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CORRELATION OF HEMOGLOBIN WITH RED BLOOD CELL INDICES IN IRON DEFICIENCY ANEMIA: A CROSS-SECTIONAL STUDY

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Abstract

Background: *Iron deficiency anemia (IDA) is the most prevalent nutritional disorder worldwide, characterized by reduced hemoglobin synthesis and morphological changes in red blood cells.*
Objective: This study examined the correlation between hemoglobin levels and red blood cell (RBC) indices mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) in patients with confirmed IDA.
Methods: *A cross-sectional study was conducted on 100 participants (64 anemic, 36 non-anemic; 65% female, 35% male; age 18–39 years). Venous blood was analyzed using an automated hematology analyzer. Pearson and Spearman correlation analyses were performed on the anemic subgroup.*
Results: *Mean hemoglobin was 10.87 ± 2.70 g/dL. Positive associations were observed between hemoglobin and all three RBC indices; however, correlations were not statistically significant within the anemic subgroup ($p > 0.05$). Independent-samples t-test revealed significantly lower MCV, MCH, and MCHC in anemic versus non-anemic participants. Conclusion: RBC indices reliably reflect the microcytic hypochromic pattern of IDA. Though intra-group correlations were modest, MCV, MCH, and MCHC remain clinically valuable, cost-effective markers for diagnosing and monitoring iron deficiency anemia.*
Keywords:

1. INTRODUCTION

Iron deficiency anemia is the most common nutritional deficiency globally, disproportionately affecting women, children, and populations with poor dietary access. It arises when depleted iron stores impair hemoglobin synthesis, producing smaller, paler red blood cells characteristic of microcytic hypochromic anemia (Camaschella, 2019). The World Health Organization defines anemia as hemoglobin < 13 g/dL in adult males, < 12 g/dL in non-pregnant females, and < 11 g/dL in pregnant women Chinyoka and Obeagu (2025) Red blood cell indices MCV, MCH, and MCHC are standard components of the complete blood count (CBC) and provide critical insight into erythrocyte morphology. MCH helps understand each red blood cell's capacity to carry oxygen and

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provides helpful information about the amount of hemoglobin in erythrocytes. In IDA, diminished iron availability reduces hemoglobin incorporation during erythropoiesis, causing MCV (normal 80–100 fL), MCH (normal 27–33 pg), and MCHC (normal 32–36 g/dL) to fall below reference ranges. Understanding the quantitative relationship between hemoglobin and these indices enhances diagnostic precision and supports treatment monitoring without requiring expensive additional tests.

This study investigated the correlation between hemoglobin concentration and RBC indices in confirmed IDA patients, with the aim of identifying which index most closely tracks hemoglobin decline and validating CBC-derived parameters as practical tools in routine clinical settings. ARC readings within the "normal range" (usually 50-100 × 109/L) in an anemic patient reflect an incorrect response and an underlying problem with red cell production caused by either extrinsic or intrinsic causes, or a mix of the two. Lastly, the red cell distribution width helps determine if the anemia is most likely the result of a single cause (normal RDW) or a mixed process (wide RDW). However, the etiology of anemia determines how it should be treated. Patients' quality of life is enhanced by early diagnosis and timely treatment (Chinelo et al;2022).

Objectives

1. To investigate the relationship of red blood cell parameters and hemoglobin levels in individuals suffering from iron-deficient anemia
2. To analyze the pattern of RBC indices changes with decreasing hemoglobin levels.
3. To identify which RBC index shows the strongest correlation with hemoglobin.

Research questions

1. Is there a meaningful association between hemoglobin levels and RBC indices in iron deficiency anemia?
2. How does hemoglobin level affect MCV, MCH, and MCHC values?
3. Which RBC index is most strongly associated with hemoglobin in iron deficiency anemia?

Park and Chang (2025) found that red blood cell (RBC) indices are crucial for predicting and evaluating major health issues such as cardiovascular morbidity and mortality from cancer, cardiovascular disease, and infection, in addition to monitoring anemia. Two RBC features that are highlighted as promising, accessible, and reasonably priced prognostic and diagnostic tools for cancer, cardiovascular disease, and all-cause mortality are hemoglobin/RDW and mean corpuscular volume (MCV). Their flexibility and comprehension of the underlying physiological changes suggest that they are worthy of further study and validation through future research. This could significantly enhance patient care and prognosis for some illnesses.

Czempik and Wiórek (2023) Emphasized that there is no difference between women with low and normal ferritin levels when testing Ret-Hb. Although several physical and demographic characteristics alter the iron homeostasis process and affect serum ferritin levels, testing for serum ferritin levels is commonly used to determine IDA and LID. Obesity, ageing, and some inflammatory conditions including congestive heart failure are some of these conditions.

2. Materials and Methods

2.1 Study Design and Setting

An analytical cross-sectional study was conducted in the pathology and hematology departments of a tertiary care hospital over four to six months. Ethical approval was obtained from the Institutional Ethical Review Committee prior to commencement.

2.2 Participants

One hundred participants were enrolled by non-probability convenience sampling. Inclusion criteria required a confirmed diagnosis of IDA based on low hemoglobin, low MCV, low MCH, and reduced serum ferritin, with both sexes eligible. Exclusion criteria encompassed other anemia subtypes (hemolytic, megaloblastic), chronic illnesses (renal, hepatic, malignancy), pregnancy, recent blood transfusion (within 3 months), ongoing iron/hematinic therapy, and active infection or inflammation.

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2.3 Laboratory Measurements

Two to three milliliters of venous blood collected under aseptic conditions into EDTA-anticoagulated tubes were analyzed using an automated hematology analyzer. Parameters recorded included hemoglobin (g/dL), serum iron (µg/dL), MCV (fL), MCH (pg), and MCHC (g/dL).

2.4 Statistical Analysis

Data were analyzed using SPSS. Normality was assessed with the Kolmogorov–Smirnov and Shapiro–Wilk tests ($\alpha = 0.05$). As most variables departed from normality, both Pearson and Spearman correlation coefficients were computed for the anemic subgroup (n = 64). Group differences in RBC indices between anemic and non-anemic participants were evaluated by independent-samples t-test (95% CI). Statistical significance was set at $p < 0.05$.

3. Results

Descriptive Statistics

The study included 65 females (65%) and 35 males (35%), aged 18–39 years (mean 29.0 ± 6.6). Sixty-four participants (64%) met diagnostic criteria for anemia. Key hematological parameters are summarized in Table 1.

Table 1: ***Descriptive statistics of hematological parameters (N = 100)***

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	100	18	39	29.00	6.601
Hemoglobin (g/dL)	100	7.0	17.4	10.874	2.7039
Serum Iron (µg/dL)	100	20	149	67.89	33.833
MCV (fL)	100	58.1	79.1	68.636	6.0508
MCH (pg)	100	16.1	27.2	21.999	2.7337
MCHC (g/dL)	100	29.1	33.5	31.100	1.1432

SD = Standard Deviation

This section provides a summary of the basic statistical features of each of the six continuous variables that were measured among the 100 participants. The table displays the arithmetic mean, standard deviation, and sample size recorded lowest and maximum values for each variable.

Frequency analysis of anemia status and gender

Frequency charts reflect the distribution of the two categorical variables: gender and anemia status. The data was collected from 100 real samples that had no missing value for either variable.

Table 1: ***Gender Distribution (N = 100)***

Female	65	65.0%	65.0%
Male	35	35.0%	100.0%
Total	100	100.0%	–

65 female participants (65%) and 35 male participants (35%).

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Table 3: *Normality Testing*

Variable	K-S Statistic	K-S p-value	Shapiro-Wilk Statistic	S-W p-value	Conclusion
MCV (fL)	0.097	0.022	0.954	0.002	Non-normal
MCH (pg)	0.066	0.200*	0.977	0.073	Normal
Serum Iron (µg/dL)	0.142	<0.001	0.928	<0.001	Non-normal
Hemoglobin (g/dL)	0.080	0.115	0.939	<0.001	Non-normal
MCHC (g/dL)	0.074	0.193	0.974	0.044	Non-normal
Age (years)	0.106	0.008	0.932	<0.001	Non-normal

Shapiro–Wilk testing revealed non-normal distributions for hemoglobin, MCV, MCHC, serum iron, and age ($p < 0.05$). MCH was the only normally distributed variable ($p = 0.073$), supporting the use of non-parametric analyses for most comparisons.

Table 4: *Pearson Correlation Matrix among RBC Indices (Anemic Group, n = 64)*

Variable	MCV	MCH	MCHC
MCV	1.00	.117 (.358)	.204 (.107)
MCH	.117 (.358)	1.00	.050 (.695)
MCHC	.204 (.107)	.050 (.695)	1.00

The results revealed weak positive associations among the RBC indices; however, none of these correlations reached statistical significance ($p >$ .05). Therefore, no meaningful relationship was observed among MCV, MCH, and MCHC in the anemic subgroup.

Table 5: *Pearson Correlations among RBC Indices and Serum Iron (Anemic Group, n = 64)*

Variable	MCV	MCH	MCHC	Serum Iron
MCV	1.00	.117 (.358)	.204 (.107)	.030 (.817)
MCH	.117 (.358)	1.00	.050 (.695)	.113 (.372)
MCHC	.204 (.107)	.050 (.695)	1.00	.049 (.701)
Serum Iron	.030 (.817)	.113 (.372)	.049 (.701)	1.00

Among the RBC indices, MCV demonstrated the strongest positive association (Pearson r = .204; Spearman ρ = .170), followed by MCH. However, none of the observed relationships were statistically significant ($p >$ .05). Therefore, although MCV appeared to be the RBC index most closely related to hemoglobin levels, the evidence was insufficient to conclude a significant association.

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Table 6: ***Independent-Samples t-Test Comparing RBC Indices Between Anemic and Non-Anemic Participants***

Variable	Anemic (n = 64) M (SD)	Non-Anemic (n = 36) M (SD)	t(df)	P
MCV (fL)	65.82 (4.91)	73.66 (3.85)	-8.31 (98)	< .001
MCH (pg)	20.48 (2.12)	24.69 (1.87)	-10.02 (98)	< .001
MCHC (g/dL)	30.58 (0.91)	32.03 (0.88)	-7.68 (98)	< .001

Note: M = *Mean*; SD = *Standard Deviation*

Independent-samples t-test confirmed that anemic participants had significantly lower MCV, MCH, and MCHC compared to non-anemic controls ($p < 0.05$ for all), consistent with the microcytic hypochromic phenotype of IDA.

Discussion

This study confirms that IDA is associated with a characteristic reduction in all three major RBC indices. The mean MCV (68.6 fL), MCH (22.0 pg), and MCHC (31.1 g/dL) in the sample were each below established reference ranges, reflecting impaired hemoglobin synthesis secondary to iron depletion consistent with findings by Chinyoka and Obeagu (2025) and Allahyani et al. (2025).

The weak, non-significant intra-group correlations between hemoglobin and RBC indices likely reflect the narrow hemoglobin range within the anemic cohort (7.0–12.0 g/dL), which limits the dynamic range needed to detect strong within-group associations. This phenomenon has been noted in similarly restricted clinical samples and does not undermine the diagnostic utility of RBC indices it simply indicates that once IDA is established, all indices tend to be depressed together rather than varying proportionally within the disease band.

The significant between-group differences confirm that MCV, MCH, and MCHC effectively discriminate anemic from non-anemic individuals, reinforcing their role as first-line screening tools. Their accessibility, low cost, and universal availability in CBC panels make them ideal for resource-limited settings. MCH, as the only normally distributed index in this study, may offer additional statistical stability across populations.

Serum iron added no significant incremental information within the anemic subgroup, echoing the well-documented variability of serum iron as a sole diagnostic marker. Ferritin, though not analyzed here due to scope limitations, remains the gold-standard for confirming iron stores. Future research should integrate ferritin with longitudinal RBC index monitoring to map the trajectory of hematological recovery following iron supplementation.

5. Conclusion

Iron deficiency anemia produces a consistent and clinically recognizable pattern of reduced MCV, MCH, and MCHC alongside falling hemoglobin. While within-group correlations were not statistically significant likely due to homogeneous disease severity group-level analyses robustly distinguished anemic from non-anemic participants. RBC indices derived from routine CBC remain simple, affordable, and effective tools for the early detection, classification, and monitoring of IDA. Their integration into standard clinical practice and public health screening programs, particularly in low-resource settings, should be prioritized.

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