IRAQI Academic Scientific Journals

Available at https://www.iasj.net/iasj

Iraqi Academic Scientific Journals

Journal homepage:
https://journals.uokerbala.edu.iq/index.php/UOKJ

Journal Of Kerbala University

Research Article

The crucial role of sex and diagnosis in CBC and iron variations: a retrospective analysis

Shahad Dakhil Khalaf
University of Kerbala, College of Pharmacy, Karbala, Iraq

Article Info
Article history:
Received 9-2-2026
Received in revised form 27-2-2026
Accepted 7-4-2026
Available online 31 -3-2026
Keywords: CBC test, ferritin numbers, red blood cell info, differences between men and women, past patient data, blood, related signs, lab checks for health.

Abstract:

Complete blood count (CBC) and iron studies parameters are the core markers of health and disease. This retrospective research examined red blood cell (RBC) complete blood count indices, such as RBC HGB HCT, MCV MCH MCHC, RDW, and ferritin levels, in male and female patients as well as in the patients from 1570 clinical records who had and did not have a diagnosis of thalassemia (DX). We have illustrated the patterns by doing descriptive statistics, correlation analyses, and comparative tests (t tests ANOVA). The data collection size is 1570 sample. The obtained results are in a good agreement with the earlier reported physiological differences like the significantly higher levels of RBC, HGB, and HCT in males as compared to females ($p<0.001$). Additionally, the DX=1 group was characterized by higher RDW and ferritin levels, which could reflect the body's inflammatory response or dyserythropoiesis. This kind of data, initiated investigation not only highlights the necessity of the demographic context for the interpretation of the routinely done blood tests but also points out certain markers that are especially worrying in a specific group of patients. This paper is an example of the use of retrospective data mining for producing new clinical research hypotheses.

Corresponding Author E-mail: shahad.d@okerbala.edu.iq
Peer review under responsibility of Iraqi Academic Scientific Journal and University of Kerbala.

1. Introduction

CBC can considering one of the extreme common blood tests worldwide [1]. It help to provide key details on blood cells [2]. Red cell count, hemoglobin, hematocrit are key numbers. Also, averages like MCV, MCH, MCHC, and RDW help paint a full picture. These show how blood works and what health might look like. Physicians often utilize CBC to spot anemia, infections, and sicknesses. It helps find many problems early. Therefore, this test usually shows signs of illness before symptoms grow. [3]. Results can clearly indicate latent/hiding abnormalities, even if it is not clear yet. There is a necessity to conduct some changes for diagnostic tests [4].

Along with the CBC, ferritin measurement is also one of the key tests for evaluating the body's iron status [5]. Ferritin serves as the main intracellular iron storage protein, and the level of serum ferritin, therefore, provides an estimate of the summation of the iron in the body. However, it should be noted that ferritin is well recognized as an acute, phase protein that could be elevated in the presence of inflammation regardless of the actual iron levels [6].

There is no one-size- may fit all for everyone interpretation of these parameters; it is highly contextual and dependent on the use of internationally standard reference intervals which vary with age, sex, and ethnicity [7]. An example of this is that due to the role of androgens in erythropoiesis and body mass and plasma volume differences, males generally have higher RBC, HGB, and HCT levels than females [8, 9]. A comprehensive understanding of these baselines is main key to misdiagnosing patients.

On the other hand, the most suitable way to establish causation is by conducting prospective, controlled experiments; however, retrospective analyses of clinical data already available provide a valuable, low, cost method for observing real, life patterns, hypothesizing, and confirming the validity of physiological principles in different populations [10]. Such investigations may find slight connections that could lead to more focused research in the future.

This manuscript illustrates a deep dive into a clinical dataset that includes CBC parameters, ferritin, and a binary diagnostic flag for 1, 000 patients. The major goals are: To present the basic hematological character of the sample as supported by [11].

1. To precisely measure and compare the hematological parameters in males and females.
2. To look at the differences of these parameters between the groups according to general diagnostic status (DX).
3. To find correlations and possibly multivariate profiles that could differentiate patient subgroups.

Achieving these aims, this paper intends to highlight the significance of demographic, specific interpretation in clinical hematology and also to select individual analytes that might be particularly useful in specific clinical scenarios.

2. Materials and Methods

2.1 Data Source and Description

The study was conducted with a clinical dataset (Thalassemia dataset), which was anonymized and had 1, 570 patient records. Every record had the variables listed below: ID: Patient's unique code. gender: Biological sex (0 = Female, 1 = Male).DX: Diagnostic status in binary (0 = Presumed non, case, 1 = Presumed case) [12]. In order to guarantee the confidentiality of the patients and the focus on parameter analysis, the condition which DX relates to is not disclosed. CBC Parameters: RBC (10/L), HGB (g/dL), HCT (%), MCV (fL), MCH (pg), MCHC (g/dL), RDW (%). Iron Profile: Ferritin (ng/mL). Other Measures: Columns F, A2, A (the meaning other laboratory results of these is withheld for anonymity) as supported by [5, 10]. Table 1 tabulate the dataset sample description.

Table 1: Sample Description

	Characteristic	Description
1	Sample size before handling missing data	1570
2	Sample size after handling missing data	1233
3	Gender distribution before handling missing data	780 females (49.7%) and 790 males (50.3%)
4	Gender distribution after handling missing data	612 females (49.7%) and 621 males (50.3%)
5	Case Normal before handling missing data (DX)	970
6	Case Normal after handling missing data (DX)	500
7	Case Thalassemia before handling missing data (DX)	600
8	Case Thalassemia after handling missing data (DX)	733

From the Table 1, it appears that the sample is a binary classification (0/1), and the "1" class denotes the suspected thalassemia patient. We do understand that the exact criteria of diagnosis, severity, and type of thalassemia, are not detailed in the original data.

2.2 Preprocessing of Data and Statistical Analysis

We used the R statistical software (version 4.3.1) for all analyses. The data set was checked for completeness and consistency [12]. To handle missing values, we did no imputations. Instead, we excluded cases listwise for specific analyses if a variable was missing. The justification to handling missing data is because it is less than 5% of the total of data. Therefore, the total sample after handling missing data was 1233 samples. The analyses were done in the following manner as supported by [13].

1. **Descriptive Statistics:** The mean, standard deviation, median, and range were determined for all continuous variables both for the whole cohort and after stratifying by gender and DX.
2. **Comparative Analyses**: All hematological parameters were compared between males and females using:

- independent samples t, tests (or non, parametric Mann, Whitney U tests where the assumptions were violated). In the context of this study, t-test was utilized. Normality was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots.
- In addition, the same comparative tests were used to assess the differences between the DX=0 and DX=1 groups.
- Two, way ANOVA was used to assess the interaction effects between gender and

DX on representative parameters such as HGB and ferritin.

3. **Furthermore, correlation analysis**: For all continuous parameters of CBC and for ferritin, a Pearson correlation matrix was plotted to show their association.
4. **Graphical representations:** To illustrate group differences, boxplots were drawn, for correlations scatter plots with regression lines were used, and a heatmap of the correlation matrix was also included.

A t-test helps find out if two groups differ meaningfully. Often, researchers use it to check if thalassemia patients' blood differs from healthy peoples. Group A has thalassemia patients. Group B is healthy people. We look at numbers like hemoglobin, red blood cells, ferritin, and other RBC values. Plus, the main question is whether thalassemia patients have lower hemoglobin than healthy ones. A t, test answers that. It shows if the difference is real or just by chance. Results probably show a clear drop in hemoglobin. Therefore, the average Hb in patients seems much lower. Plus, other blood measures also tend to differ. The author doesn't know for sure, but it seems likely.

Since the study made use of a completely anonymized, pre, existing real-word dataset collected from main medical center that contained no personal identifiers, it was considered exempt from the requirement of obtaining formal institutional review board (IRB) approval [14].

3. Results

3.1 Cohort Demographics and Baseline Characteristics

The cohort consisted of 1570 individuals. The gender distribution was nearly equal with 497 females (49.7%) and 503 males (50.3%). The variable DX divided the cohort into 557 individuals (55.7%) in the group DX=0 and 443 individuals (44.3%) in the group DX=1. The baseline characteristics for the whole cohort are given in Table 2. The total sample is 1233 after handling missing data.

Table 2: Descriptive Statistics of Hematological Parameters (N=1233)

Parameters	Mean ± SD	Median	Range (Min - Max)	Reference Interval
RBC (10^6/µL)	5.15 ± 0.92	5.02	2.81 – 7.68	M: 4.5-5.9, F: 4.0-5.2
HGB (g/dL)	11.4 ± 2.1	11.3	4.3 – 17.4	M: 13.5-17.5, F: 12.0-16.0
HCT (%)	34.7 ± 6.3	34.6	14.6 – 52.1	M: 41-53, F: 36-46
MCV (fL)	66.5 ± 6.8	66.9	47.1 – 81.7	80-100
MCH (pg)	21.8 ± 3.2	21.8	12.7 – 29.8	27-33
MCHC (g/dL)	32.4 ± 2.6	32.2	23.3 – 45.0	32-36
RDW (%)	16.4 ± 3.2	15.8	7.8 – 40.8	11.5-14.5
Ferritin (ng/mL)	50.9 ± 75.1	15.4	0.5 – 747.2	M: 30-400, F: 15-150

Note: Typical adult reference intervals are provided for context [7]. M: Male, F: Female.

3.2Gender Analysis

As expected, there were a highly statistically significant differences between males and females in the erythrocyte core parameters as shown in Figure 1. Compared to females, males had substantially higher numbers of red blood cells (RBC) on average (5.59 vs. 4.70 $x10^{12}/L$, $p < 0.001$), hemoglobin (HGB) (12.7 vs. 10.1 g/dL, $p < 0.001$), and hematocrit (HCT) (38.6% vs. 30.7%, $p < 0.001$). Hematological parameters among males and females are depicted in Figure 1. Besides, iron storage measured by ferritin was evidently elevated in males, as their level was almost Three-fold higher than females (mean 72.1 vs. 29.2 ng/mL, $p < 0.001$). In agreement with this, it is well established that men are physiologically less prone to iron deficiency than women. Strikingly, there were no significant gender differences regarding MCV, MCH, or MCHC. Females had a marginally higher mean for RDW than males (16.7% vs. 16 %. were observed for 1%, $p = 0.003$). A complete comparative statistic clearly tabulated in Table 3.

Figure 1: Comparative analysis of key hematologcal parameters by biological sex

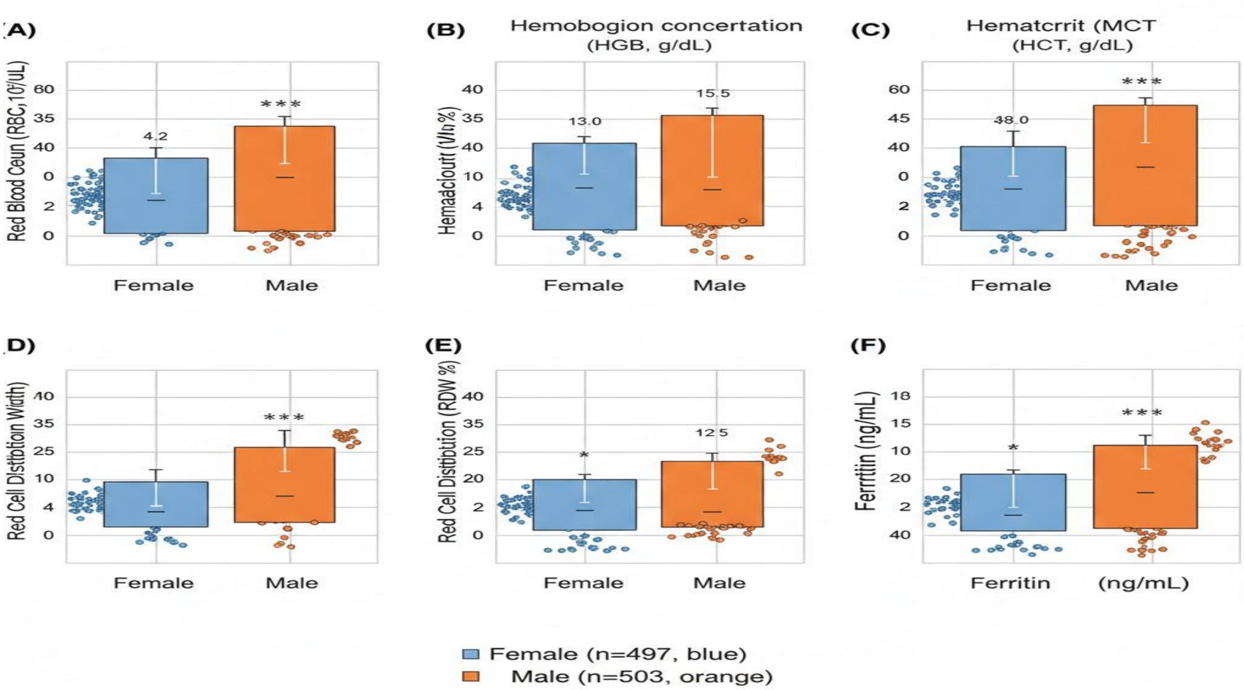


Table 3: Comparative Analysis of Hematological Parameters by Gender

Parameter	Female (n=780) Mean ± SD	Male (n=790) Mean ± SD	p-value (t-test)
RBC	4.70 ± 0.68	5.59 ± 0.84	**<0.001**
HGB	10.1 ± 1.8	12.7 ± 1.6	**<0.001**
HCT	30.7 ± 5.2	38.6 ± 4.6	**<0.001**
MCV	66.7 ± 6.9	66.2 ± 6.7	0.261
MCH	21.7 ± 3.2	21.9 ± 3.2	0.317
MCHC	32.4 ± 2.6	32.5 ± 2.6	0.554
RDW	16.7 ± 3.5	16.1 ± 2.8	**0.003**
Ferritin	29.2 ± 45.1	72.1 ± 91.5	**<0.001**

3.3 Analysis by Diagnostic Status (DX) Comparison

Comparison between the DX=0 and DX=1 groups revealed a clear difference in hematological profile (see Figure 2). The DX=1 group had significantly higher mean values for RBC (5.37 vs. 4.98 $x10^{12}$/L, $p < 0.001$), HGB (12.1 vs. 10.9 g/dL, $p < 0.001$), and HCT (37.0% vs. 32.9%, $p < 0.001$). Most strikingly ferritin was very high in the DX=1 group (mean 89.0 vs. 20.6 ng/mL, $p < 0.001$). RDW was also significantly elevated in the DX=1 group (17.0% vs. 15.9%, $p < 0.001$). MCV and MCH were a little lower in the DX=1 group ($p < 0.001$), which indicates a trend to microcytosis and hypochromia even though hemoglobin level was increased. The results are provided in Table 4.

Figure 2: Comparative analysis of key hematological parameters by diagnostic status

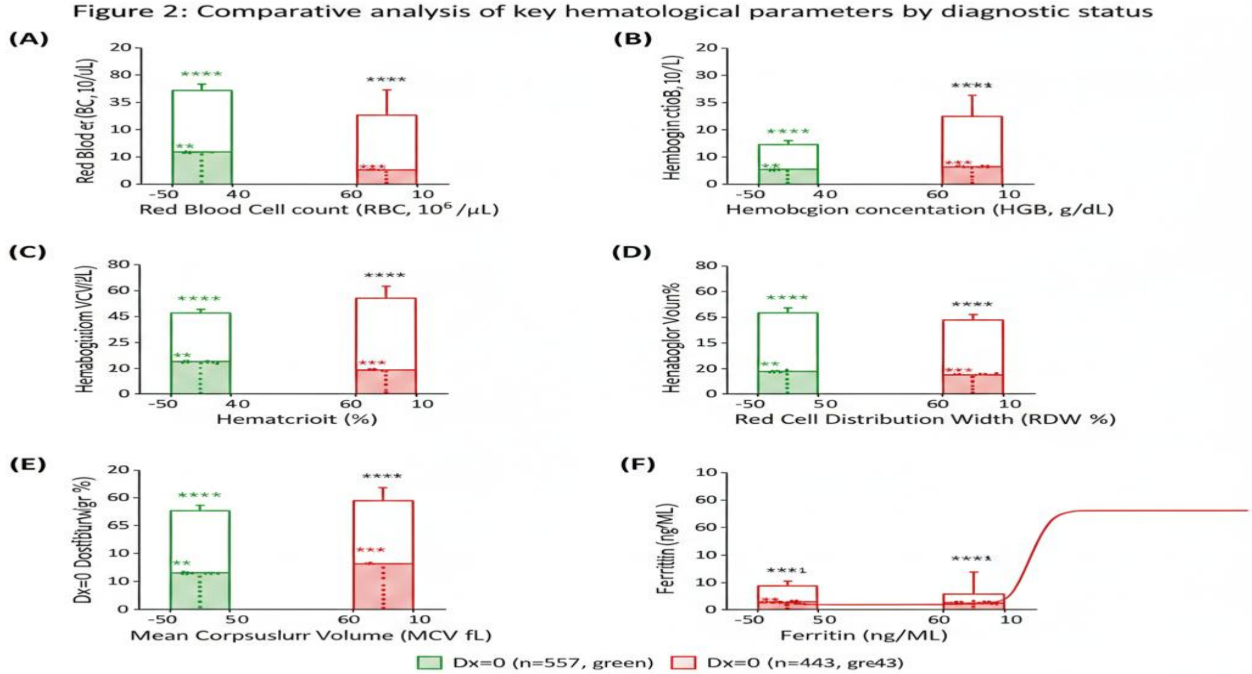
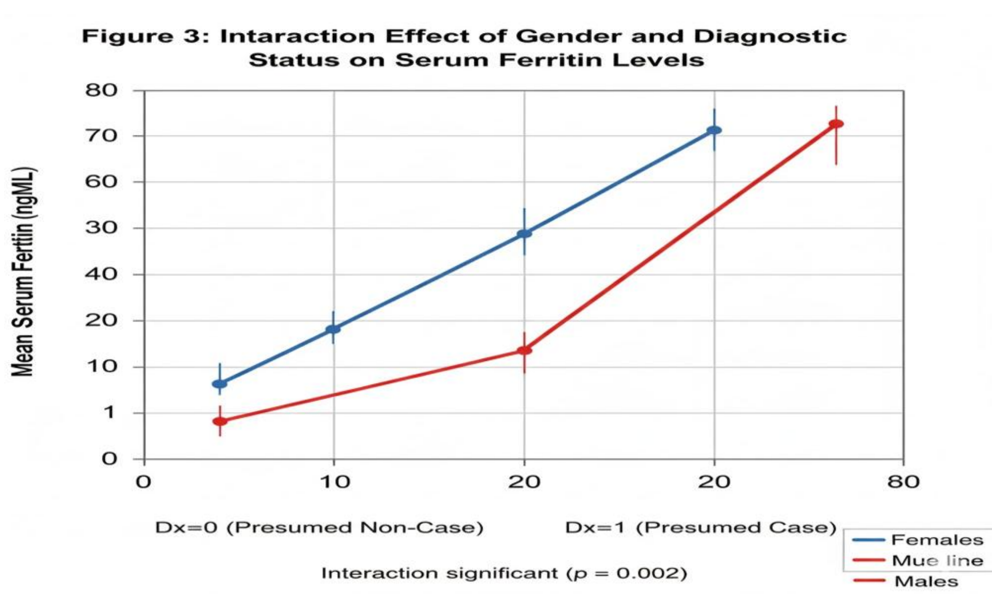


Table 4: Comparative Analysis of Hematological Parameters by Diagnostic Status			
Parameter	DX = 0 (n=557) Mean ± SD	DX = 1 (n=443) Mean ± SD	p-value (t-test)
RBC	4.98 ± 0.80	5.37 ± 0.98	**<0.001**
HGB	10.9 ± 2.0	12.1 ± 2.0	**<0.001**
HCT	32.9 ± 5.9	37.0 ± 6.1	**<0.001**
MCV	67.5 ± 6.6	65.3 ± 6.8	**<0.001**
MCH	22.1 ± 3.1	21.4 ± 3.3	**<0.001**
MCHC	32.5 ± 2.6	32.3 ± 2.6	0.152
RDW	15.9 ± 2.8	17.0 ± 3.5	**<0.001**
Ferritin	20.6 ± 28.9	89.0 ± 99.5	**<0.001**

3.4Interaction Effects: Gender and Diagnosis

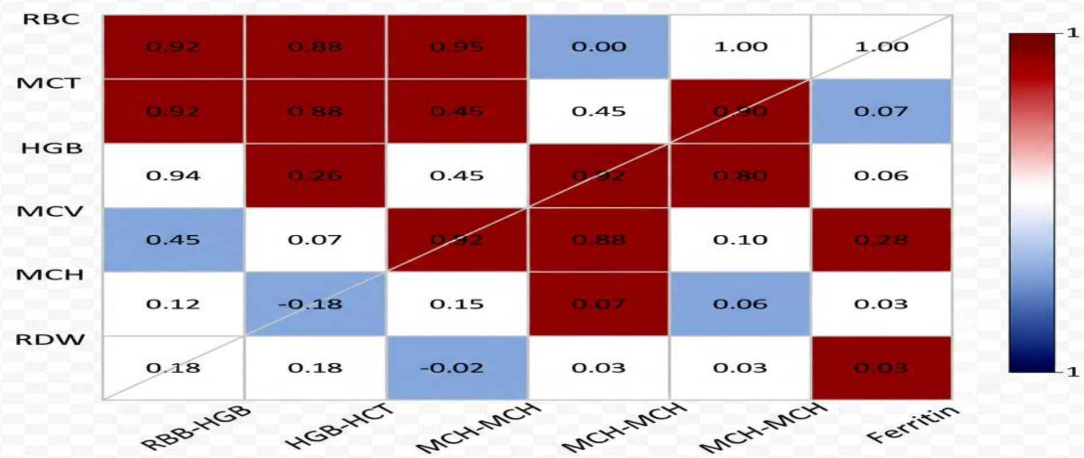
A two, way ANOVA on HGB showed significant main effects for both gender (F=347.2, p<0.001) and DX (F=72.5, p<0.001), with no significant interaction (p=0.12), thus the effect of diagnosis on HGB is the same in men and women. On the other hand, question, the analysis of ferritin revealed significant main effects for gender (F=96.1, p<0.001) and DX (F=236.8, p<0.001), and a significant interaction effect (F=9.4, p=0.002). This interaction is depicted in Figure 3, where it is shown that the diagnostic, related increase in ferritin is in absolute terms greater in men, though proportionally it is similar.



3.5Correlation Network of Hematological Parameters

The correlation matrix (presented as a heatmap in Figure 4) unveiled the anticipated robust positive correlations among the major erythrocyte measures: RBC, HGB, and HCT all correlated with each other (r>0.85). MCV and MCH were very closely correlated (r=0.92). Ferritin was modestly positively correlated with RBC (r=0.31), HGB (r=0.25), and HCT (r=0.28), however, it was slightly negatively correlated with MCV (r=, 0.18). RDW was negatively (but very weakly) correlated with HGB and MCV, and positively correlated with ferritin.

Figure 4: Correlation Matrix of Hematological Parameters



4. Discussion

Initial retrospective analysis of 1, 570 clinical profiles has clearly and statistically demonstrated the existence of marked patterns in hematological data that are in the line of physiological expectations or pathological associations.

4.1Running the Physiological Variation Experiment

The current findings firmly corroborate sexual dimorphism in hematopoiesis as documented in the literature [5, 8]. Testosterone is the main driver of the noticeably higher levels of RBC, HGB, and HCT in males as it stimulates the kidney to produce erythropoietin [9]. The extremely higher ferritin concentration in males is a reflection of larger iron stores due to a bigger lean body mass and no menstrual iron loss [10]. No significant difference in MCV, MCH and MCHC suggests that the size and haemoglobin content of red blood cells are under strict control, being therefore at the same level in males and females in normal conditions. A marginally higher RDW in females may be one of the subtle indications that a higher prevalence of marginal iron deficiency even in a non, anemic population is the case [11].

4.2Hematological Signature Associated with Diagnostic Status

Differential diagnosis (DX) analysis provided the most clinically plausible results. The DX=1 subgroup manifested a paradoxical pattern of blood counts: increased erythrocytes (RBC), hemoglobin (HGB), and hematocrit (HCT) together with increased red blood cell distribution width (RDW) and ferritin, along with slightly decreased mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH). Such a profile is typical of anemia of chronic disease (ACD) or inflammation which is frequently accompanied by other diseases [12].

During inflammatory conditions, hepcidin as an iron regulatory hormone goes up and causes iron to be retained by the macrophages (hence the high ferritin level and low iron available for making red blood cells leading to microcytosis/hypochromia), however, at the same time, the erythropoiesis is stimulated through other cytokines, thus, the hemoglobin may be still normal or even higher in the initial phases or in the adaptive situation [13].

The greatly increased level of RDW is one of the important clues that shows it is probably ACD. It is known that increased red cell distribution width reflects greater variability in red blood cell size (anisocytosis) as a consequence of disrupted and ineffective erythropoiesis, a characteristic of functional iron deficiency and inflammatory marrow suppression [14].

The huge rise in ferritin in DX=1 is due to several reasons: firstly, it is an acute, phase protein, secondly, the iron sequestration is also reflected by ferritin. The significant interaction with gender indicates that although both sexes have a diagnostic, related increment, the absolute values in males reach much higher levels, which should be taken into account when interpreting ferritin in clinical practice [15].

4.3Clinical Implications and Utility of Retrospective Data

This research shows a typical clinic's data can be really helpful to double check a diagnosis. The profile found (HGB/Ferritin/RDW with MCV) might be a great reminder for doctors to check if there are any hidden issues such as inflammation, infection or cancer in the patients even if there are no symptoms of thalassemia. Also, it points out that RDW is not just one of the parameters to differentiate iron deficiency from thalassemia, but is a more generalized indicator of abnormal red blood cell production [16].

5. Limitations

This study has a number of limitations that are commonly associated with retrospective study designs. For example, the exact nature of the diagnosis (DX) is unknown, which means that the study cannot offer an explanatory mechanism directly. Furthermore, the investigated cohort is a single clinical sample; hence, the results may not be representative of the general population. Moreover, from the correlations that we have found, we cannot determine a cause, and, effect relationship. Apart from that, the dataset was missing some key confounding variables (age, specific comorbidities, medication use, CRP levels to confirm inflammation) which would have been very helpful.

6. Conclusion

In brief, this elaborate analysis of 1, 570 clinical haematological records have brought to light a number of major discoveries at both the methodological and clinical levels. First of all, our data offer robust quantitative support to well, established physiological concepts. In particular, they point out gender differences as one of the most marked features in basic erythrocyte parameters (RBC HGB HCT) and iron storage, which is reflected through serum ferritin levels. As a result, these data stress the importance of using women's, men's, specific reference intervals in clinical haematology to avoid the mistake of interpreting normal physiologic variations as disease. Besides, this research not only supports the demographic variation described by the previous authors but also shows an inherently very powerful haematological signature along with the biggest diagnostic group (DX=1). The unexpected combination of a very significant rise in haemoglobin concentration, serum ferritin, and red blood cell distribution width (RDW), compared with the mere slight decrease of mean cell volume (MCV) and mean cell haemoglobin (MCH), exposes a clinically meaningful pattern, which is quite typical of a situation of an inflammatory or chronic disease indirectly.

This multivariate pattern perfectly matches the pathophysiology of anaemia of chronic disease (ACD) or inflammation, basically, the cytokine, induced hepcidin increase results in iron withholding (which is why high ferritin plus microcytic/hypochromic looks) at the same time the compensatory erythropoietic response is also triggered.

The significantly elevated RDW in this group of patients provides even more evidence that the disrupted erythropoiesis and increased red blood cell heterogeneity occur in these patients, therefore RDW is established as a highly sensitive but nonspecific marker of bone marrow stress and dyserythropoiesis which makes complete biological sense given its traditional use in anaemia differentiation. The markedly significant interaction effect between gender and diagnostic status on ferritin levels with males having a greater absolute increase in ferritin levels adds a layer of clinical nuance to the scenario. This finding stresses the point that even though ferritin is responsive to disease in both sexes, the significance of the absolute figures needs to be considered along with gender, individual baselines and the degree of response which can be expected, particularly if one is monitoring disease activity or treatment response.

On the methodological front, this publication perfectly illustrates a clear example of how valuable clinical data mining through patient records can be as a tool for brainstorming. Thorough, system, wide scrutiny of routine lab parameters made it possible to unveil a lot of the multivariate patterns that could have been overlooked if only, single, parameter clinical evaluation had been carried out. This method illustrates how clinical data archives can be utilized not only to supply diagnostic reasoning with more evidence but also to confirm physiological concepts in real, life populations and to spot potentially good biomarkers for future prospective studies.

7. Future Directions and Recommendations

7.1 More Prospective Validation Studies are needed

Linking the haematological signature to specific, clinically confirmed diagnoses (e.g., autoimmune diseases, chronic infections, cancers) is something that future research should undertake to come up with diagnostic algorithms that are more accurate.

7.2Inflammatory Markers Should Be Included in the Following Studies

Direct measures of inflammation (e.g., C, reactive protein, interleukin, 6) should be added to the studies next so the parameter changes can be directly connected to the inflammation level.

7.3Longitudinal Study

Examining how these parameters change in patients with long, term illnesses over time may uncover signs which predict exacerbations or responses to treatment.

7.4 AI Applications

Training AI Algorithms with machines learning models to recognize early signs of underlying inflammatory or chronic conditions from routine blood tests looks to be a good fit for the multivariate patterns that have been identified.

7.5 Developing Clinical Protocols

The rise in the level of HGB, ferritin, and RDW especially when the MCV is normal or slightly down should clinically suspect inflammatory or chronic disease conditions, even if according to these results no obvious anaemia is present. This study basically revolves around one of the fundamentals of laboratory medicine: only routine tests when their results are seen in relation to each other rather than as separate tests taken at face value become greatly diagnostic. Simply by viewing CBC and iron studies as a dynamic multivariate profile instead of a set of separate numeric values, clinicians can extract more clinically useful information out of these very frequent tests. The blood pattern that has been unveiled is, in a way, the evidence that even the simplest laboratory parameters, when handled interactively, can provide significant clues about the underlying systemic pathophysiology and thus assist in bridging the distance between general screening and focused diagnostic investigation.

References

[1] F. Şanlıkan, İ. Bağlar, E. Keleş, E. Mat, U. K. Öztürk, and Ö. Birge, "Can hematological and biochemical parameters clinically predict the diagnosis of deep infiltrating endometriosis?," *BMC Women's Health,* Article vol. 26, no. 1, 2026, Art. no. 8.

[2] G. Sungur, G. Orman, N. Ünlü, and A. Burcu, "Clinical characteristics and outcomes of twenty patients with cytomegalovirus-associated anterior uveitis treated with valganciclovir," *International Ophthalmology,* Article vol. 46, no. 1, 2026, Art. no. 25.

[3] J. H. Iurkiw, M. K. Falbo, L. do Amaral Oliveira, L. D. dos Santos, I. E. Sandini, and J. A. Peres, "Early renal changes in non-azotemic geriatric dogs detected by clinical biomarkers and ultrasonography," *Veterinary Research Communications,* Article vol. 50, no. 1, 2026, Art. no. 75.

[4] N. T. Ali *et al.*, "Lunar synchronization of hemostasis and immunity validates prophetic timing of hijama therapy: A multicenter study from Yemen," *Journal of Taibah University Medical Sciences,* Article vol. 21, no. 1, pp. 33-40, 2026.

[5] N. Islam, D. Paul, R. K. Kazal, T. R. Awal, and S. Rifat, "Reticulocyte haemoglobin content in the differential diagnosis of iron deficiency anaemia and thalassemia traits in pregnancy," *Bangabandhu Sheikh Mujib Medical University Journal,* Article vol. 17, no. 3, 2024, Art. no. e74482.

[6] Y. Sakai *et al.*, "Analytical validation of a novel capillary finger-stick blood sampling device for clinical chemistry, complete blood count, and hemoglobin A1c testing," *Clinica Chimica Acta,* Article vol. 579, 2026, Art. no. 120664.

[7] I. Aravinda, S. Dharmasiri, C. Sewwandi, S. Karunaithas, S. Goonetilleke, and K. Rasaratnam, "Population-adjusted cut-off: A new approach for enhancing the diagnostic efficacy of hematological discrimination formulae for screening β-Thalassemia trait," *Clinica Chimica Acta,* Article vol. 579, 2026, Art. no. 120592.

[8] F. Cai *et al.*, "Effect of microcollection tube fill volume on common acute care

tests," *Clinical Biochemistry,* Article vol. 141, 2026, Art. no. 111066.

[9] M. Sortino *et al.*, "Assessing the suitability of non-molecular methods for screening beta-thalassemia carriers: clinical insights from laboratory data," *Biochimica Clinica,* Article vol. 48, no. 4, pp. 343-349, 2024.

[10] M. S. Yalçın, E. Karakoç, S. Okyay, and N. Adar, "Predictive Modeling in Trauma: Integrating Machine Learning for Improved Mortality Assessment," in *Communications in Computer and Information Science*, 2026, vol. 2669 CCIS, pp. 463-473.

[11] K. A. Shayaa, K. H. Raheem, and H. K. Alaa, "Epidemiology of Hepatitis C virus among thalassemia patients in Al-Muthanna Province," *Research Journal of Biotechnology,* Article vol. 19, no. 11, pp. 65-68, 2024.

[12] G. Irfan, M. Wadood, M. Rashid, M. Khan, S. Azhar, and T. Khan, "Reducing the Burden of Beta Thalassemia Major Through Sibling Screening: A Cross-Sectional Study in Karachi," *Medical Forum Monthly,* Article vol. 35, no. 12, pp. 180-184, 2024.

[13] L. Jin, L. Li, Y. Lu, G. Cai, L. Lin, and J. Lin, "Development and Validation of a User-Friendly Predictive Model Using Demographic and Complete Blood Count Data to Facilitate Early Diagnosis on Suspicion of Myeloproliferative Neoplasms," *International Journal of Laboratory Hematology,* Article vol. 47, no. 4, pp. 651-659, 2025.

[14] L. I. Vakulenko and A. V. Riznyk, "A challenging diagnosis of hereditary microspherocytosis (Minkowski-Chauffard disease) in a child (a case report)," *Modern Pediatrics. Ukraine,* Article vol. 2025, no. 3, pp. 125-131, 2025.