22 (36.7)	26 (43.3)	0.46
Marital status, n (%)			
Married	52 (86.7)	49 (81.7)	
Unmarried	8 (13.3)	11 (18.3)	0.45

Diabetic women exhibited significantly higher fasting blood glucose (8.6 ± 2.1 mmol/L) compared with non-diabetic women (5.1 ± 0.6 mmol/L; p < 0.001). Similarly, mean HbA1c levels were markedly elevated among diabetic women (8.1 ± 1.3%) relative to non-diabetic women (5.4 ± 0.4%; p < 0.001). Serum creatinine levels were slightly higher in diabetic women (1.02 ± 0.21 mg/dL) than in non-diabetic women (0.94 ± 0.18 mg/dL), but the difference did not reach statistical significance (p = 0.06). Regarding lipid profile, diabetic women showed significantly higher total cholesterol (212 ± 38 mg/dL vs 186 ± 34 mg/dL; p < 0.01), LDL-cholesterol (132 ± 32 mg/dL vs 112 ± 28 mg/dL; p = 0.002), and triglyceride levels (186 ± 54 mg/dL vs 138 ± 46 mg/dL; p < 0.001). In contrast, HDL-cholesterol levels were significantly lower among diabetic women (42 ± 9 mg/dL) compared with non-diabetic women (49 ± 10 mg/dL; p < 0.001) (Table 2).

Table 2 Clinical and Biochemical Characteristics of Study Participants (n = 120)

Variable	Diabetic Women (n = 60)	Non-Diabetic Women (n = 60)	p-value
FBS (mmol/L), mean ± SD	8.6 ± 2.1	5.1 ± 0.6	<0.001
HbA1c (%), mean ± SD	8.1 ± 1.3	5.4 ± 0.4	<0.001
Creatinine (mg/dL), mean ± SD	1.02 ± 0.21	0.94 ± 0.18	0.06
Lipid profile			
Total cholesterol (mg/dL)	212 ± 38	186 ± 34	<0.01
HDL-cholesterol (mg/dL)	42 ± 9	49 ± 10	<0.001
LDL-cholesterol (mg/dL)	132 ± 32	112 ± 28	0.002
Triglycerides (mg/dL)	186 ± 54	138 ± 46	<0.001

Mean hemoglobin concentration was significantly lower in diabetic women (10.9 ± 1.4 g/dL) than in non-diabetic women (12.1 ± 1.3 g/dL; $p < 0.001$). RBC count was also significantly reduced in diabetic women ($4.12 \pm 0.46 \times 10^6/\mu L$) compared with non-diabetic women ($4.48 \pm 0.42 \times 10^6/\mu L$; $p < 0.001$). Total WBC count was modestly higher in diabetic women ($7.8 \pm 1.9 \times 10^3/\mu L$) than in non-diabetic women ($7.1 \pm 1.6 \times 10^3/\mu L$), with a statistically significant difference ($p = 0.03$). Platelet counts did not differ significantly between groups ($p = 0.21$). Red cell indices showed significantly lower MCV (81.6 ± 6.4 fL vs 84.9 ± 5.8 fL; $p = 0.004$) and MCH (26.1 ± 2.8 pg vs 27.9 ± 2.6 pg; $p = 0.002$) among diabetic women (Table 3).

Table 3 Complete Blood Count (CBC) Parameters of Study Participants (n = 120)

Variable	Diabetic Women (n = 60)	Non-Diabetic Women (n = 60)	p-value
Hemoglobin (g/dL)	10.9 ± 1.4	12.1 ± 1.3	<0.001
RBC count ($\times 10^6/\mu L$)	4.12 ± 0.46	4.48 ± 0.42	<0.001
Total WBC count ($\times 10^3/\mu L$)	7.8 ± 1.9	7.1 ± 1.6	0.03
Platelet count ($\times 10^3/\mu L$)	286 ± 72	271 ± 68	0.21
MCV (fL)	81.6 ± 6.4	84.9 ± 5.8	0.004
MCH (pg)	26.1 ± 2.8	27.9 ± 2.6	0.002

Anemia prevalence was significantly higher among diabetic women (56.7%) compared with non-diabetic women (30.0%; $p = 0.003$). Median serum ferritin levels were significantly lower in diabetic women [48 ng/mL (IQR 32–86)] than in non-diabetic women [62 ng/mL (IQR 41–102); $p = 0.02$]. Mean serum iron concentration was also reduced in diabetic women (62 ± 18 µg/dL) relative to non-diabetic women (74 ± 20 µg/dL; $p = 0.004$). Conversely, total iron-binding capacity (TIBC) was significantly higher in diabetic women (418 ± 52 µg/dL) compared with non-diabetic women (392 ± 47 µg/dL; $p = 0.01$) (Table 4).

Table 4 Iron Status and Anemia Parameters in Diabetic and Non-Diabetic Women

Parameter	Diabetic Women (n = 60)	Non-Diabetic Women (n = 60)	p-value
Hemoglobin (g/dL)	10.9 ± 1.4	12.1 ± 1.3	<0.001
Anemia prevalence, n (%)	34 (56.7)	18 (30.0)	0.003
Serum ferritin (ng/mL), median (IQR)	48 (32–86)	62 (41–102)	0.02
Serum iron (µg/dL)	62 ± 18	74 ± 20	0.004
TIBC (µg/dL)	418 ± 52	392 ± 47	0.01

HbA1c showed a significant negative correlation with hemoglobin ($r = -0.41$, $p < 0.001$), serum ferritin ($r = -0.29$, $p = 0.002$), and serum iron levels ($r = -0.33$, $p < 0.001$). A significant positive correlation was observed between HbA1c and TIBC ($r = 0.27$, $p = 0.004$) (Table 5).

Table 5 Association Between Glycemic Control and Iron-Related Anemia Parameters

Variable	Correlation coefficient (r)	p-value
Hemoglobin	−0.41	<0.001
Serum ferritin	−0.29	0.002
Serum iron	−0.33	<0.001
TIBC	+0.27	0.004

After adjustment for potential confounders, diabetic status remained independently associated with lower hemoglobin levels ($\beta = -0.38$, 95% CI: −1.21 to −0.56; $p < 0.001$). Higher HbA1c levels were also independently associated with reduced hemoglobin concentration ($\beta = -0.29$, 95% CI: −0.42 to −0.15; $p < 0.001$). Increasing age was negatively associated with hemoglobin levels ($\beta = -0.18$; $p = 0.01$), whereas serum ferritin showed a positive association with hemoglobin concentration ($\beta = +0.22$; $p = 0.02$) (Table 6).

Table 6 Multivariable Linear Regression Analysis of Factors Associated with Hemoglobin Levels

Predictor	β (standardized)	95% CI	p-value
Diabetic status	−0.38	−1.21 to −0.56	<0.001
HbA1c (%)	−0.29	−0.42 to −0.15	<0.001
Age (years)	−0.18	−0.04 to −0.01	0.01
Serum ferritin	+0.22	0.01 to 0.03	0.02

In table 7 multivariable logistic regression analysis, diabetic status was associated with a significantly higher odds of anemia (adjusted OR = 2.64, 95% CI: 1.31–5.34; $p = 0.007$). Participants with HbA1c ≥ 7% had over two-fold increased odds of anemia (adjusted OR = 2.11, 95% CI: 1.08–4.12; $p = 0.03$). Low serum ferritin was the strongest predictor of anemia (adjusted OR = 3.02, 95% CI: 1.48–6.18; $p = 0.002$). Age ≥ 45 years showed a positive but non-significant association with anemia risk ($p = 0.09$).

Table 7 Logistic Regression Analysis Identifying Predictors of Anemia

Predictor	Adjusted OR	95% CI	p-value
Diabetic status	2.64	1.31–5.34	0.007
HbA1c ≥ 7%	2.11	1.08–4.12	0.03
Low ferritin	3.02	1.48–6.18	0.002
Age ≥ 45 years	1.76	0.92–3.38	0.09

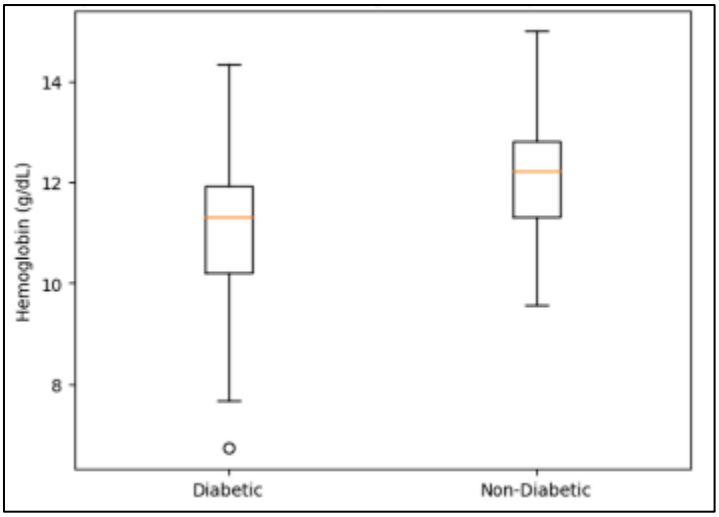

Figure 1 Distribution of Hemoglobin Levels by Diabetic Status

This box plot illustrates the distribution of hemoglobin levels among diabetic and non-diabetic women. Diabetic women showed markedly lower hemoglobin concentrations compared with non-diabetic women, consistent with the significantly higher prevalence of anemia observed in this group (Figure 1).

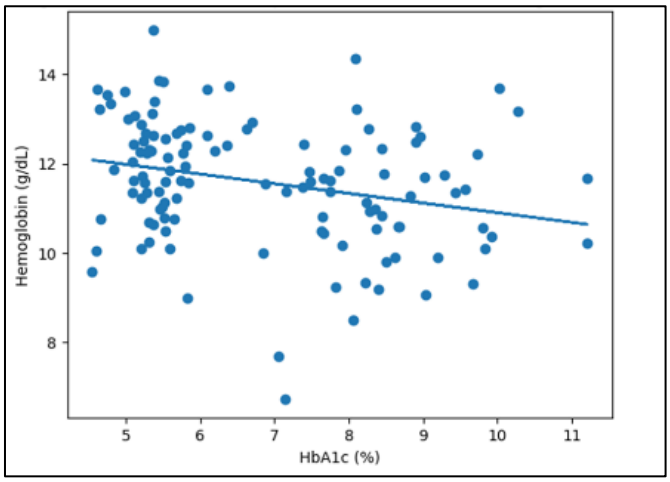

Figure 2 Linear Relationship Between HbA1c and Hemoglobin Levels

The scatter plot with fitted regression line demonstrates a significant inverse linear association between HbA1c and hemoglobin levels, indicating that poorer glycemic control is associated with lower hemoglobin concentration across the study population. This finding supports the regression results shown in figure 2.

4. Discussion

The present study demonstrates a clear and clinically meaningful association between diabetes mellitus and alterations in hematological as well as iron-related parameters among adult women in Bangladesh. Diabetic women exhibited significantly lower hemoglobin concentrations (10.9 ± 1.4 g/dL) compared with non-diabetic women (12.1 ± 1.3 g/dL), along with a substantially higher prevalence of anemia (56.7% vs 30.0%). These findings indicate that anemia is considerably more common among women with diabetes, even in the absence of overt renal disease. Similar observations have been reported in Bangladeshi hospital-based studies, where anemia prevalence among patients with diabetes ranged from approximately 45% to 60%, particularly among women and older adults[13]. Studies from India have also reported lower mean hemoglobin levels in diabetic populations, typically ranging between 10.5 and 11.5 g/dL, supporting the consistency of our findings within the regional context[14]. The observed reductions in red blood cell count, mean corpuscular volume, and mean corpuscular hemoglobin in diabetic women further suggest a tendency toward

iron-deficiency or mixed anemia, which may be exacerbated by chronic inflammation and metabolic dysregulation associated with diabetes[15].

Alterations in iron metabolism were a prominent feature in diabetic women in the present study. Median serum ferritin levels were significantly lower in diabetic women [48 ng/mL (IQR 32–86)] compared with non-diabetic women [62 ng/mL (IQR 41–102)], accompanied by reduced serum iron levels and increased total iron-binding capacity. This pattern is consistent with iron-deficiency anemia rather than anemia of chronic disease alone. Comparable findings have been reported in South Asian studies, including Indian[16] and Pakistani[17] cohorts, where diabetic patients demonstrated lower serum iron and ferritin levels along with elevated TIBC values. For instance, Indian studies have reported mean serum iron concentrations between 55 and 65 μg/dL in diabetic individuals, closely aligning with the value observed in our diabetic group (62 ± 18 μg/dL)[18]. In Bangladesh, dietary iron insufficiency, menstrual blood loss, and limited access to balanced nutrition may further compound the effects of diabetes on iron homeostasis, particularly among women. The coexistence of diabetes and iron deficiency may therefore represent a dual burden that requires integrated metabolic and nutritional management[19].

A key strength of the present study is the demonstration of a significant inverse relationship between glycemic control and hematological status. HbA1c showed moderate but significant negative correlations with hemoglobin ($r = -0.41$), serum ferritin ($r = -0.29$), and serum iron ($r = -0.33$), along with a positive correlation with TIBC. These findings indicate that poorer glycemic control is associated with worsening iron deficiency and anemia. Similar associations have been documented in Indian and Sri Lankan studies, where HbA1c levels above 7% were linked to lower hemoglobin concentrations and increased anemia risk[20]. In multivariable analyses, diabetic status and higher HbA1c remained independently associated with reduced hemoglobin levels, while low ferritin emerged as the strongest predictor of anemia (adjusted OR = 3.02). These results suggest that chronic hyperglycemia may impair erythropoiesis through oxidative stress, low-grade inflammation, and reduced iron availability, even before the onset of advanced diabetic complications. Taken together, the findings highlight the importance of routine anemia and iron status screening in women with diabetes, particularly in resource-limited South Asian settings, to improve overall clinical outcomes[21].

5. Conclusion

This study demonstrates that diabetic women in Bangladesh have a significantly higher burden of anemia and adverse iron-related alterations compared with non-diabetic women. Poor glycemic control was independently associated with lower hemoglobin levels, reduced iron stores, and increased risk of anemia. These findings highlight the need for routine assessment of hematological and iron status alongside glycemic monitoring in women with diabetes to enable early identification and targeted management of anemia, particularly in resource-limited settings.

Limitations

This study has several limitations. Its cross-sectional design precludes causal inference between glycemic control and anemia-related parameters. Data were collected from a single tertiary care center using hospital records, which may limit generalizability to the broader community. Additionally, dietary iron intake, inflammatory markers, and vitamin B12 or folate levels were not assessed, which could have influenced hematological outcomes.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest.

Statement of informed consent

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

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