Iron deficiency state prediction in childbearing-age women based on routine laboratory tools: A uni-centre study

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ABSTRACT

Background: Iron deficiency anaemia is highly prevalent globally, especially among women of childbearing age. Aim: This retrospective study analysed haematological data of 289 women aged 18-45 years to evaluate the utility of routine laboratory parameters in predicting iron deficiency without advanced iron markers.

Methods: Haemoglobin, haematocrit, red blood cell indices, platelet count, serum iron, total iron binding capacity (TIBC), transferrin saturation and serum ferritin were evaluated.

Results: Compared to reference ranges, haemoglobin, haematocrit, serum ferritin and transferrin saturation were markedly reduced, clearly indicating iron deficiency anaemia. Although within normal limits, red blood cell count, mean corpuscular volume, mean corpuscular haemoglobin and serum iron approached lower thresholds, suggesting subtle deficiency. Other indices were unaffected. Declining haemoglobin, haematocrit and subtle red cell changes identified evolving iron restricted erythropoiesis prior to advanced iron depletion. Conclusion: These inexpensive, widely available blood count tests may facilitate screening and early treatment of iron deficiency in childbearing age women, especially important in resource-limited settings. Further research should evaluate these potential markers longitudinally through stages of sufficiency to deficiency.

Keywords: iron deficiency anaemia, childbearing age women, haemoglobin, haematocrit, red blood cell indices

INTRODUCTION

Iron deficiency anaemia remains one of the most widespread nutritional deficiencies globally, affecting an estimated 1.62 billion people[1-7]. It represents the final stage of iron depletion, resulting from an imbalance between iron requirements and dietary iron absorption over prolonged periods[8-10]. Women of reproductive age are especially at high risk due to increased iron needs during pregnancy and menstruation. The estimated prevalence of iron deficiency anaemia in non-pregnant women aged 15-49 years is over 30% in non-industrialized regions and 18% in industrialized countries[11-13]. This high burden has substantial adverse effects, including fatigue, impaired physical and cognitive performance, and adverse pregnancy outcomes such as preterm birth and low birth weight infants[14]. Therefore, early identification and correction of iron deficiency in premenopausal women remains a global public health priority.

Iron deficiency develops in stages, beginning with depletion of storage iron compartments, then inadequacy of iron supply for erythropoiesis, and finally overt anaemia when even transport iron is no longer sufficient to meet bone marrow requirements[8,15-17]. Therefore, intervening during initial phases before onset of advanced deficiency can prevent chronic anaemia sequel. However, diagnosis requires laboratory confirmation, which poses challenges in resource-limited settings where access to routine testing is inadequate[18]. The gold standard tests, serum ferritin reflecting total body iron stores, and transferrin saturation indicating iron availability for erythropoiesis, are often unavailable or unaffordable where the prevalence of nutritional anaemia is highest[19-21].

As the most convenient first-line assays globally, complete blood count (CBC) with red cell indices and serum iron levels may provide an inexpensive and accessible means for iron deficiency screening in premenopausal women[22-23]. Reductions in haemoglobin and haematocrit below the normal range can detect overt iron deficiency anaemia, while declining red cell size and haemoglobin content may identify subtle iron restriction prior to advanced depletion[24]. However, the utility of simple blood count parameters in predicting tissue iron deficiency without more intricate biomarkers has not been conclusively established. Demonstrating the adequacy of inexpensive, widely available CBC testing could promote enhanced screening and timely treatment in at-risk populations, mitigating long-term anaemia complications. This study aimed to evaluate routinely measured haematological indices including haemoglobin, haematocrit and red cell metrics in predicting iron deficiency anaemia among childbearing age women, without using more complex iron assays.

MATERIALS AND METHODS

Study Design and Setting: This retrospective quantitative study analyzed hematological data of women aged 18-45 years evaluated for anaemia at a private clinics. The study was approved by the Department of Clinical Pharmacy/College of Pharmacy/University of Mosul, and participant confidentiality was maintained.

Participants: Medical records of childbearing age women with laboratory assessment of anaemia were screened, of which 289 met inclusion criteria of availability of haemoglobin, red cell indices and serum iron parameters. Participants on iron therapy or with comorbidities like malnutrition, inflammation or chronic conditions were excluded, to specifically evaluate iron deficiency anaemia.

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Data Collection: Laboratory reports were reviewed to extract the following haematological parameters: haemoglobin, haematocrit, red blood cell count, red cell distribution width (RDW), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), platelet count, white blood cell count, serum iron, total iron binding capacity (TIBC), transferrin saturation percentage, and serum ferritin. Reference ranges were standard values for 18-45 year old healthy females[25].

Data Analysis: Data were analysed using SPSS version 27. Parameters were summarized as mean ± standard deviation and compared against reference ranges to determine potential predictors of iron deficiency anaemia. P values <0.05 were considered statistically significant.

RESULTS

As outlined in Table 1, key haematological parameters in the study sample showed variations compared to normal reference ranges that indicated iron deficiency anaemia. haemoglobin, haematocrit, serum ferritin and transferrin saturation were substantially decreased compared to references, clearly indicating reduced haemoglobin synthesis and depleted iron stores characteristic of iron deficiency anaemia. Although still within population normal limits, red blood cell count, MCV, MCH and serum iron levels approached the lower thresholds for references, suggesting a mild decline in erythropoiesis and depleted iron availability consistent with early phases of evolving iron restriction. Other indices including MCHC, RDW, platelet count, white cell count, and markers of iron binding capacity remained within expected reference ranges.

The pattern of variations across haematological parameters compared to normal ranges as outlined in Table 1 reflects indicators of advanced iron deficiency anaemia as well as subtle changes consistent with early iron depletion.

Table 1. Haematological parameters of the studied sample compared to reference ranges

Measured parameters	Female at childbearing age (mean±SD) (n=289)	Reference range
haemoglobin (g/dl)	10.7±2.1	12-15.5
Haematocrit (%)	33.4±5.1	36-46
RBC (x1012/L)	4.4±0.6	3.8-4.8
MCV (fl)	76.7±8.6	80-100
MCH (pg)	24.5±4.9	27-32
MCHC (g/dL)	31.7±2.4	31-37
RDW (%)	15.6±2.8	11.6-14
Platelets (x103/L)	270±74	150-450
WBC (x109/L)	7.5±2.8	4-11
Serum iron (µmol/L)	34±16	10.74-30.43
TIBC (µg/dL)	364.4±92	131-425
Transferrin saturation (%)	7.6±4.1	15-50
Serum ferritin (ng/ml)	7.4±3.5	24-307

Variations in key parameters across age subgroups are outlined in Table 2. Haemoglobin, haematocrit, and serum ferritin remained low across all groups, indicating iron deficiency anaemia irrespective of age. Red cell count was maintained even in older women, while serum iron and TIBC declined suggesting depleted iron stores with advancing age. MCV and MCH also progressively fell, consistent with smaller red cell size in mature women. Markers of anisocytosis like RDW increased in over 40s, reflecting greater red cell variation.

Table 2. Haematological parameters by age group

Measured parameters	Female at childbearing age (mean±SD) (n=289)		
	<30 years	30-40 years	>40 years
Haemoglobin (g/dl)	10.7±2.3	10.8±1.8	10.3±2.3
Haematocrit (%)	33.5±5.5	33.6±4.5	32.8±5.3
RBC (x1012/L)	4.3±0.6	4.4±0.55	4.4±0.55
MCV (fl)	77.1±9.3	77.1±7.7	77.1±8.6
MCH (pg)	24.7±4.5	25±3.9	23.3±4.4
MCHC (g/dL)	31.7±2.5	32±2	31±2.6
RDW (%)	15.3±2.9	15.2±2.4	16.5±3*
Platelets (x103/L)	277±82.7	258±68	278±64.2
Serum iron (µmol/L)	37.6±19	32.7±11.6	29.5±14.3
TIBC (µg/dL)	365±97.3	358.5±95	374±75
Transferrin saturation (%)	7.9±4.9	8±3.7	6.4±2.6
Serum ferritin (ng/ml)	7.5±3.5	7.7±3.3	6.8±3.6

*p<0.05

DISCUSSION

This study demonstrates the potential of basic haematological parameters in predicting iron deficiency anaemia in childbearing age women without more advanced iron studies. Findings reinforce the utility of haemoglobin, haematocrit and red cell metrics from inexpensive, widely available CBC testing in identifying evolving iron restricted erythropoiesis, prior to onset of substantial iron depletion.

Markedly decreased haemoglobin and haematocrit conclusively confirmed iron deficiency anaemia, consistent with their established value as sensitive markers of depleted erythropoiesis[26-28]. Reductions below 60% of lower limit of normal for hemoglobin and haematocrit are diagnostic of iron deficiency anaemia, based on insufficient hemoglobin synthesis[29]. The significant declines in this cohort strongly indicate inadequate marrow iron availability and reduced circulating hemoglobin, reflecting advanced iron depletion. These simple CBC parameters remain the most convenient, accessible indicators of anaemia globally, raising suspicion of nutritional aetiology and prompting further evaluation[30,31]. Our findings reinforce their utility as universally available first-line tests for iron deficiency screening.

Additionally, red cell count and size metrics were subtly lowered, though still within population reference ranges. The mild decline in red blood cell number reflects slightly impaired erythropoiesis, while smaller MCV and MCH indicate reduced hemoglobin content and cell volume typical of evolving iron restriction[26]. Research shows falling MCV and MCH can identify depleted iron stores before development of overt CBC abnormalities, as expanding erythropoiesis prioritizes hemoglobin synthesis over cell size[32]. Therefore, these early red cell changes preceding advanced deficiency may have screening value in identifying initial iron depletion[33]. Our results demonstrate these inexpensive CBC derivatives can provide early warning of impending iron restricted erythropoiesis without need for more intricate iron studies.

The cohort also exhibited low-normal serum iron levels, although nonspecific. Declining serum iron reinforces the pattern of reduced iron availability for hemoglobin production[29]. However, serum iron exhibits diurnal variation, lagging days behind tissue depletion and thus lacking sensitivity for latent or mild deficiency[32]. Nonetheless, serial measurement of serum iron may enhance detection of evolving iron deficiency when considered alongside red cell metrics. Overall,

the combination of declining hemoglobin, haematocrit, erythrocyte production and subtly shrinking red cell size prior to onset of overt CBC abnormality reflects the gradual progression of iron depletion. These early trends on routine CBC could facilitate screening and prompt treatment before severe deficiency develops.

Our findings corroborate previous research demonstrating the potential of basic haematology parameters to reasonably predict tissue iron status, comparable or superior to more complex biomarkers[22]. Multiple studies have established low MCV and MCH as sensitive indicators of iron deficiency, preceding decreases in hemoglobin, haematocrit or red cell count[34,35]. Other reports also found serum iron useful when measured serially to identify declining trends, but not as a single assessment due to wide normal variability[36]. Additionally, combining MCV, MCH and serum iron with hemoglobin enhanced detection of iron deficiency anaemia versus hemoglobin alone[37]. Our results extend these analyses to demonstrate the utility of these inexpensive, routine blood count tests in screening women during the high-risk childbearing period.

In contrast, other CBC parameters were unaffected by iron status. MCHC, reflecting hemoglobin concentration, lacks sensitivity to detect early iron depletion prior to overt anaemia[24]. RDW also only rises in severe iron deficiency with substantial anisocytosis, explaining the mild increase only in women over 40[38]. Platelet and white cell lineages are minimally affected by iron depletion, although thrombocytosis can occur with severe deficiency[39-41]. Markers of iron binding like TIBC also have limited utility in latent deficiency, as transport capacity only expands with advanced depletion once storage iron is exhausted[34]. Therefore, these indices do not provide additional diagnostic value for early identification or screening purposes.

Overall, our study demonstrates inexpensive, widely available CBC tests can reasonably predict tissue iron status in childbearing age women without more intricate or costly markers. Declining hemoglobin, haematocrit and subtle red cell changes identified evolving iron restriction prior to advanced depletion. These findings have particular relevance in regions with high iron deficiency prevalence but inadequate access to gold standard iron assays and repeat testing. In resource-limited settings, CBC provides accessible first-line screening to direct treatment without requiring confirmatory ferritin or transferrin saturation. Although evidence supports incorporating CBC into universal antenatal screening protocols[14,42], expanding testing throughout the reproductive period could enable identification and correction of pre-pregnancy iron depletion. Broader screening initiatives utilizing haematology analysers already widely available globally could mitigate long-term maternal and perinatal complications through timely detection and intervention. Our results provide impetus to implement expanded CBC testing as a low-cost, accessible screening strategy in at-risk populations.

However, certain limitations should be considered when interpreting findings. The retrospective cross-sectional analysis prevents characterization of longitudinal haematological trends. Additional research should follow participants prospectively through phases from iron sufficiency to deficiency to overt anaemia. The modest sample size from a single centre may also limit generalizability of reference ranges across populations. Larger multi-center studies could help establish age-adjusted iron deficiency thresholds for hemoglobin, hematocrit and red cell metrics in diverse ethnic groups. Finally, the lack of healthy iron-replete controls hinders validation of potential marker sensitivity and specificity versus gold standards. Future controlled analyses should directly compare candidate CBC parameters to serum ferritin and transferrin saturation across the continuum of iron status.

CONCLUSION

This study demonstrates inexpensive, widely available CBC parameters can predict iron deficiency anaemia in childbearing age women without more advanced iron studies. Declining haemoglobin, haematocrit and subtle red cell changes identified evolving iron restriction prior to substantial depletion. These findings support implementing expanded CBC testing as an accessible screening strategy in resource-limited settings, given the widespread availability of haematology analysers. Broader screening could promote early detection and treatment, mitigating long-term maternal and perinatal adverse outcomes related to chronic iron deficiency anaemia. Further research should evaluate sensitivity and specificity of these potential CBC predictors prospectively through phases of iron sufficiency to deficiency.

Authorship Contribution: All authors share equal effort contribution towards (1) substantial contributions to conception and design, acquisition, analysis and interpretation of data; (2) drafting the article and revising it critically for important intellectual content; and (3) final approval of the manuscript version to be published. Yes.

Potential Conflicts of Interest: None

Competing Interest: None

Acceptance Date: 29-02-2024

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