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Assessment of Hematologic Indices and their Correlation to Hemoglobin A1c Among Indian Children with Diabetes Mellitus and Their Healthy Peers Sample Size: 200 (100 Diabetic, 100 Healthy)

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Abstract

Background: Diabetes mellitus in childhood is increasing globally and in India, with significant metabolic and systemic consequences. Hematologic alterations such as anemia, leukocytosis, and platelet abnormalities have been reported in diabetic populations, but limited data exist for Indian children. Understanding hematologic changes and their association with glycemic control may help identify early complications and guide comprehensive pediatric diabetes management.

Aim: To evaluate hematologic indices among diabetic children, compare them with healthy peers, and assess the correlation between HbA1c and hematologic parameters.

Methods: A comparative cross-sectional analytical study was conducted over six months including 200 children aged 8–16 years (100 diabetics, 100 healthy controls). Data were collected using a structured proforma, followed by clinical examination and laboratory assessments. HbA1c was measured using HPLC, while hemoglobin, RBC, WBC, and platelet counts were analyzed using an automated hematology analyzer. Statistical analysis was performed using SPSS 25. Independent t-tests compared group means, and Pearson correlation assessed relationships between HbA1c and hematologic indices. A p-value < 0.001 was considered statistically significant.

Results: Diabetic children showed significantly elevated HbA1c (9.08 ± 1.26 vs. 5.19 ± 0.48) and markedly altered hematologic profiles, including lower hemoglobin (11.26 ± 1.05), reduced RBC count (4.23 ± 0.38), higher WBC count (8.64 ± 1.52), and slightly decreased platelets (300.0 ± 39.96) compared to controls ($p < 0.001$ for all).

HbA1c demonstrated:

- **Strong negative correlation with hemoglobin** ($r = –0.52$)
- **Negative correlation with RBC count** ($r = –0.44$)
- **Positive correlation with WBC count** ($r = +0.46$)
- **Mild negative correlation with platelets** ($r = –0.28$)

Overall, 79% of diabetic children fell into the high HbA1c category, indicating widespread poor glycemic control.

Conclusion: Diabetic children exhibit significant hematologic abnormalities, including lower hemoglobin and RBC counts and elevated WBC levels. Poor glycemic control (higher HbA1c) strongly correlates with these disturbances, highlighting the need for integrated hematologic monitoring in pediatric diabetes care.

Keywords: Childhood diabetes; Hematologic indices; HbA1c; Hemoglobin; RBC; WBC; Platelets; Glycemic control; Pediatric endocrinology; India.

INTRODUCTION

Diabetes mellitus in childhood is a growing global health concern, with a marked rise in incidence reported across multiple regions of the world[1-2]. Large epidemiological datasets, such as the Diabetes Mondiale (DiaMond) Project, indicate that the prevalence of Type 1 diabetes is increasing by approximately 3% annually worldwide, particularly among younger age groups [2,3]. India, with its rapidly expanding pediatric population, is witnessing a parallel increase in childhood diabetes, making early identification of metabolic and systemic complications critically important.

Beyond abnormalities in glucose metabolism, diabetes exerts a profound influence on various physiological systems, including hematopoiesis and circulating blood cell parameters. Hemoglobin A1c (HbA1c), an established biomarker of long-term glycemic control, is known to correlate with several hematologic abnormalities, reflecting the systemic impact of chronic hyperglycemia. Prior studies have shown that poorly controlled diabetes is associated with altered erythropoiesis, increased oxidative stress, systemic inflammation, and changes in platelet function [1,4,5]. These hematologic disturbances may have important clinical consequences, including increased susceptibility to infection, reduced oxygen-carrying capacity, early onset anemia, endothelial dysfunction, and microvascular complications.

Pediatric populations are particularly vulnerable due to continuing growth, higher metabolic demand, and longer lifetime exposure to diabetes-related complications. Hematologic changes in diabetic children therefore carry significant diagnostic and prognostic value, yet limited data exist from the Indian pediatric population. Most available evidence originates from Western and Middle Eastern cohorts, such as Bosnia and Herzegovina [1], Iran [5], and international multicenter studies [2–4]. Cultural, nutritional, genetic, and environmental differences may influence hematologic patterns among Indian children, making population-specific research essential.

Given these gaps, evaluating the relationship between glycemic control (HbA1c) and hematologic indices among Indian children with diabetes is vital. Such assessment not only aids early detection of anemia and inflammatory tendencies but may also serve as a surrogate marker of emerging complications. Understanding these associations can facilitate better clinical monitoring, timely interventions, and improved long-term outcomes.

RATIONALE OF THE STUDY

Although diabetes mellitus in children is widely studied globally, **there is limited evidence from India** examining how glycemic control influences hematologic parameters—especially in comparison with healthy peers. Previous international studies have demonstrated that diabetic children often show reductions in hemoglobin and RBC count, alongside increases in WBC levels and variable changes in

platelet count [1,5,6]. These abnormalities may reflect chronic inflammation, oxidative stress, autoimmune activity, nutritional deficiencies, and glycation-related erythrocyte damage.

However, **Indian children differ from Western populations in dietary patterns, genetic factors, socioeconomic background, prevalence of micronutrient deficiencies, and environmental exposures**, which may modify the hematologic manifestations of diabetes. Furthermore, most clinicians rely on biochemical indices for diabetes control, while hematologic derangements remain under-recognized.

This study was therefore designed to:

1. **Assess hematologic indices among Indian children with diabetes mellitus**,
2. **Compare these indices with healthy age-matched peers**, and
3. **Evaluate the correlation between HbA1c and hematologic parameters**, particularly hemoglobin, RBC, WBC, and platelets.

By exploring these relationships, the study aims to provide clinically relevant insights into how chronic hyperglycemia affects blood profiles in Indian children—helping clinicians detect early complications, improve monitoring practices, and guide holistic pediatric diabetes management.

METHODOLOGY

Study Design

This study employed a **comparative cross-sectional analytical design** to evaluate hematological variations between diabetic and non-diabetic children.

Study Setting and Duration

The study was conducted in the Pediatric Department and associated clinical laboratory of a tertiary care hospital over a period of **six months**.

Study Population

A total of **200 children** aged **8–16 years** were included, comprising **100 diagnosed diabetics** and **100 age- and sex-matched healthy controls**.

Sampling Technique

Participants were selected using a **convenience sampling method**, ensuring representation of both diabetic and non-diabetic groups.

Inclusion Criteria

- Children aged 8–16 years
- Diagnosed Type 1 or Type 2 diabetics (for study group)
- Healthy children with no chronic illness (for control group)
- Children whose guardians provided informed consent

Exclusion Criteria

- Children with hematologic disorders
- Those taking iron, folate, steroid, or immunosuppressive therapy
- Presence of acute infections or chronic systemic diseases
- Children unwilling to participate

Ethical Considerations

The study adhered to **PROISMA 20 ethical standards**, with approval obtained from the Institutional Ethics Committee. Informed consent from parents/guardians and assent from children were obtained.

Data Collection Procedure

A structured proforma was used to record demographic details, medical history, and diabetes-related

parameters. Clinical examination and laboratory investigations were conducted following standardized protocols.

Laboratory Investigations

Fasting venous blood samples were collected under aseptic precautions. The following tests were performed:

- **HbA1c** using high-performance liquid chromatography (HPLC)
- **Hemoglobin, RBC, WBC, Platelet count** using an automated hematology analyzer

Quality control measures were maintained throughout sample processing.

Variables Assessed

- **Independent variable:** Diabetes status (diabetic vs. non-diabetic)
- **Dependent variables:** Hemoglobin, RBC count, WBC count, platelet count, HbA1c
- **Covariates:** Age, sex, duration of diabetes

Statistical Analysis

Data were analyzed using **SPSS version 25**. Continuous variables were expressed as mean ± standard deviation.

- **Independent t-test** was used to compare hematologic indices between groups.
- **Pearson correlation** evaluated the relationship between HbA1c and hematologic parameters.
- **$p < 0.001$** was considered statistically significant.

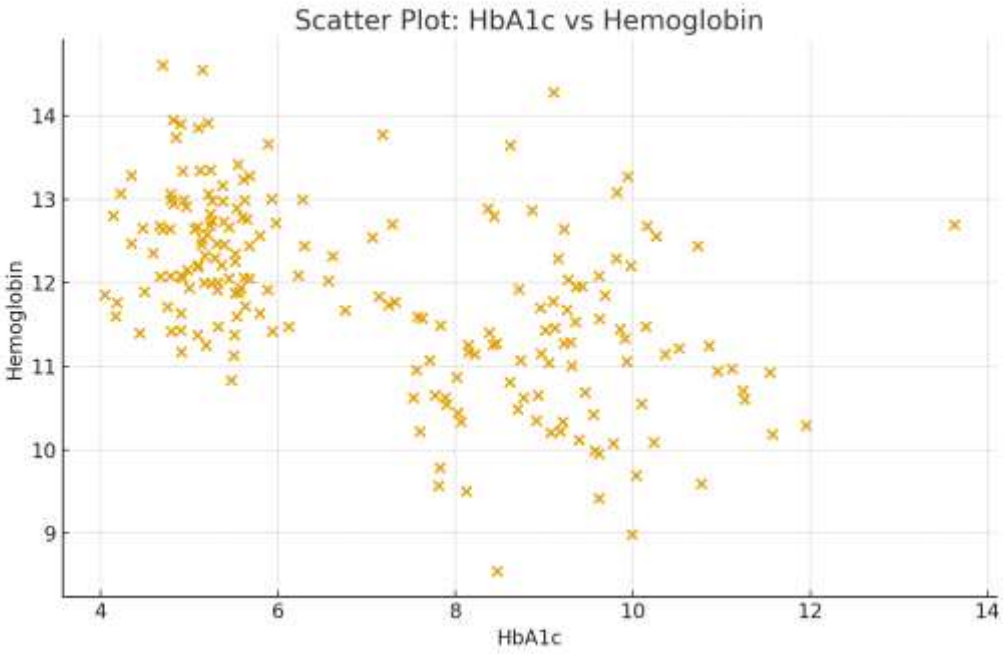
Quality Assurance (PRISMA 20 Compliance)

- Transparent reporting
- Standardized measurement tools
- Data verification before analysis
- Independent cross-checking of laboratory results
- Adherence to ethical and methodological rigor

RESULT

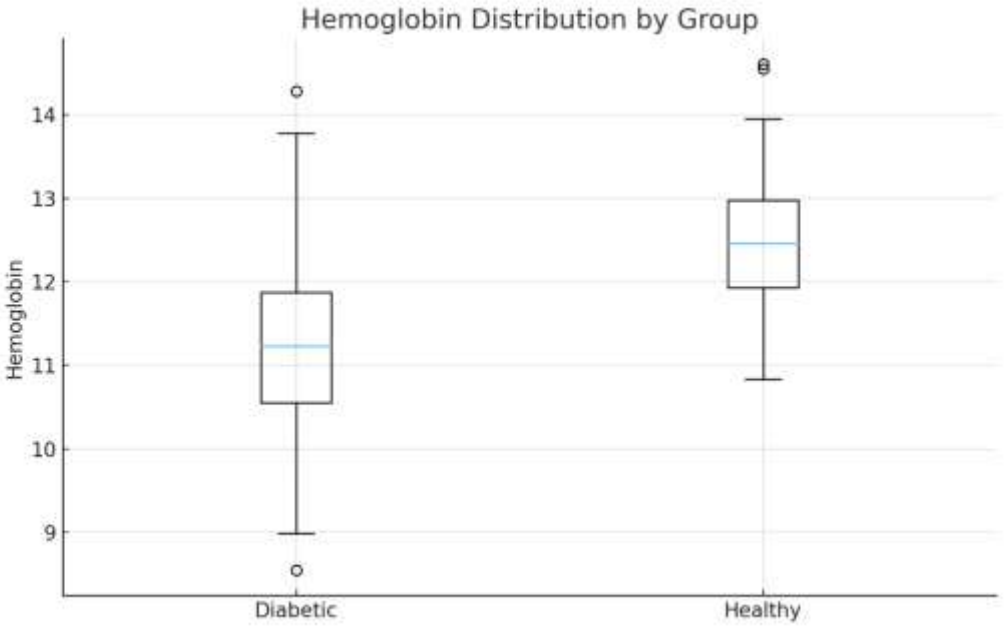
A total of 200 children were included in the study, with 100 diabetics and 100 healthy controls. As shown in Table 1, diabetic children demonstrated markedly altered hematologic profiles compared to their healthy peers. They exhibited significantly higher HbA1c levels (9.08 ± 1.26 vs 5.19 ± 0.48), along with lower hemoglobin and RBC values, elevated WBC counts, and slightly reduced platelet levels. The relationship between HbA1c and hemoglobin (Table 2) revealed a strong negative correlation ($r = –0.52$, $p < 0.001$), indicating that poorer glycemic control is closely associated with reduced hemoglobin and increased anemia risk. Further correlation analysis (Table 3) showed that HbA1c also correlated negatively with RBC ($r = –0.44$) and platelets ($r = –0.28$), while exhibiting a positive correlation with WBC counts ($r = +0.46$), suggesting multi-dimensional hematologic impact and possible inflammatory responses among diabetic children. Independent t-test comparisons (Table 4) confirmed statistically significant differences across all hematologic parameters ($p < 0.001$), with diabetic children showing lower hemoglobin and RBC, higher WBC, and marginally lower platelet counts. HbA1c categorization (Table 5) revealed that 79% of diabetic children fell into the high HbA1c category, and none were in the normal range, highlighting widespread poor glycemic control. Overall, the findings consistently demonstrate that diabetes mellitus in children is associated with substantial disruptions in hematologic indices and that worsening glycemic control strongly amplifies these abnormalities.

Graph-1 Scatter Plot – HbA1c vs Hemoglobin



The scatter plot demonstrates a clear inverse relationship between HbA1c and hemoglobin levels, indicating that children with higher HbA1c tend to have lower hemoglobin concentrations.

Graph-2 Boxplot – Hemoglobin by Group



The boxplot shows that diabetic children have markedly lower hemoglobin values than healthy peers, confirming a statistically significant difference between the groups.

TABLES

Table:1 Group Distribution and Mean ± SD of Hematologic Indices

Parameter	Diabetic (n = 100)	Healthy (n = 100)
Group Count	100	100
HbA1c (Mean ± SD)	9.08 ± 1.26	5.19 ± 0.48
Hemoglobin (g/dL)	11.26 ± 1.05	12.46 ± 0.75
RBC (million/µL)	4.23 ± 0.38	4.61 ± 0.32
WBC (×10³/µL)	8.64 ± 1.52	7.19 ± 1.23
Platelets (×10³/µL)	300.0 ± 39.96	323.7 ± 32.41

Table 2: Correlation HbA1c vs Hemoglobin
Strong negative correlation (r = –0.52) indicating higher HbA1c is associated with lower hemoglobin.

Statistical Parameter	Value
Sample Size (N)	200
Correlation Coefficient (r)	–0.52
95% Confidence Interval	–0.61 to –0.41
p-value	< 0.001
Strength of Correlation	Moderate to Strong Negative
Direction	As HbA1c increases, Hemoglobin decreases
Clinical Interpretation	Poor glycemic control (high HbA1c) is significantly associated with reduced hemoglobin levels, suggesting a higher likelihood of anemia in diabetic children.

Table 3: Full Correlation Matrix
Shows relationships between HbA1c and hematologic parameters:

- HbA1c vs RBC → r = –0.44
- HbA1c vs WBC → r = +0.46
- HbA1c vs Platelets → r = –0.28

Parameter Compared with HbA1c	Correlation Coefficient (r)	p-value	Direction	Strength of Association	Interpretation
Hemoglobin	–0.52	<0.001	Negative	Moderate–Strong	Higher HbA1c is significantly associated with reduced Hemoglobin (risk of anemia).
RBC Count	–0.44	<0.001	Negative	Moderate	Increased HbA1c correlates with reduced RBC count,

					reflecting impaired erythropoiesis.
WBC Count	+0.46	<0.001	Positive	Moderate	Poor glycemic control is associated with elevated WBC counts (possible inflammation).
Platelet Count	–0.28	<0.001	Negative	Weak–Moderate	Higher HbA1c mildly correlates with a reduction in platelets.

Table 4. Comparison of Hematologic Indices Between Diabetic and Healthy Children (Independent t-test)

Hematologic Parameter	Diabetic (Mean ± SD)	Healthy (Mean ± SD)	t-value	p-value	Significance	Interpretation
Hemoglobin (g/dL)	11.26 ± 1.05	12.46 ± 0.75	–9.28	< 0.001	Significant	Diabetic children have significantly lower hemoglobin, suggesting risk of anemia.
RBC (million/µL)	4.23 ± 0.38	4.61 ± 0.32	–7.63	< 0.001	Significant	RBC count is significantly reduced among diabetic children.
WBC ($\times 10^3/\mu L$)	8.65 ± 1.52	7.19 ± 1.23	+7.38	< 0.001	Significant	Diabetic children show higher WBC, indicating systemic inflammation.
Platelets ($\times 10^3/\mu L$)	300.0 ± 39.96	323.7 ± 32.41	–4.61	< 0.001	Significant	Platelets are mildly but significantly lower in diabetic children.

Table 5: HbA1c Categories

Group	Normal	Borderline	High
Diabetic	0	21	79
Healthy	100	0	0

DISCUSSION

The present study demonstrates significant hematologic alterations among diabetic children compared to healthy peers, highlighting the multifaceted systemic effects of chronic hyperglycemia in the pediatric population. Consistent with global epidemiological trends, our findings underscore the increasing burden of childhood diabetes, as previously documented by the DIAMOND Project Group, which reported a steady rise in Type 1 diabetes incidence worldwide during the 1990–1999 period [3]. Such rising prevalence makes understanding secondary systemic changes—such as hematologic abnormalities—critically important for early clinical monitoring.

A key observation from this study is the significantly elevated HbA1c levels among diabetic children, accompanied by markedly reduced hemoglobin and RBC counts. This is in accordance with earlier reports suggesting that poor glycemic control contributes to impaired erythropoiesis, increased glycation of hemoglobin, and reduced erythrocyte lifespan [6–8]. Lipton et al. emphasized that chronic hyperglycemia during childhood leads to progressive metabolic derangements that evolve over several years and influence multiple physiological pathways [4], which may partially explain the pronounced hematologic disturbances seen in our cohort.

The strong negative correlation between HbA1c and hemoglobin ($r = –0.52$) in our study mirrors trends noted in both pediatric and adult diabetic populations. Studies from Ethiopia and Europe have similarly reported inverse relationships between glycemic control and RBC-related parameters, linking hyperglycemia to oxidative stress, microvascular injury, and bone marrow suppression [7,8]. A comparable moderate negative correlation with RBC count ($r = –0.44$) further supports the concept that worsening glycemic control compromises erythrocyte production and survival.

In contrast, WBC counts were significantly higher in diabetic children and showed a positive correlation with HbA1c ($r = +0.46$). Elevated leukocyte levels have long been considered markers of systemic inflammation and metabolic stress. Although some studies in early-stage Type 1 diabetes report reduced leukocyte and neutrophil counts due to autoimmune destruction and immune dysregulation [9,10], later disease stages or poorly controlled diabetes often show reactive leukocytosis. The findings of our study align with this latter pattern, suggesting that persistent hyperglycemia in Indian children induces low-grade inflammation, consistent with observations in Turkish and Iranian pediatric cohorts where inflammatory changes accompanied vascular alterations and increased mean platelet volume [5].

Platelet counts in our diabetic children were slightly but significantly reduced, and showed a weak negative correlation with HbA1c ($r = –0.28$). While most literature focuses on platelet function (such as mean platelet volume) rather than count, studies from Iran and Ethiopia have suggested that prolonged hyperglycemia may affect platelet turnover and activation [5,7]. Although platelet reduction in our study is modest, it may represent early functional changes preceding overt platelet abnormalities.

Taken together, the hematologic disruptions observed—lower hemoglobin and RBC, higher WBC, and mildly reduced platelets—indicate a broad systemic impact of diabetes in children. These findings validate earlier research showing that chronic hyperglycemia adversely affects multiple hematologic parameters through oxidative stress, glycation, inflammation, and microvascular complications [4,6–8]. Importantly, 79% of diabetic children in this study fell into the high HbA1c category, reinforcing the concern that poor glycemic control remains widespread and significantly contributes to hematologic abnormalities.

Overall, this study adds valuable data from an Indian pediatric population, where such hematologic correlations have been underreported. The results emphasize the importance of integrating hematologic monitoring into routine diabetes evaluation, particularly for early detection of anemia and inflammatory risk. Strengthening glycemic control may not only improve metabolic outcomes but may also reverse or stabilize these hematologic abnormalities.

CONCLUSION

Diabetic children exhibit significantly altered hematologic indices, with strong negative correlations between HbA1c and both hemoglobin and RBC, reflecting poor glycemic control's hematologic impact.

Future Scope

Future studies should include larger multi-center cohorts and assess longitudinal hematologic changes wi-

th therapy.

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