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Comparison of hematological parameters and glycemic status in patients with type 2 diabetes mellitus: A case - control study

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Abstract:
Type 2 diabetes mellitus (T2DM) is associated with chronic hyperglycemia that adversely affects erythrocyte morphology and function, leading to significant hematological alterations. Hence, 100 patients with T2DM were compared with 100 age- and sex-matched non-diabetic controls for hematological and glycemic parameters. Patients with T2DM had significantly lower hemoglobin, RBC count, PCV, MCV, MCH and MCHC, indicating a microcytic hypochromic pattern, while fasting blood sugar, postprandial blood sugar and HbA1c levels were significantly higher than those of controls (all $p < 0.05$). These findings show a strong association between T2DM and impaired hematological status alongside poor glycemic control. Thus, routine hematological screening should be incorporated into diabetes care, as coexisting anemia may influence HbA1c interpretation and overall disease management.

Keywords: Anemia, type 2 diabetes mellitus (T2DM), HbA1c, hemoglobin, glycemic control

Background:
Type 2 diabetes mellitus (T2DM) has emerged as one of the major global non-communicable disease challenges, with its prevalence continuing to increase worldwide **[1]**. According to the 11th edition of the International Diabetes Federation Diabetes Atlas, approximately 589 million adults aged 20–79 years were living with diabetes in 2024, with the number projected to increase substantially by 2050 **[2]**. T2DM accounts for approximately 90–95% of all diabetes cases worldwide. India has a particularly high burden, with the ICMR-INDIAB study estimating approximately 101 million adults with diabetes and 136 million with prediabetes **[3]**. Chronic hyperglycemia in T2DM contributes to microvascular and macrovascular complications through oxidative stress, advanced glycation, inflammation and endothelial dysfunction **[4]**. Diabetes is also frequently associated with anemia, which may remain unrecognized in routine clinical practice **[5]**. Anemia in patients with diabetes is multifactorial and may result from impaired erythropoietin production, diabetic kidney disease, chronic inflammation, reduced erythrocyte survival and nutritional deficiencies including iron deficiency **[6]**. Hyperglycemia and oxidative stress can additionally alter erythrocyte membrane properties, deformability and survival, potentially producing changes in red blood cell indices **[7]**. Hematological abnormalities are clinically relevant because anemia can contribute to tissue hypoxia and may influence the interpretation of HbA1c, particularly in the presence of iron deficiency or altered erythrocyte turnover **[10]**. Therefore, it is of interest to compare the hematological parameters, including hemoglobin, RBC count, PCV, MCV, MCH and MCHC and glycemic parameters, including FBS, PPBS and HbA1c, between patients with T2DM and non-diabetic controls.

Methodology:
Study design and setting:
This case–control study was conducted in the Department of Biochemistry and the Department of Pathology, Shri Rawatpura Sarkar Institute of Medical Sciences and Research (SRIMSR), Naya Raipur, Chhattisgarh, India, between January 2026 and May 2026.

Study population:
Cases comprised 100 adults with established T2DM diagnosed according to the American Diabetes Association (ADA) criteria (FBS ≥ 126 mg/dL and/or 2-hour post-load or postprandial plasma glucose ≥ 200 mg/dL and/or HbA1c ≥ 6.5% or classical symptoms with random plasma glucose ≥ 200 mg/dL), attending the diabetes clinic. Controls comprised 100 age- and sex-comparable non-diabetic individuals (FBS < 100 mg/dL and HbA1c < 5.7%) drawn from apparently healthy attendants and volunteers from the same catchment population.

Inclusion criteria (cases):
Adults aged ≥ 18 years with confirmed T2DM who consented to participate.

Inclusion criteria (controls):
Apparently healthy, non-diabetic adults of comparable age and sex who consented to participate

Exclusion criteria (both groups):
[1] Type 1 diabetes mellitus.
[2] Known chronic kidney disease or overt diabetic nephropathy.
[3] Established chronic liver disease.
[4] Known hemoglobinopathy or hemolytic disorder.
[5] Recent blood transfusion, acute blood loss, or haematinic (iron/vitamin B12/folate/erythropoietin) therapy within the preceding three months.
[6] Malignancy.
[7] Pregnancy and lactation.
[8] Any acute febrile or inflammatory illness at the time of sampling.

Sample size:
A total of 200 participants (100 cases and 100 controls, ratio 1:1) were enrolled. This sample size is consistent with comparable case–control studies of hematological parameters in T2DM and provides adequate power to detect the clinically meaningful between-group differences in hemoglobin and glycemic indices observed here at a two-sided significance level of 0.05.

Data collection and clinical assessment:

For each participant, a structured proforma captured demographic details, relevant medical and drug history and duration of diabetes. Anthropometric measurements were obtained using standardized techniques; body mass index (BMI) was calculated as weight in kilograms divided by height in meter's squared (kg/m²).

Laboratory investigations:
Venous blood samples were collected under aseptic precautions after an overnight fast of at least 8 hours. Complete blood count parameters hemoglobin, RBC count, packed cell volume (PCV), MCV, MCH and MCHC were analyzed on a Nihon Kohden hematology analyzer. Fasting blood sugar (FBS) and postprandial blood sugar (PPBS, two hours after a standard meal) were estimated by the glucose oxidase–peroxidase (GOD-POD) method using a Mindray BS-240 biochemistry fully auto-analyzer. HbA1c was measured using an Agappe Mispa-i2 analyzer.

Operational definitions:
Anemia was defined according to World Health Organization (WHO) hemoglobin thresholds (< 13 g/dL in men and < 12 g/dL in non-pregnant women). Red cell morphology was categorized using standard index cut-offs (microcytosis, MCV < 80 fL; hypochromia, MCH < 27 pg and/or MCHC < 32 g/dL).

Statistical analysis:
Data were compiled in a spreadsheet and analyzed using standard statistical software. Continuous variables are expressed as mean ± standard deviation (SD) and categorical variables as frequency and percentage. Between-group comparisons of continuous variables were performed using the independent-samples (unpaired) Student t-test and categorical variables using the Pearson chi-square test. A two-tailed p-value < 0.05 was considered statistically significant.

Results:
A total of 200 participants were analyzed (100 cases with T2DM and 100 non-diabetic controls). Patients with T2DM were, on average, older than controls (53.2 ± 9.1 vs 47.2 ± 10.3 years) and had a significantly higher BMI (27.4 ± 3.8 vs 22.7 ± 1.7 kg/m²), both differences reaching statistical significance ($p < 0.05$). Males constituted 52.0% of cases and 61.0% of controls; the sex distribution did not differ significantly between the groups ($p = 0.198$). The baseline characteristics are summarized in **Table 1**. Marked differences in the hematological profile were observed between the two groups **(Table 2).** Mean hemoglobin was substantially lower in patients with T2DM than in controls (8.2 ± 1.9 vs 12.5 ± 2.4 g/dL), as were RBC count (4.7 ± 0.9 vs 5.2 ± 0.7 ×10⁶/µL) and PCV (33.7 ± 5.4 vs 41.6 ± 5.1 %). The red cell indices were correspondingly reduced in cases – MCV (70.6 ± 9.5 vs 81.3 ± 8.7 fL), MCH (19.6 ± 0.33 vs 31.9 ± 0.29 pg) and MCHC (27.7 ± 1.56 vs 34.2 ± 2.81 g/dL). All hematological comparisons were statistically significant ($p < 0.05$). Taken together, the low MCV, MCH and MCHC indicate a predominantly microcytic, hypochromic pattern of anemia among the diabetic cases. As expected, all glycemic indices were significantly higher in patients with T2DM than in controls **(Table 3).** Fasting blood sugar was 129 ± 21 mg/dL in cases versus 92 ± 6 mg/dL in controls, postprandial blood sugar was 224 ± 55 mg/dL versus 108 ± 24 mg/dL and HbA1c was 8.2 ± 1.8% versus 5.2 ± 0.7% (all $p < 0.05$). The mean HbA1c of 8.2% among cases indicates suboptimal glycemic control in the diabetic group.

Table 1: Demographic and anthropometric characteristics of the study participants

Characteristic	T2DM (n = 100)	Controls (n = 100)	p-value
Age (years)	53.2 ± 9.1	47.2 ± 10.3	< 0.05
Male, n (%)	52 (52.0)	61 (61.0)	0.198
Female, n (%)	48 (48.0)	39 (39.0)	0.198
BMI (kg/m²)	27.4 ± 3.8	22.7 ± 1.7	< 0.05

Values are expressed as mean ± SD or number (%).
BMI, body mass index; T2DM, type 2 diabetes mellitus; SD, standard deviation
$p < 0.05$ was considered statistically significant.

Table 2: Comparison of hematological parameters between patients with T2DM and controls

Parameter	T2DM (n = 100)	Controls (n = 100)	p-value
Hemoglobin (g/dL)	8.2 ± 1.9	12.5 ± 2.4	< 0.05
RBC count (×10⁶/µL)	4.7 ± 0.9	5.2 ± 0.7	< 0.05
PCV (%)	33.7 ± 5.4	41.6 ± 5.1	< 0.05
MCV (fL)	70.6 ± 9.5	81.3 ± 8.7	< 0.05
MCH (pg)	19.6 ± 0.33	31.9 ± 0.29	< 0.05
MCHC (g/dL)	27.7 ± 1.56	34.2 ± 2.81	< 0.05

Values are expressed as mean ± SD. RBC, red blood cell; PCV, packed cell volume; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration. $p < 0.05$ was considered statistically significant.

Table 3: Comparison of glycemic parameters between patients with T2DM and controls

Parameter	T2DM (n = 100)	Controls (n = 100)	p-value
FBS (mg/dL)	129 ± 21	92 ± 6	< 0.05
PPBS (mg/dL)	224 ± 55	108 ± 24	< 0.05
HbA1c (%)	8.2 ± 1.8	5.2 ± 0.7	< 0.05

Values are expressed as mean ± SD. FBS, fasting blood sugar; PPBS, postprandial blood sugar; HbA1c, glycated hemoglobin. $p < 0.05$ was considered statistically significant.

Discussion:
This hospital-based case–control study showed significantly lower hemoglobin, RBC count and PCV among patients with T2DM than non-diabetic controls. MCV, MCH and MCHC were also reduced, indicating a predominantly microcytic hypochromic pattern of anemia. FBS, PPBS and HbA1c were significantly higher in the diabetic group, confirming poorer glycemic control. The coexistence of anemia and inadequate glycemic control was the principal finding of this study. Previous studies have reported that anemia is common in diabetes and may occur early during diabetic renal involvement **[11].** Diabetes-related erythropoietin deficiency, chronic inflammation, altered erythrocyte survival and nutritional deficiencies may contribute to reduced hemoglobin levels **[12]**. The microcytic hypochromic pattern observed here may additionally indicate an important contribution from iron deficiency. Iron deficiency can alter erythrocyte turnover and affect HbA1c values, potentially leading to inaccurate estimation of glycemic control **[13].** Therefore, HbA1c should be interpreted cautiously in patients with significant anemia and considered alongside glucose measurements. The higher age and BMI among diabetic participants were consistent with established risk factors for T2DM. The comparable sex distribution between

groups suggests that sex was unlikely to substantially influence the observed hematological differences. These findings support the routine assessment of hematological parameters alongside glycemic indices in patients with T2DM **[14]**. However, the single-centre design and absence of iron, vitamin B12, folate and renal parameters limited assessment of the specific etiology of anemia. Further multi-centre studies incorporating comprehensive hematological, nutritional and renal assessments are warranted.

Conclusion:

Patients with T2DM had significantly lower hemoglobin, RBC count, PCV and red cell indices, consistent with microcytic hypochromic anemia, along with poorer glycemic control than controls. Anemia is an important and often overlooked accompaniment of poorly controlled T2DM. Routine hematological screening in diabetes care may enable early correction of anemia and more accurate interpretation of HbA1c.

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