e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(2); 70-75

Original Research Article

Correlation between RBC Indices and Iron Absorption Physiology in Adolescents with Nutritional Anemia

Sahaja Chiliveru[1], Madiha Mehvish[2], Kapil Khanna[3]

[1]Postgraduate, Department of Physiology, Chalmeda Anand Rao Institute of Medical Sciences, Bommakal, Karimnagar, Telangana, India

[2]Professor, Department of Physiology, CAIMS, Karimnagar, Telangana, India

[3]MD Physiology (2nd Year), Department of Physiology, Santosh Deemed to be University Ghaziabad, Uttar Pradesh, India

Received: 03-12-2025 / Revised: 02-01-2026 / Accepted: 04-02-2026

Corresponding Author: Dr. Kapil Khanna

Conflict of interest: Nil

Abstract:

Background: Nutritional anemia remains a major health concern among adolescents, with iron deficiency being the predominant underlying factor. Red blood cell (RBC) indices are routinely available hematological parameters that may reflect alterations in iron absorption and utilization, yet their relationship with iron absorption physiology in adolescents is not well characterized.

Material and Methods: A cross-sectional analytical study was conducted among 123 adolescents aged 10–19 years diagnosed with nutritional anemia. Complete blood counts were performed to assess RBC indices, including mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, and red cell distribution width. Biochemical markers of iron absorption physiology, namely serum iron, total iron-binding capacity, transferrin saturation, and serum ferritin, were measured under standardized conditions. Correlations between hematological indices and biochemical parameters were evaluated using appropriate statistical tests.

Results: The mean hemoglobin concentration was 9.6 ± 1.1 g/dL, with microcytic and hypochromic indices evident. Serum iron (42.8 ± 13.6 µg/dL), transferrin saturation (10.9 ± 4.3%), and serum ferritin levels (14.2 ± 6.1 ng/mL) were reduced, while total iron-binding capacity was elevated (392.4 ± 46.9 µg/dL). Mean corpuscular volume and mean corpuscular hemoglobin showed moderate positive correlations with serum iron and transferrin saturation and negative correlations with total iron-binding capacity. Red cell distribution width demonstrated inverse correlations with serum iron, transferrin saturation, and serum ferritin. Moderate anemia was the most prevalent severity category (58.5%).

Conclusion: RBC indices show significant correlations with biochemical markers of iron absorption physiology in adolescents with nutritional anemia, indicating their potential utility as accessible indicators of impaired iron availability and utilization in this population.

Keywords: Adolescents; Nutritional anemia; Red blood cell indices; Iron absorption; Iron deficiency.

DOI: 10.25258/ijcpr.18.2.11

Introduction

Anemia during adolescence represents a clinically important nutritional disorder because this life stage is characterized by rapid linear growth, expansion of blood volume, and (in many girls) the onset of menstrual iron losses, all of which increase iron requirements. Contemporary adolescent-focused field data continue to show a substantial burden of anemia and highlight dietary factors as relevant correlates, underscoring the need for practical approaches to identify iron-related abnormalities early in routine care and screening programs [1,2]. In addition to symptomatic morbidity (fatigue, reduced exercise tolerance), iron deficiency in adolescents is also relevant to neurocognitive function and school performance, and it may persist into early adulthood if not detected and corrected [2].

From a physiological standpoint, iron deficiency anemia reflects a mismatch between iron demand for erythropoiesis and iron supply from dietary intake and absorption. Intestinal iron absorption is influenced by meal composition (e.g., enhancers such as ascorbic acid and inhibitors such as phytates), but it is also regulated by systemic control mechanisms, especially hepcidin–ferroportin signaling, which modulates the amount of iron transferred from enterocytes into the circulation [3]. In iron deficiency anemia without inflammatory blockade, biochemical changes typically include low circulating transport iron and storage iron, alongside compensatory increases in iron-binding capacity; these shifts are consistent with reduced serum iron and transferrin saturation with an elevated total iron-binding capacity, accompanied by low ferritin reflecting depleted iron stores [3,4]. Because adolescents frequently have dietary patterns that rely heavily on non-heme iron sources and may also consume iron absorption inhibitors, the physiological "absorption side" of iron balance is particularly relevant in this age group [2,3].

Although advanced tools such as stable isotope studies provide direct quantification of absorption, clinical and epidemiological work often relies on indirect biochemical markers and hematological indices. Serum ferritin remains widely used for estimating iron stores, while serum iron, total iron-binding capacity, and transferrin saturation reflect circulating iron availability and binding capacity; however, these biochemical tests are not always available or routinely ordered in resource-constrained settings [3,5]. In contrast, complete blood count–derived RBC indices are inexpensive and commonly accessible. Microcytosis and hypochromia—reflected by reduced mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH)—are classic hematological features of iron-restricted erythropoiesis, while increased red cell distribution width (RDW) reflects greater heterogeneity of erythrocyte size during disordered erythropoiesis [5,6]. Recent adolescent studies have shown that hemoglobin and RBC indices (MCV, MCH, MCHC, and RDW) demonstrate measurable diagnostic performance for iron deficiency when compared against ferritin-defined iron deficiency status [5]. Similarly, in rural adolescent girls, red cell indices—including RDW in combination with hemoglobin—have been evaluated as potential screening tools for iron deficiency anemia, with ferritin commonly used as the biochemical reference marker for iron deficiency classification [6].

Despite these observations, there remains a practical gap: RBC indices are frequently interpreted as isolated hematological descriptors rather than being explicitly linked to iron absorption physiology and iron availability in adolescents with nutritional anemia. Establishing how standard RBC indices correlate with biochemical markers that reflect iron absorption and systemic iron handling could improve the interpretability of routine hematology reports and support rational triage for further iron profiling in adolescent populations. Therefore, the present study was designed to evaluate the correlation between RBC indices and biochemical markers reflecting iron absorption physiology among adolescents with nutritional anemia.

Material and Methods

Study design and setting: A cross-sectional analytical study was conducted to evaluate the relationship between RBC indices and physiological markers of iron absorption among adolescents diagnosed with nutritional anemia. The study was carried out at a tertiary-care teaching hospital.

Study population: Adolescents aged 10–19 years presenting to outpatient or school-linked screening services were considered for inclusion. Participants were enrolled after initial screening confirmed anemia of nutritional origin.

Inclusion criteria

- Age between 10 and 19 years
- Hemoglobin concentration below age- and sex-specific cut-off values as defined by the World Health Organization
- Peripheral blood picture suggestive of nutritional anemia
- Willingness to participate, with written informed consent from parents or guardians and assent from participants

Exclusion criteria

- History or laboratory evidence of hemoglobinopathies or inherited red cell disorders
- Anemia secondary to acute or chronic infections, inflammatory conditions, renal disease, or hematological malignancies
- Recent blood transfusion or parenteral iron therapy within the preceding three months
- Current use of medications known to interfere with iron metabolism

Sample size determination

The sample size was estimated based on detecting a moderate correlation between RBC indices and biochemical indicators of iron absorption. Assuming a correlation coefficient of 0.30, a confidence level of 95%, and a statistical power of 80%, the minimum required sample size was calculated to be 84 participants. To account for potential exclusions due to incomplete biochemical data or hemolyzed samples, a final sample size of 100 adolescents was targeted and 123 sample size was achieved.

Sampling technique: A consecutive sampling method was employed. Eligible participants meeting the inclusion criteria during the study period were enrolled until the predetermined sample size was reached.

Clinical and anthropometric assessment: A structured clinical evaluation was performed for all participants, including demographic details, dietary history with emphasis on iron intake and inhibitors of absorption, and menstrual history in female participants. Anthropometric measurements such as height and weight were recorded using standardized techniques, and body mass index (BMI) was calculated.

Hematological parameters: Venous blood samples were collected under aseptic precautions. Complete blood counts were analyzed using an automated hematology analyzer calibrated daily according to manufacturer recommendations. The following RBC indices were recorded:

- Mean corpuscular volume (MCV)
- Mean corpuscular hemoglobin (MCH)
- Mean corpuscular hemoglobin concentration (MCHC)
- Red cell distribution width (RDW)

Peripheral blood smears stained with Leishman stain were examined to corroborate automated findings and assess red cell morphology.

Biochemical assessment of iron absorption physiology: Iron absorption physiology was indirectly assessed using established biochemical markers reflecting iron availability and utilization. These included:

- Serum iron concentration
- Total iron-binding capacity (TIBC)
- Transferrin saturation
- Serum ferritin levels

Blood samples for biochemical analysis were obtained in the morning after an overnight fast to minimize diurnal variation. Serum ferritin values were interpreted in conjunction with clinical findings to exclude inflammatory confounding.

Data management and quality control: All laboratory analyses were performed in a single accredited laboratory to reduce inter-assay variability. Internal quality control samples were run daily for both hematological and biochemical assays. Data were double-entered into a predesigned database and cross-verified for accuracy.

Statistical analysis: Data analysis was performed using standard statistical software. Continuous variables were expressed as mean ± standard deviation. The normality of variables was assessed using the Shapiro–Wilk test. Correlations between RBC indices and iron absorption markers were evaluated using Pearson's correlation coefficient. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 123 adolescents with nutritional anemia were included in the final analysis. The mean age of the study population was 14.8 ± 2.3 years, with the largest proportion belonging to the 10–13-year age group (38.2%). Female participants constituted 56.1% of the sample. Underweight status, based on body mass index, was observed in 42.3% of participants, and low dietary iron intake was reported by 64.2% of the study population (Table 1).

The mean hemoglobin concentration among participants was 9.6 ± 1.1 g/dL. Red blood cell indices demonstrated a predominantly microcytic and hypochromic pattern, with reduced mean corpuscular volume (71.4 ± 6.8 fL), mean corpuscular hemoglobin (22.1 ± 2.7 pg), and mean corpuscular hemoglobin concentration (30.4 ± 1.9 g/dL). Red cell distribution width was elevated, with a mean value of 17.6 ± 2.4%, indicating increased anisocytosis (Table 2).

Biochemical parameters reflecting iron absorption physiology showed reduced iron availability. Mean serum iron concentration was 42.8 ± 13.6 µg/dL, while total iron-binding capacity was elevated at 392.4 ± 46.9 µg/dL. Transferrin saturation was markedly decreased, with a mean value of 10.9 ± 4.3%. Serum ferritin levels were low, with a mean concentration of 14.2 ± 6.1 ng/mL (Table 3).

Correlation analysis demonstrated statistically significant associations between RBC indices and biochemical markers of iron absorption. Mean corpuscular volume showed a positive correlation with serum iron ($r = 0.41$) and transferrin saturation ($r = 0.44$), and a negative correlation with total iron-binding capacity ($r = -0.36$). Similar patterns were observed for mean corpuscular hemoglobin, which exhibited moderate positive correlations with serum iron ($r = 0.46$), transferrin saturation ($r = 0.49$), and serum ferritin ($r = 0.42$), along with a negative correlation with total iron-binding capacity ($r = -0.39$). Red cell distribution width demonstrated inverse correlations with serum iron ($r = -0.48$), transferrin saturation ($r = -0.46$), and serum ferritin ($r = -0.40$), and a positive correlation with total iron-binding capacity ($r = 0.43$). All reported correlations were statistically significant ($p < 0.05$) (Table 4).

Based on hemoglobin levels, the majority of participants were classified as having moderate anemia (58.5%). Mild anemia was observed in 30.9% of adolescents, while severe anemia was present in 10.6% of the study population (Table 5).

Table 1: Baseline demographic and clinical characteristics of the study population (n = 123)

Variable	Value
Age (years), mean ± SD	14.8 ± 2.3
Age group, n (%)	
10–13 years	47 (38.2)
14–16 years	41 (33.3)
17–19 years	35 (28.5)
Sex, n (%)	
Male	54 (43.9)
Female	69 (56.1)
Body mass index (kg/m^2), mean ± SD	18.9 ± 2.4
Underweight (BMI <18.5), n (%)	52 (42.3)
Menstruating females (n = 69), n (%)	61 (88.4)
Reported low dietary iron intake, n (%)	79 (64.2)

Table 2: Hematological parameters and RBC indices among adolescents with nutritional anemia (n = 123)

Parameter	Mean ± SD	Reference range
Hemoglobin (g/dL)	9.6 ± 1.1	12.0–15.0
Red blood cell count ($\times 10^6/\mu L$)	4.21 ± 0.52	4.5–5.5
Mean corpuscular volume (fL)	71.4 ± 6.8	80–96
Mean corpuscular hemoglobin (pg)	22.1 ± 2.7	27–33
Mean corpuscular hemoglobin concentration (g/dL)	30.4 ± 1.9	32–36
Red cell distribution width (%)	17.6 ± 2.4	11.5–14.5

Table 3: Biochemical markers reflecting iron absorption physiology (n = 123)

Parameter	Mean ± SD	Reference range
Serum iron (µg/dL)	42.8 ± 13.6	60–170
Total iron-binding capacity (µg/dL)	392.4 ± 46.9	250–370
Transferrin saturation (%)	10.9 ± 4.3	20–45
Serum ferritin (ng/mL)	14.2 ± 6.1	30–300

Table 4: Correlation between RBC indices and biochemical markers of iron absorption (n = 123)

RBC index	Serum iron (r)	TIBC (r)	Transferrin saturation (r)	Serum ferritin (r)
Mean corpuscular volume (MCV)	0.41*	−0.36*	0.44*	0.38*
Mean corpuscular hemoglobin (MCH)	0.46*	−0.39*	0.49*	0.42*
Mean corpuscular hemoglobin concentration (MCHC)	0.32*	−0.28*	0.35*	0.31*
Red cell distribution width (RDW)	−0.48*	0.43*	−0.46*	−0.40*

*Correlation significant at $p < 0.05$

Table 5: Distribution of anemia severity based on hemoglobin levels (n = 123)

Severity	Hemoglobin range (g/dL)	n (%)
Mild	10.0–11.9	38 (30.9)
Moderate	7.0–9.9	72 (58.5)
Severe	<7.0	13 (10.6)

Discussion

In this cross-sectional cohort of adolescents with nutritional anemia, red blood cell (RBC) indices demonstrated consistent, biologically coherent associations with biochemical markers that reflect systemic iron availability. Across the correlation matrix (Table 4), hemoglobin and microcytic/hypochromic indices (MCV and MCH) tracked positively with markers of circulating/utilizable iron (serum iron and transferrin saturation) and iron stores (serum ferritin), while showing inverse relationships with indices of binding capacity (e.g., TIBC), supporting the concept that routine CBC-derived indices mirror iron-restricted erythropoiesis. This pattern aligns with contemporary interpretations of iron studies in which transferrin saturation is a proximate indicator of iron immediately available for erythropoiesis, whereas ferritin represents storage iron but is context-sensitive (particularly in inflammatory states) [7,8].

The directionality of our findings (Tables 4–5) is also consistent with guideline-level physiology: declining iron supply to the marrow reduces hemoglobinization and, over time, yields smaller erythrocytes (lower MCV) with reduced hemoglobin content (lower MCH) [9]. Mechanistically, intestinal absorption and iron recycling are governed by the hepcidin–ferroportin axis; when hepcidin is inappropriately elevated (e.g., due to inflammation) or when iron intake is chronically inadequate, ferroportin-mediated iron egress is restricted, lowering circulating iron and transferrin saturation despite variable ferritin values [10,11]. Thus, the observed coupling between RBC indices and transferrin saturation (Table 4) is physiologically plausible, because transferrin saturation is tightly linked to iron delivery to erythroid precursors [8,10].

Our results also support the potential pragmatic use of CBC indices as a first-line triage tool in adolescent screening contexts where biochemical assays may be limited. Prior adolescent-focused studies have reported that hemoglobin and RBC indices, including RDW, demonstrate fair diagnostic performance for iron deficiency when benchmarked against ferritin [12]. Similarly, population-based work in adolescent girls has highlighted the utility of combining RDW with hemoglobin to improve identification of iron deficiency/iron deficiency anemia in field settings [13]. Importantly, our data extend these observations by demonstrating graded correlations of the same hematologic parameters with multiple iron markers (Table 4), reinforcing that these indices capture iron-restricted erythropoiesis across a spectrum of depletion severity (Table 5).

Nevertheless, concordance between RBC indices and ferritin is not expected to be perfect. Recent evidence shows that while RDW and certain RBC indices may correlate with ferritin, their discriminatory ability can be modest and context dependent, emphasizing that biochemical confirmation remains necessary where feasible [14]. In our study, the pattern of associations (Table 4) supports a complementary approach: CBC indices may flag probable iron-restricted erythropoiesis, while transferrin saturation and ferritin refine classification and severity (Table 5), consistent with recent reviews advocating multi-marker interpretation rather than reliance on any single test [7,8].

An additional implication is the potential role of dynamic erythropoietic markers, such as reticulocyte hemoglobin (Ret-He/CHr), which reflect recent iron incorporation into newly produced erythrocytes and may be less confounded by inflammatory elevation of ferritin [15]. While Ret-He was not measured in the present work, its use could strengthen future studies aiming to approximate “functional” iron availability at the marrow level and to bridge the gap between absorption physiology and hematologic phenotype [15].

Limitations: First, the study design is cross-sectional; correlations (Tables 4–5) cannot establish temporal causality between absorption physiology and RBC indices. Second, biochemical proxies (serum iron, transferrin saturation, ferritin, TIBC) reflect systemic iron handling but do not directly quantify fractional iron absorption; therefore, our conclusions should be framed as correlations with iron availability and storage rather than direct absorption measurements. Finally, because ferritin is an acute-phase reactant, residual confounding by unmeasured inflammation may have attenuated or distorted ferritin-based associations, reinforcing the value of combined-marker interpretation [7,8].

Overall, the correlation profile observed (Tables 4–5) supports the biological validity of using RBC indices—especially MCV, MCH, and RDW—as accessible hematologic correlates of iron availability in adolescents with nutritional anemia, while underscoring that confirmatory iron studies remain important for accurate phenotyping and for distinguishing iron deficiency from other causes of microcytosis.

Conclusion

The present study demonstrates a clear and statistically significant association between red blood cell indices and biochemical markers reflecting iron absorption physiology in adolescents with nutritional anemia. Lower values of mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration, along with elevated red cell distribution width, were consistently associated with reduced serum iron, decreased transferrin saturation, elevated total iron-binding capacity, and low serum ferritin levels. These findings highlight that routinely measured RBC indices closely mirror underlying disturbances in iron availability and utilization in this population. The observed predominance of moderate anemia underscores the clinical relevance of early hematological assessment, suggesting that RBC indices may serve as accessible indicators for identifying impaired iron absorption physiology among adolescents with nutritional anemia.

References

1. Khanal A, Paudel R, Wagle CN, Subedee S, Pradhan PMS. Prevalence of anemia and its associated factors among adolescent girls on Weekly Iron Folic Acid supplementation (WIFAS) implemented and non-implemented schools at Tokha municipality, Kathmandu. PLOS Glob Public Health. 2024;4(1):e0002515. doi: 10.1371/journal.pgph.0002515

2. Cohen CT, Powers JM. Nutritional Strategies for Managing Iron Deficiency in Adolescents: Approaches to a Challenging but Common Problem. Adv Nutr. 2024;15(5):100215. doi: 10.1016/j.advnut.2024.100215
3. Kolarš B, Mijatović Jovin V, Živanović N, et al. Iron Deficiency and Iron Deficiency Anemia: A Comprehensive Overview of Established and Emerging Concepts. Pharmaceuticals (Basel). 2025;18(8):1104. doi:10.3390/ph18081104
4. Loveikyte R, van den Berg Y, van der Meulen-de Jong AE, Vlasveld LT. The Role of Hepcidin and an Oral Iron Absorption Test in Identifying the Root Cause of Iron-Restricted Anemia (Enter-Iron). Acta Haematol. 2024;147(4):402-412. doi:10.1159/000535275
5. Alsafi WM, Gaffer AA, Al-Nafeesah A, AlEed A, Alfaifi J, Adam I. Diagnostic Accuracy of Hemoglobin Levels and Red Blood Cell Parameters for Iron Deficiency in Adolescents: A Cross-Sectional Study. Glob Pediatr Health. 2024; 11:2333794X241304642. doi:10.1177/2333794X241304642
6. Dhurde VS, Patel AB, Locks LM, Hibberd PL. Diagnostic performance of red cell indices in detecting iron deficiency and iron deficiency anemia among rural adolescent girls aged 14-19 years in Nagpur District. PLOS Glob Public Health. 2025;5(9):e0005108. doi: 10.1371/journal.pgph.0005108.
7. Kriel M, Opie J, Rusch J, Richardson D, Louw V. Old tests and new paradigms: How to interpret iron studies and related biomarkers for the diagnosis of iron deficiency in adults. Blood Rev. 2025; 74:101337. doi: 10.1016/j.blre.2025.101337
8. Rusch JA, van der Westhuizen DJ, Gill RS, Louw VJ. Diagnosing iron deficiency: Controversies and novel metrics. Best Pract Res Clin Anaesthesiol. 2023;37(4):451-467. doi: 10.1016/j.bpa.2023.11.001
9. Iolascon A, Andolfo I, Russo R, et al. Recommendations for diagnosis, treatment, and prevention of iron deficiency and iron deficiency anemia. Hemasphere. 2024;8(7):e108. doi:10.1002/hem3.108
10. Qiu L, Frazer DM, Hu M, et al. Mechanism and regulation of iron absorption throughout the life cycle. J Adv Res. 2025; 77:107-118. doi: 10.1016/j.jare.2025.01.002
11. Alzu'bi M, Bawa'neh H, Alshorman A, et al. Defining an optimal cut-off point for reticulocyte hemoglobin as a marker for iron deficiency anemia: An ROC analysis. PLoS One. 2023;18(7):e0288505. doi: 10.1371/journal.pone.0288505
12. Alsafi WM, Gaffer AA, Al-Nafeesah A, AlEed A, Alfaifi J, Adam I. Diagnostic Accuracy of Hemoglobin Levels and Red Blood Cell Parameters for Iron Deficiency in Adolescents: A Cross-Sectional Study. Glob Pediatr Health. 2024; 11:2333794X241304642. doi:10.1177/2333794X241304642
13. Dhurde VS, Patel AB, Locks LM, Hibberd PL. Diagnostic performance of red cell indices in detecting iron deficiency and iron deficiency anemia among rural adolescent girls aged 14-19 years in Nagpur District. PLOS Glob Public Health. 2025;5(9):e0005108. doi: 10.1371/journal.pgph.0005108
14. Babah OA, Chieme CF, Abioye AI, Spaine SO, Adeyemo TA, Afolabi BB. Red blood cell indices versus serum ferritin as surrogate markers of iron deficiency during pregnancy. PLoS One. 2025;20(10):e0334098. doi: 10.1371/journal.pone.0334098
15. Choorapoikayil S, Kotlyar MJ, Kawohl L, et al. Reticulocyte hemoglobin content: a new frontier in iron deficiency diagnostics for major surgical patients. BMC Anesthesiol. 2025;25(1):40. doi:10.1186/s12871-025-02905-6