Section: Miscellaneous

Original Research Article

RED BLOOD CELL PARAMETERS AND ITS CORRELATION WITH GLYCAEMIC INDEX IN PATIENTS WITH TYPE II DIABETES MELLITUS

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ABSTRACT

Background: Chronic hyperglycaemia in diabetes mellitus leads to biochemical and structural alterations in red blood cells (RBCs), potentially influencing routine hematological indices. Understanding how RBC parameters reflect glycaemic control may provide additional, cost-effective tools for patient monitoring. The aim is to evaluate red blood cell parameters and their correlation with glycaemic indices in patients with diabetes mellitus.

Materials and Methods: A comparative cross-sectional study was conducted among 200 diabetic patients, categorized into two groups: Group A (n=100) with good glycaemic control and Group B (n=100) with poor glycaemic control. Socio-demographic variables, anthropometric indices, and clinical parameters including HbA1c, fasting blood sugar (FBS), and postprandial blood sugar (PPBS) were recorded. RBC indices such as RBC count, hemoglobin (Hb), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW) were compared between groups and correlated with glycaemic markers.

Results: Patients with poor glycaemic control demonstrated significantly higher BMI (27.4 ± 3.6 kg/m²) and WHR (0.96 ± 0.05) compared to Group A. HbA1c, FBS, and PPBS were markedly elevated in Group B (all $p<0.001$). RBC parameters also differed significantly: Group B exhibited lower RBC count (4.38 ± 0.39 million/µL), Hb (12.6 ± 1.4 g/dL), and HCT (38.2 ± 4.3%), along with higher MCV (92.3 ± 6.0 fL), MCH (30.8 ± 2.1 pg), and RDW (15.4 ± 1.6%) (all $p<0.001$). Correlation analysis revealed strong associations between glycaemic indices and RBC parameters, particularly RDW and HbA1c.

Conclusion: Poor glycaemic control is associated with significant alterations in red blood cell indices. Routine hematological parameters, especially RDW, may serve as valuable supplementary markers for assessing metabolic control and monitoring disease progression in diabetic patients.

Keywords: Glycaemic index, correlation, RBC parameters, diabetes mellitus, tertiary care, comparative study.

INTRODUCTION

Diabetes mellitus is an escalating global public-health problem, with recent estimates showing a marked rise in prevalence and disease burden across regions and age groups. The rapid increase in diabetes cases and its attendant complications has intensified the need for accessible biomarkers that can assist in early detection, risk stratification and monitoring of disease progression.[1]

Persistent hyperglycaemia causes biochemical and structural changes in circulating erythrocytes, chiefly through non-enzymatic glycation of haemoglobin and oxidative damage to red cell membranes.[2] Such processes may alter red blood cell (RBC) lifespan, deformability and turnover, leading to measurable changes in standard RBC indices. These alterations

can influence conventional glycaemic markers (for example, discordance between mean glucose and HbA1c expressed as the hemoglobin glycation index) and may also reflect the severity of microvascular complications in diabetic patients.[3-6]

Commonly reported RBC parameters—haemoglobin concentration, hematocrit, red cell count, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC) and red cell distribution width (RDW)—are routinely produced as part of the complete blood count (CBC). Emerging clinical and epidemiological studies indicate significant associations between several of these indices (particularly RDW) and markers of glycaemic control and diabetic complications, suggesting that simple haematological indices might serve as inexpensive adjuncts to metabolic assessment in diabetes care.[7-9]

Given the ubiquity and low cost of CBC testing, characterizing the relationship between RBC parameters and glycaemic indices could provide clinicians with additional, readily available information to identify patients at higher risk of poor control or complications. The present study therefore aims to evaluate RBC indices in diabetic patients and to analyse their correlation with established glycaemic measures (including fasting plasma glucose, mean glucose and HbA1c/hemoglobin glycation index). By elucidating these relationships, we seek to determine whether routine erythrocyte parameters can augment conventional glycaemic assessment and contribute to risk stratification in diabetes management.

MATERIALS AND METHODS

Study Design and Setting: A cross-sectional observational study was conducted in the Department of Medicine and Physiology with clinical Laboratory Services of a tertiary care hospital. The study was carried out over a period of 12 months, during which eligible diabetic patients attending outpatient or inpatient services were consecutively enrolled.

Study Population: Adults diagnosed with diabetes mellitus, irrespective of gender, were included. Diabetes was defined according to the American Diabetes Association criteria (fasting plasma glucose ≥126 mg/dL, 2-hour postprandial glucose ≥200 mg/dL, or HbA1c ≥6.5%).

Inclusion Criteria

- Patients aged ≥18 years.
- Known or newly diagnosed Type 2 diabetes mellitus.
- Individuals willing to provide informed consent.

Exclusion Criteria

- Patients with known hematological disorders (e.g., anemia due to hemoglobinopathies).
- Chronic kidney disease stages 4–5 or hepatic failure.
- Recent blood transfusion (within 3 months).
- Pregnant women.
- Active infections or inflammatory conditions that may alter blood cell indices.
- Patients on drugs affecting erythropoiesis (e.g., iron therapy, erythropoietin).

Sample Size

A sample size was calculated based on sample size calculator for comparing two independent means i.e between glycaemic indices and red blood cell parameters as per study by Arkew M et al where mean and Sd of haemoglobin in g/dl in patients with good glycaemic control and poor glycaemic control was 15.60±0.92 and 15.16±1.11 respectively.[10]

Assuming a pooled standard deviation of 1.11 units, the study would require a sample size of 100 for each group (i.e. a total sample size of 200, assuming equal group sizes), to achieve a power of 80% and a level of significance of 5% (two sided), for detecting a true difference in means between the test and the reference group of 0.43 (i.e. 15.6 - 15.16) units.[11]

To ensure adequate statistical power, a minimum of 200 subjects were included and grouped as follows.

Group A: 100 diabetic patients with good glycaemic control

Group B: 100 diabetic patients with poor glycaemic control

Data Collection Procedure

After obtaining written informed consent, demographic and clinical details were recorded using a structured proforma. A venous blood sample (5 mL) was collected from each participant under aseptic precautions after an overnight fast.

Laboratory Investigations

1. Red Blood Cell Parameters: RBC indices were measured using an automated hematology analyzer, including:

- Hemoglobin (Hb)
- Total RBC count
- Hematocrit (HCT/PCV)
- Mean Corpuscular Volume (MCV)
- Mean Corpuscular Hemoglobin (MCH)
- Mean Corpuscular Hemoglobin Concentration (MCHC)
- Red Cell Distribution Width (RDW)
- Quality control procedures were performed daily as per laboratory standards.

2. Glycaemic Indices

Glycaemic status was assessed using:

Fasting Plasma Glucose (FPG) - measured using the glucose oxidase–peroxidase method.

HbA1c (%) — analyzed via high-performance liquid chromatography (HPLC) or an NGSP-certified method.

Postprandial Blood Glucose (PPBG)

Glycaemic Index/Control Category — classified based on HbA1c levels (e.g., good, poor control).

Statistical Analysis: Data were entered into a statistical software package (SPSS version 28). Continuous variables were expressed as mean ± standard deviation, while categorical variables were summarized as percentages. Normality of data was assessed using the Kolmogorov–Smirnov test.

Correlation between RBC parameters and glycaemic indices (HbA1c, FPG) was evaluated using Pearson's correlation coefficient for normally distributed data, and Spearman's rank correlation for non-parametric data. Group comparisons (e.g., HbA1c categories) were performed using independent t-tests as appropriate. A p-value <0.05 was considered statistically significant.

Ethical Considerations: Ethical approval was obtained from the Institutional Ethics Committee prior to study commencement. All participants were informed about the study objectives, and confidentiality of data was ensured.

RESULTS

A total of 200 patients with diabetes mellitus were included in the study, divided into two groups based on their glycaemic control:

- Group A (n = 100): Good glycaemic control
- Group B (n = 100): Poor glycaemic control

A total of 200 patients with diabetes mellitus were enrolled and categorized into two equal groups based on their glycaemic status: Group A with good glycaemic control (n = 100) and Group B with poor glycaemic control (n = 100). The two groups were comparable in age (53.4 ± 8.2 vs. 55.1 ± 7.9 years) and gender distribution (58/42 vs. 61/39; p = 0.64). However, patients in Group B exhibited significantly higher BMI (27.4 ± 3.6 kg/m²) and WHR (0.96 ± 0.05) compared to Group A (25.7 ± 3.1 kg/m² and 0.91 ± 0.04, respectively; p < 0.01). Glycaemic indicators were markedly elevated in Group B, with HbA1c levels of 9.2 ± 1.1% versus 6.4 ± 0.4% in Group A, alongside significantly higher fasting blood sugar (174.2 ± 24.9 vs. 108.6 ± 12.8 mg/dL) and postprandial blood sugar (262.7 ± 36.1 vs. 152.3 ± 18.5 mg/dL) (all p < 0.001). The duration of diabetes was also longer among poorly controlled patients (9.3 ± 4.1 vs. 6.1 ± 3.4 years; p < 0.001), and combination therapy was more commonly used in Group B (71%) compared to Group A (37%). [Table 1]

Table 1: Comparison of Socio-Demographic, Anthropometric and Clinical Characteristics Between Group A and Group B

Parameter	Group A (Good Control) (n=100)	Group B (Poor Control) (n=100)	p-value
Age (years)	53.4 ± 8.2	55.1 ± 7.9	0.18
Gender (M/F)	58 / 42	61 / 39	0.64
BMI (kg/m²)	25.7 ± 3.1	27.4 ± 3.6	0.002*
Waist-Hip Ratio (WHR)	0.91 ± 0.04	0.96 ± 0.05	<0.001*
HbA1c (%)	6.4 ± 0.4	9.2 ± 1.1	<0.001*
Fasting Blood Sugar (mg/dL)	108.6 ± 12.8	174.2 ± 24.9	<0.001*
Postprandial Blood Sugar (mg/dL)	152.3 ± 18.5	262.7 ± 36.1	<0.001*
Duration of Diabetes (years)	6.1 ± 3.4	9.3 ± 4.1	<0.001*
OHA Agents (Monotherapy/Combination)	63 / 37	29 / 71	<0.001*

Comparison of red blood cell parameters revealed significant hematological alterations associated with poor glycaemic control. Group B demonstrated lower RBC count (4.38 ± 0.39 million/µL), hemoglobin levels (12.6 ± 1.4 g/dL), and hematocrit (38.2 ± 4.3%) compared to Group A (4.71 ± 0.42 million/µL, 13.8 ± 1.2 g/dL, and 41.9 ± 3.8%, respectively; all p < 0.001). In contrast, MCV and MCH values were higher in Group B (92.3 ± 6.0 fL and 30.8 ± 2.1 pg) than in Group A (88.4 ± 5.1 fL and 29.2 ± 1.6 pg; p < 0.001). MCHC showed a modest reduction among poorly controlled patients (32.5 ± 1.3 vs. 33.1 ± 1.2 g/dL; p = 0.004). RDW exhibited the most pronounced difference, increasing from 13.1 ± 1.2% in Group A to 15.4 ± 1.6% in Group B (p < 0.001), indicating greater anisocytosis in patients with uncontrolled diabetes. [Table 2]

Table 2: Comparison of Red Blood Cell Parameters Between Group A and Group B

RBC Parameters	Group A (Good Control)	Group B (Poor Control)	p-value
RBC Count (million/µL)	4.71 ± 0.42	4.38 ± 0.39	<0.001*
Hemoglobin (g/dL)	13.8 ± 1.2	12.6 ± 1.4	<0.001*
Hematocrit (%)	41.9 ± 3.8	38.2 ± 4.3	<0.001*
MCV (fL)	88.4 ± 5.1	92.3 ± 6.0	<0.001*
MCH (pg)	29.2 ± 1.6	30.8 ± 2.1	<0.001*
MCHC (g/dL)	33.1 ± 1.2	32.5 ± 1.3	0.004*
RDW (%)	13.1 ± 1.2	15.4 ± 1.6	<0.001*

Correlation analysis showed that higher glycaemic levels were associated with significant alterations in red blood cell parameters. HbA1c demonstrated a moderate negative correlation with RBC count (r = –0.41), hemoglobin (r = –0.44), and hematocrit (r = –0.38). Fasting blood sugar also showed negative correlations with these parameters (r = –0.36, –0.39, and –0.32 respectively), and PPBS followed the same pattern with r-values of –0.33, –0.36, and –0.30.

Red cell indices related to cell size—MCV and MCH—showed mild positive correlations with glycaemic markers. MCV correlated with HbA1c at r = +0.29, with FBS at +0.24, and PPBS at +0.21. MCH showed similar but slightly stronger correlations, with r = +0.31, +0.26, and +0.22.

MCHC showed weak and non-significant correlations with all glycaemic indices (r = –0.18 with HbA1c, –0.12 with FBS, and –0.10 with PPBS). The strongest association observed was between RDW and glycaemic markers. RDW had r-values of +0.53 with HbA1c, +0.48 with FBS, and +0.44 with PPBS, indicating a strong positive correlation and suggesting greater anisocytosis with worsening glycaemic control. [Table 3 and Figure 1]

Table 3: Correlation of Glycaemic Indices With RBC Parameters (Pearson Correlation Coefficients)

RBC Parameter	HbA1c (r-value)	FBS (r-value)	PPBS (r-value)	Interpretation
RBC Count	–0.41*	–0.36*	–0.33*	Moderate negative correlation
Hemoglobin	–0.44*	–0.39*	–0.36*	Moderate negative correlation
Hematocrit	–0.38*	–0.32*	–0.30*	Negative correlation
MCV	+0.29*	+0.24	+0.21	Mild positive correlation
MCH	+0.31*	+0.26	+0.22	Mild–moderate positive correlation
MCHC	–0.18	–0.12	–0.10	Weak correlation
RDW	+0.53*	+0.48*	+0.44*	Strongest positive correlation

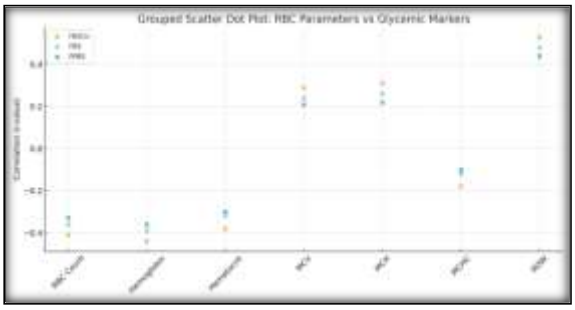

Figure 1: correlation of RBC parameters versus glycaemic markers

DISCUSSION

Prolonged exposure of red blood cells to elevated glucose concentrations in patients with diabetes mellitus results in continuous hemoglobin glycation, leading to both structural and functional changes in the hemoglobin molecule.[12] Beyond protein glycation, chronic hyperglycaemia also alters the mechanical properties and internal viscosity of erythrocytes, increases their aggregation tendency, and heightens osmotic fragility.[13,14] These changes ultimately affect erythrocyte morphology and circulation dynamics. Such abnormalities are reflected in routinely measured red blood cell parameters, including RBC count, hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW). Recent evidence indicates that these RBC-related indices may serve as valuable adjunct markers for assessing glycaemic control and monitoring the development of diabetic complications.[15,16] Supporting this, a retrospective study from Libya demonstrated that RBC parameters closely paralleled HbA1c and blood glucose trends, underscoring their relevance in clinical evaluation of diabetic patients.[17]

In the present study, individuals with good and poor glycaemic control showed comparable baseline characteristics, with similar ages (53.4 ± 8.2 vs. 55.1 ± 7.9 years) and gender distribution (58/42 vs. 61/39; p = 0.64). Comparable demographic distributions were also reported in previous studies. Ebrahim et al. observed mean ages of 38.75 (±10.58) and 37.70 (±9.94) years among T2DM patients and controls, respectively, with males comprising 53.3% and 51.7% of the groups.[18] Arkew M et al. likewise reported mean ages of 43.13 ± 9.43 and 43.00 ± 8.82 years, with 73 (67.40%) males in both diabetic and control groups.[10] Bhutto A.R. et al. documented a mean age of 48.63 ± 12.462 years in a cohort of 119 diabetic patients, of whom 74 (62.2%) were males and 45 (37.8%) females.[19]

In our study, poor glycaemic control was associated with higher BMI (27.4 ± 3.6 vs. 25.7 ± 3.1 kg/m²) and WHR (0.96 ± 0.05 vs. 0.91 ± 0.04), with both differences reaching strong statistical significance ($p < 0.01$). Similar findings were reported by Arkew et al., who observed significantly higher WHR ($p < 0.001$) and BMI ($p < 0.001$) among T2DM participants.[10] Glycaemic markers were markedly elevated in Group B, as demonstrated by higher HbA1c (9.2 ± 1.1% vs. 6.4 ± 0.4%), fasting blood sugar (174.2 ± 24.9 vs. 108.6 ± 12.8 mg/dL), and postprandial blood sugar (262.7 ± 36.1 vs. 152.3 ± 18.5 mg/dL), all $p < 0.001$. Group B also had a longer duration of diabetes (9.3 ± 4.1 vs. 6.1 ± 3.4 years) and greater reliance on combination therapy (71% vs. 37%). Arkew et al. similarly reported a mean FBG of 159.93 ± 27.40 mg/dL and diabetes duration of 7.65 ± 3.40 years, with 99 (90.00%) patients on metformin.[10]

Marked differences in RBC parameters were evident between the groups. Poorly controlled patients had lower RBC count (4.38 ± 0.39 vs. 4.71 ± 0.42 million/μL), hemoglobin (12.6 ± 1.4 vs. 13.8 ± 1.2 g/dL), and hematocrit (38.2 ± 4.3% vs. 41.9 ± 3.8%). Conversely, MCV (92.3 ± 6.0 vs. 88.4 ± 5.1 fL), MCH (30.8 ± 2.1 vs. 29.2 ± 1.6 pg), and RDW (15.4 ± 1.6 vs. 13.1 ± 1.2%) were significantly higher in Group B—indicative of altered erythrocyte morphology and greater anisocytosis. Arkew et al. similarly found significantly higher RBC count, HCT ($p = 0.002$), and HGB ($p = 0.028$) among patients with better glycaemic control, although other RBC indicators did not differ significantly ($p > 0.05$).[10] Meshesha MD et al. also demonstrated an 8% higher hemoglobin level among those with good control (HbA1c <7), as well as a 4% higher mean MCH (μ_1–μ_2 =1.04; 95% CI: 1.008–1.071).[6] Asmamaw T et al. reported significant differences in RBC count

(4.79±0.5 vs. 4.38±0.8), hemoglobin (14.13±1.4 vs. 13.60±1.6), MCV (89.52±4.7 vs. 92.62±7.5), MCH (29.63±1.6 vs. 30.77±2.9), and RDW (13.68±1.1 vs. 14.63±1.2) between good and poorly controlled patients.[20]

Our correlation findings further support the association between glycaemic burden and RBC abnormalities. HbA1c demonstrated moderate negative correlations with RBC count (r = –0.41), hemoglobin (r = –0.44), and hematocrit (r = –0.38), while FBS and PPBS showed similar negative correlations. Conversely, MCV and MCH exhibited mild positive correlations with all glycaemic indicators, and RDW showed the strongest positive relationship (r = +0.53 with HbA1c, +0.48 with FBS, +0.44 with PPBS). Comparable patterns were reported in earlier studies. Arkew et al. documented significant negative correlations between glycaemic control and RBC count (r = −0.239, p = 0.012), hemoglobin (r = −0.193, p = 0.044), and hematocrit (r = −0.265, p = 0.005).[10] Ebrahim et al. observed negative correlations between FBG and RBC count, hemoglobin, HCT, MCV, MCH, and RDW-SD in T2DM patients (P < 0.05).[18] Bhutto et al. reported a significant association between HbA1c and RDW (p = 0.035),[19] while Meshesha et al. identified a significant negative correlation between HbA1c and MCH (r = −0.158; p = 0.023).[6] Asmamaw et al. found an inverse association between HbA1c and RBC count (r = −0.280, p = 0.002), along with positive correlations with MCV (r = 0.267, p = 0.003), MCH (r = 0.231, p = 0.010), and RDW (r = 0.496, p = 0.000).[20]

Overall, RBC parameters—especially RDW—are increasingly recognized as inexpensive, accessible, and sensitive biomarkers reflecting glycaemic load and oxidative stress in diabetes. Given that complete blood count testing is widely available, integrating RBC indices with traditional glycaemic markers may aid in early detection of hematologic alterations and facilitate timely clinical intervention in poorly controlled diabetic patients.

CONCLUSION

The present study demonstrates that chronic hyperglycaemia in diabetes mellitus significantly influences red blood cell indices, reflecting both structural and functional alterations in erythrocytes. Patients with poor glycaemic control showed reduced RBC count, hemoglobin, and hematocrit, along with elevated MCV, MCH, and RDW—patterns that align with reported hematologic disturbances associated with oxidative stress and impaired erythropoiesis. The strong positive correlation between RDW and glycaemic markers, particularly HbA1c, suggests that RDW may serve as a sensitive and cost-effective indicator for identifying patients at risk of poor metabolic control. Overall, routine red blood cell parameters, which are easily accessible through standard hematological testing, may provide valuable supplementary information for evaluating glycaemic status and monitoring disease progression in diabetic patients. Incorporating these indices into regular clinical assessment could facilitate earlier recognition of complications and improve long-term management outcomes.

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