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Clinical, biochemical, and hematological profile of Iron deficiency anemia in The Garmian population, Kurdistan region of Iraq

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ABSTRACT

Iron deficiency anemia (IDA) is a common micronutrient deficiency affecting reproductive-aged individuals, and it is a significant cause of anemia globally. In the Kurdistan Region, research on IDA is limited, highlighting the need for further investigation due to its significant health implications. The aim is to study the prevalence of anemia and IDA using red blood cell parameters and serum iron studies.

Methodology: the study was conducted in the Garmian Administration, Kurdistan Region of Iraq, from January to May 2023, and examined 170 cases (30 males, 140 females) with low MCV and MCH levels. Researchers collected sociodemographic and medical history data and assessed anemia and IDA prevalence using RBC parameters and serum iron studies.

Results:

The study revealed higher rates of anemia among females compared to males, being more severe in females who exhibited lower levels of serum Hb, HCT, RBC, and MCV. Additionally, 43.6% of females had IDA, while no males had IDA. in females, IDA was associated with lower Hb, HCT, RBC, MCHC, higher RDWI, and Mentzer Index. Shortness of breath and easy fatigability were significantly linked to IDA.

Conclusion, Anemia and IDA are significant issues in the study area, especially among women with low MCV and MCH. The study found low levels of certain RBC parameters and high values of RDWI and Mentzer Index as predictors of IDA in women with symptoms including shortness of breath and easy fatigability. Broader surveys are recommended to explore the possible causes of IDA in the study area and design preventive measures.

Keywords: Anemia, IDA, Iron study, CBC, Garmian, Kalar.

1. Introduction

Anemia is a medical condition characterized by low levels of erythrocytes or hemoglobin in the bloodstream compared with the standard range of these parameters. This condition is categorized based on the size of red blood cells and hemoglobin concentration[1]. According to the World Health Organization (WHO), anemia is characterized by a hemoglobin level > 12.0 g/dL in non-pregnant women, >13.0 g/dL in adult men, and 11g/dL during pregnancy[2].

Iron deficiency anemia is a common type of anemia caused by insufficient iron levels in the body. It is a widespread condition that affects many individuals globally, with children comprising about half of the affected population[3, 4]. Additionally, millions of adults also experience iron deficiency, making it the leading cause of anemia and the most prevalent nutritional insufficiency worldwide[5]. Statistics indicate that approximately 1.24 billion people across the globe suffer from iron deficiency anemia, with notable variations observed among countries with varying income levels[6]. Iron deficiency remains the prevailing nutritional deficiency worldwide[7].

Iron plays a vital role in various biological processes, such as respiration, energy generation, DNA synthesis, and cell growth. The human body has developed mechanisms to preserve iron, such as recycling it from broken-down erythrocytes and holding onto it without a specific excretion mechanism. Nevertheless, because excessive iron levels can be harmful, the iron absorption is restricted to a range of 1–2 mg/day[8].

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The development of IDA is complex and multifactorial; however, it typically occurs when the body's iron requirements are not met through absorption, irrespective of the underlying cause. IDA patients may experience insufficient iron intake, impaired absorption or transportation of iron, physiological losses related to age or reproductive factors, or chronic blood loss due to underlying medical conditions[9].

Signs and symptoms of iron deficiency anemia can vary in severity but often include fatigue, weakness, pale skin, shortness of breath, and dizziness[10]. Individuals may experience decreased exercise tolerance and impaired cognitive function. It is crucial to note that symptoms can be nonspecific and overlap with other health conditions, emphasizing the importance of proper diagnosis through laboratory tests[11].

While history and physical examination can aid in recognizing iron deficiency anemia (IDA) and determining its underlying causes, the primary means of diagnosing IDA is through laboratory tests. Four specific tests are commonly employed: serum iron (SI), serum transferrin saturation (TSat) or total iron binding capacity (TIBC), serum ferritin (SF), and hemoglobin level (Hb). Among these tests, serum ferritin levels are considered the most sensitive and are recommended initial diagnostic test. The total iron binding capacity (TIBC) is often measured simultaneously with serum iron and provides information on the potential capacity of transferrin molecules to bind with serum iron[12, 13].

In cases of significant iron deficiency, the blood profile typically shows small red blood cells (microcytosis) and low hemoglobin levels (hypochromia). The mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) are usually lower than average in these cases. Although MCV and MCH values are not diagnostic on their own, they can be helpful indicators for monitoring changes in iron deficiency over time[14].

Changes in the size and shape of red blood cells, such as microcytosis (smaller cells) and anisocytosis (variable-sized cells), can be early signs of anemia. These changes can be observed by measuring the red cell distribution width (RDW)[9]. Thalassemia is a medical condition that leads to anemia characterized by microcytic hypochromic blood cells. The most effective indicators to distinguish between iron deficiency and thalassemia are the mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), red blood cell count (RBC), and red cell distribution width (RDW). In thalassemia, despite the presence of anemia, the RBC count remains elevated, while it remains in low-level iron deficiency. This specific feature aids in distinguishing thalassemia from iron-deficiency anemia using the Mentzer Index, which considers MCV and RBC levels[15]. Studying anemia and iron deficiency anemia is essential because of its global health impacts, reproductive outcomes, and guiding public health interventions. Furthermore, it is also crucial for their diagnosis and treatment, which could be associated with nutritional status, socioeconomic factors, and regional variations. By addressing this issue, researchers and healthcare practitioners can work toward improving the health and well-being of populations affected by anemia and IDA.

Most of the research conducted on anemia and iron deficiency anemia in the Garmian Administration (GA) has primarily concentrated on pregnant women and children, neglecting non-pregnant women of reproductive ages, and has used only a single iron parameter, such as ferritin, for diagnosing IDA. for diagnosing IDA[16-18]. However, there is limited data available on men and non-pregnant women of reproductive age in these studies.

The current study aims to present a glimpse of the prevalence of iron deficiency anemia in adult male and female cases with low MCV and low MCH using red blood cell parameters and serum iron studies in GA, Iraqi Kurdistan region.

2. Materials and Methods

2.1. Study area

The current study was conducted in Kalar district, the center of Garmian province in Iraqi Kurdistan. It is located approximately 140 km southeast of Sulaymaniyah and 30 km from the Iranian border, which is its geographical area. The district has a population of approximately 250,000.

2.2. Study design

In this study, a cross-sectional study was used for the investigation of the clinical, biochemical, and hematological profile of iron deficiency anemia among cases with low MCV and low MCH attending public and private hospitals in Kalar district, the center of GA.

2.3. Study population

The study population included 170 cases (30 males and 140 females), who had low MCV and low MCH levels. The age of the participants ranged from 17 to 50 years. Each case's personal history was documented using a explicitly designed questionnaire in a consent form to collect sociodemographic data such as age, height, weight, marital status, employment, family income, literacy, medical history, and family history of iron deficiency, which was filled out during a face-to-face interview conducted by the researcher.

2.4. Inclusion and Exclusion Criteria

The study included cases with microcytic hypochromic anemia characterized by low MCV (<80fL) and low MCH (<27 pg) with an age range of 17–50 years. Cases with a history of conditions such as Helicobacter pylori infection, inflammation, bleeding (including occult blood), or other chronic diseases were specifically excluded from the study. By excluding individuals with these conditions, researchers can isolate the effects of pure iron deficiency anemia and better understand its specific causes, manifestations, and outcomes.

2.5. Sample collection

Blood samples were collected from the cases attending the public and private hospitals in Kalar district, Iraqi Kurdistan Region, from 1st January to 15th May, 2023. This period was convenient for patients to attend hospitals.

In this study, approximately 6 ml of venous blood was drawn from each case by using disposable syringes and needles. Four milliliters of the collected blood were placed in gel and clot activator-containing collection tubes, without any anticoagulant, to allow clot formation. Subsequently, the tubes were centrifuged at 3500 rpm for 10 min to separate sera. The sera were then transferred to disposable Eppendorf tubes (1.5 ml) as 0.5 ml aliquots to minimize the need for repeat thawing and freezing. These aliquots were stored in a deep freezer for the iron study using a COBAS C311 analyzer, which is for its accuracy compared with the classical method.

The COBAS C311 analyzer is a fully automated, software-controlled system manufactured in Japan. The color intensity can be measured photometrically. It is directly proportional to the iron concentration. The remaining 2 ml of venous blood was mixed with EDTA to prevent coagulation and used for complete blood count (CBC) analysis using an automated method.

2.6. Differential Value and Statistical Analysis

Each returned questionnaire was assigned an identity number (ID). Before data entry and analysis, the study questions were codified. The data were entered into a Microsoft Excel spreadsheet for statistical analysis. In this study and according to WHO Criteria, female case (Ferritin<15mg/L, TSat<15 & Hb<12g/dL) and male (Ferritin<20mg/L, TSat<20 & Hb<13g/dL) were considered to be iron-deficient. Furthermore, for men, hemoglobin levels of 11–12.9 g/dl and 8–10.9 g/dl and <8g/dl were classified as mild, moderate, and severe anemia, respectively. On the other hand, for non-pregnant women, the corresponding hemoglobin levels are 11–11.9 g/dl, 8-10.9g/dl, and <8g/dl for mild, moderate, severe anemia, and a specific threshold, respectively[2].

The data of the current study were expressed as mean, standard error of mean (Mean ± S.E.M), and both Microsoft Excel Spreadsheet 2010 and SPSS (statistical package for social science) (Version 21.0) statistical software were used to analyze the data. Differences in mean values between groups were analyzed using a two-sample t-test (independent Student's t-test). The chi-square test was used to analyze categorical data and determine if there was a significant association between two variables. Statistically, the P value ($P < 0.05$) was considered significant.

2.7. Ethical approval

The ethical committee at the Research Center, University of Garmian, granted the necessary ethical approval (No.: GRCEC114) for the study. In addition, all study participants provided informed consent voluntarily, having been fully informed about the study's objectives.

3. Results

3.1. Incidence of Cases

The results of the current study indicated that cases of low MCV and MCH are distributed according to age, sex, BMI, economic, educational, marital status, and symptomatic complication.

3.1.1. Sociodemographic data concerning severity of anemia

In the current study, among the sociodemographic data, only age and sex showed a significant relationship with the severity of anemia with *p*-values of 0.027 and 0.000, respectively, as shown in **Error! Reference source not found.**.

Table 1: Sociodemographic data concerning severity of anemia.

Sociodemographic characteristics	Anemia level					*P*-Value
	Non-anemic	Mild anemia	Moderate anemia	Severe anemia	total	
Age groups						
17-26	6(13.6%)	21(47.7%)	14(31.8%)	3(6.8)	44(25.8%)	0.027
27-36	14(31.1%)	9(20%)	21(46.6%)	1(2.22%)	45(26.4%)	
37-46	6(10.1%)	17(28.8%)	32(54.2%)	4(6.7%)	59(34.7%)	
47-50	4(18.1%)	4(18.1%)	13(59.0%)	1(4.5%)	22(12.9%)	
Total	30(17.6%)	51(30%)	80(47.05%)	9(5.2%)	170(100%)	
Sex						
Female	18(12.8%)	36(25.7%)	77(55%)	9(6.4%)	140(82.3%)	0.000
Male	12(40%)	15(50%)	3(10%)	0(0.0%)	30(17.6%)	
Total	30(17.6%)	51(30%)	80(47.05%)	9(5.2%)	170(100%)	
BMI						
Underweight	1(14.2%)	1(14.2%)	4(57.1%)	1(14.2%)	7(4.1%)	0.525
Normal weight	10(21.7%)	16(34.7%)	18(39.1%)	2(4.3%)	46(27.0%)	
Overweight	12(18.4%)	23(35.3%)	27(41.5%)	3(4.6%)	65(38.2%)	
Obese	7(13.4%)	11(21.1%)	31(59.6%)	3(5.7%)	52(30.5%)	
total	30(17.6%)	51(30%)	80(47.05%)	9(5.2%)	170(100%)	
Geography						
Rural	5(31.2%)	5(31.2%)	5(31.2%)	1(6.2%)	16(9.4%)	0.419
Urban	25(16.2%)	46(29.8%)	75(48.7%)	8(5.1%)	154(90.5%)	
total	30(17.6%)	51(30%)	80(47.05%)	9(5.2%)	170(100%)	

marital status						
Single	8(22.2%)	16(44.4%)	10(27.7%)	2(5.5)	36(21.1%)	0.062
Married	22(16.4%)	35(26.1%)	70(52.2%)	7(5.2%)	134(78.8%)	
total	30(17.6%)	51(30%)	80(47.05%)	9(5.2%)	170(100%)	
Economic Status						
low income	5(16.6%)	8(26.6%)	17(56.6%)	0(0.0%)	30(17.6%)	0.074
middle income	24(18.0%)	40(30.0%)	62(46.6%)	7(5.2%)	133(78.2%)	
high income	1(14.2&)	3(42.8%)	1(14.2%)	2(28.5%)	7(4.1%)	
total	30(17.6%)	51(30%)	80(47.05%)	9(5.2%)	170(100%)	
Educational status						
Illiterate	4(13.3%)	7(23.3%)	18(60%)	1(3.3%)	30(17.6%)	0.633
Up to secondary school	20(19.4%)	30(29.1%)	48(46.6%)	5(4.8%)	103(60.5%)	
University-educated and above	6(16.2%)	14(37.8%)	14(37.8%)	3(8.1%)	37(21.7%)	
total	30(17.6%)	51(30%)	80(47.05%)	9(5.2%)	170(100%)	

3.1.2. Signs and symptoms of iron deficiency anemia (IDA) among the cases

Error! Reference source not found. shows the relationship between the signs and symptoms of iron deficiency among iron deficiency anemia (IDA) and non-IDA cases. The results showed that easy fatigability (*p*-value=0.001) and shortness of breath (*p*-value=0.034) had a significant relationship with iron deficiency anemia.

Table 2: Signs and Symptoms of Iron deficiency anemia among of cases.

Iron Status	Signs & Symptoms		Total	*P*-Value
	Head Ache			
	No	**Yes**		
Non-IDA	29(26.4%)	81(73.6%)	110(100%)	0.966
IDA	16(26.7%)	44(73.3%)	60(100%)	
Total	45(26.4)	125(73.5)	170	
	Easy Fatigability			
	No	**Yes**		
Non-IDA	28(26.4%)	82(73.6%)	110(100%)	0.001
IDA	3(5.00%)	57(95.00)	60(100%)	
Total	31(18.2)	139(81.8)	170	
	Restlessness Leg Syndrome			
	No	**Yes**		
Non-IDA	30(27.30%)	80(72.7%)	110(100%)	0.575
IDA	14(23.3%)	46(76.7%)	60(100%)	
Total	31(18.2)	139(81.8)	170	
	Shortness of breath			
	No	**Yes**		
Non-IDA	37(33.6%)	73(66.4%)	110(100%)	0.034
IDA	11(18.3%)	49(81.7%)	60(100%)	
Total	48(28.2)	122(71.8)	170	
	Hair Loss			
	No	**Yes**		
Non-IDA	35(31.8%)	75(68.2%)	110(100%)	0.351
IDA	15(25%)	45(75%)	60(100%)	
Total	50(29.4)	120(70.6)	170	
	Poor Resistance to Cold Temperature			
	No	Yes		
Non-IDA	49(44.5%)	61(55.5%)	110(100%)	0.636
IDA	29(48.3%)	31(51.7%)	60(100%)	
Total	78(45.9)	92(54.1)	170	
	Pallor			
	No	**Yes**		
Non-IDA	40(36.4%)	70(63.6%)	110(100%)	0.539
IDA	19(31.7%)	41(68.3%)	60(100%)	

Total	59(34.7)	111(65.3)	170	
	Pica			
	No	**Yes**		
Non-IDA	82(74.5%)	28(25.5%)	110(100%)	0.189
IDA	39(65%)	21(35%)	60(100%)	
Total	121(71.1)	49(28.8)	170	

3.2. Hematological and Biochemical Analysis

3.2.1. Hemoglobin (Hb) and red blood parameters CBC

Based on hemoglobin level, the current study showed that only 18 (12.95%) out of the total 140 female cases had normal levels of hemoglobin (≥ 12g/dl), whereas 12 (40%) out of the total 30 male cases had normal levels of hemoglobin (>13g/dl). Concerning anemia among female cases, the study found that 36 (25.7%) were mildly anemic (Hb 11-12.9g/dl), 77 (55.0%) moderately anemic Hb (8-10.9g/dl), and 9 (6.4%) severely anemic (Hb <8g/dl), whereas for male cases, the study showed that 15 (50%) were mildly anemic (Hb 11-12.9g/dl), 3(10%) moderately anemic (8-10.9g/dl), and none of male cases was severely anemic (Hb <8g/dl). (**Error! Reference source not found.** and Error! Reference source not found.).

Table 3: Distribution of cases concerning level of anemia.

Level of Anemia	**Female (n=140)**		**Male(n=30)**	
	No.	%	No.	%
Normal (Hb> 13/dl)	18	12.9	12	40.0
Mild (Hb 11-12.9g/dl)	36	25.7	15	50.0
moderate (8-10.9g/dl)	77	55.0	3	10.0
severe(>8g/dl)	9	6.4	0	0.0
total	140	100	30	100

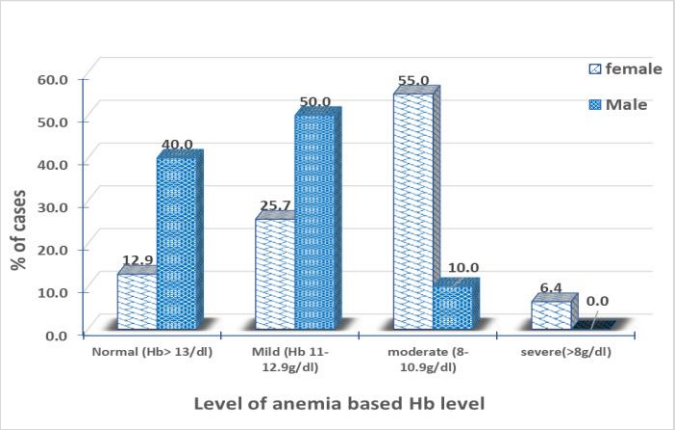

Figure 1: Distribution of cases concerning severity of anemia

3.2.2. Red blood Parameters CBC

Table *4* shows the results of the complete blood count (CBC) analysis, comparing CBC parameters in female and male cases.

Table 4: CBC parameters in cases concerning sex

CBC parameters	**Female**	**Male**
Hb	10.532 ± 0.116	12.673± 0.250
HCT	33.336 ± 0.405	40.183±0.791
RBC	4.986 ± 0.054	5.999 ± 0.143
MCV	67.531 ± 0.528	66.763 ± 1.028
MCH	21.243 ± 0.203	21.12± 5.0.321
MCHC	31.432 ± 0.163	31.637± 5.137
RDW%	15.218 ± 0.160	15.107± 0.218

Values expressed as Mean ± S.E.

3.2.3. Serum Iron Study Parameters

According to WHO Criteria, female case (Ferritin<15mg/L, TSat<15 & Hb<12g/dL) and male (Ferritin<20mg/L, TSat<20 & Hb<13g/dL) considered to be iron-deficient. In the current study, the sex-dependent distribution of iron deficiency anemia cases was 0.0(0.0%) for males out of 30 cases and 60 (43.6%) for females out of 140 females. (**Table *5*** and Error! Reference source not found.A).

Table 5: Distribution of iron deficiency anemia among the cases concerning sex.

Iron level	**Female**		**Male**	
	No.	(%)	No.	(%)
Non-iron-deficient cases	80	57.1	30.0	100.0
Iron-deficient anemic cases	60	42.9	0.0	0.0
total	140	100.0	30.0	100.0

The results of the complete blood count (CBC) analysis of iron-deficient anemic females demonstrated significant difference in serum Hb, HCT, RBC and MCHC level (9.761±0.157 g/dl, 31.195±0.657 mg/dl and 4.613±0.053 mg/dl, 30.844±0.244 mg/dl) compared with non-iron-deficient anemic females (11.123±0.153g/dl, 35.014±0.470g/dl, 5.307±0.077 mg/dl, 31.809±0.291g/dl) respectively, and non-significant difference of MCV MCH, and RDW% level were found between iron-deficient anemic females and non-iron-deficient anemic female (**Table *6*** and **Error! Reference source not found.**B).

Table 6: CBC parameters in iron-deficient and non-iron-deficient female cases

CBC items	**Iron Deficient Female**	**Non-Iron-Deficient Female**	**Statistical evaluation**
Hb	9.761±0.157	11.123±0.153	P. Value <0.05
HCT %	31.195±0.657	35.014±0.470	P. Value <0.05
RBC (M/µl)	4.613±0.053	5.307±0.077	P. Value <0.05
MCV	68.564±0.782	66.449±0.908	N.S.

MCH	21.193±0.330	21.119±0.320	N.S.
MCHC	30.844±0.244	31.809±0.291	P. Value <0.05
RDWI	15.650±0.206	14.614±0.228	P. Value <0.05
Mentzer Index	15.020±0.277	12.676±0.305	P. Value <0.05

Values expressed as Mean ± S.E.

The results of the current study showed that the Mentzer index [Mean corpuscular volume (in fL)/RBC count (in M/µl)) and RDWI of the current study showed a significant elevation (P< 0.05) in the iron-deficient anemic female cases (15.020±0.277 and 15.650±0.206) as compared with the Non-Iron-Deficient anemic Female (12.676±0.305 and 14.614±0.228) of the same age groups respectively (**Table *6*** and Error! Reference source not found.B).

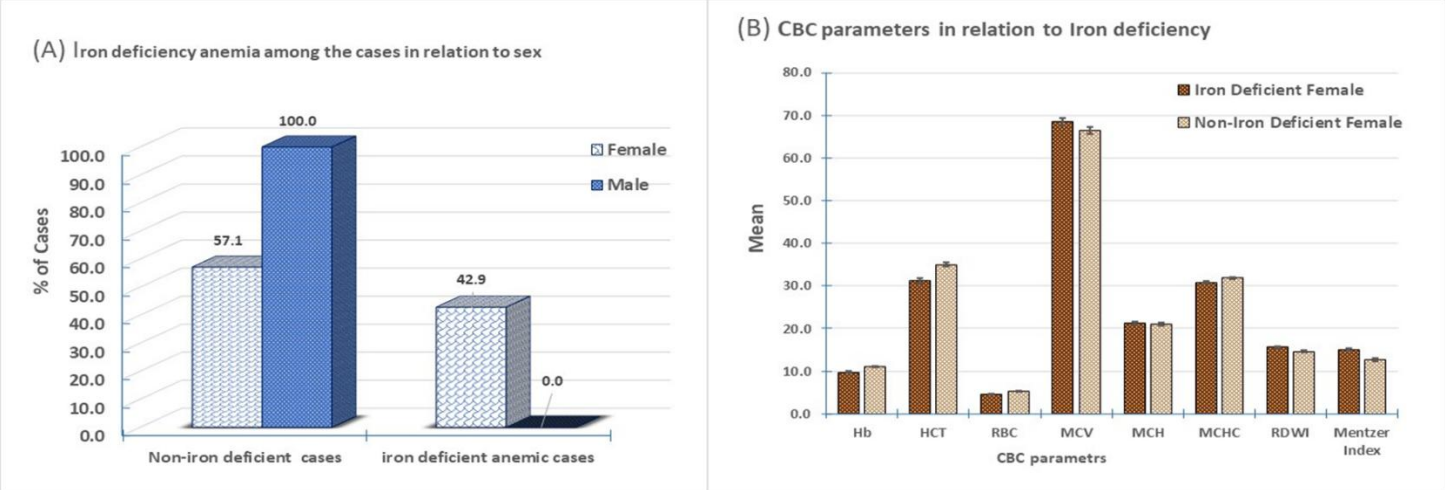

Figure 2: Distribution of iron deficiency anemia among the cases concerning sex.

On comparison of iron study parameters between iron-deficient anemic female cases (Serum iron level 9.761±2.308, ferritin level 6.006±0.44, Total iron binding capacity TIBC 464.236±8.137, transferrin saturation 6.148±0.469, unsaturated iron binding capacity UIBC 435.863±8.114) and non-iron-deficient anemic female cases in this study (Serum iron Level 93.184±6.583, ferritin Level 78.401±15.005, TIBC 359.714±11.852, Transferrin saturation 26.542±1.667, UIBC 266.530±12.188), the results showed very significant differences between the two groups (**Table *7*** and Figure 3).

Table 7: Iron study parameters in iron-deficient and non-iron-deficient female cases

Iron study Parameters	Iron-Deficient anemic Female Mean ± S.E.	Non-Iron-Deficient anemic Female Mean ± S.E.	Statistical evaluation	Normal Range
Serum iron Level (µg/dL)	9.761±2.308	93.184±6.583	***P. Value*** <0.05	45- 170 µg/dL
Ferritin Level (µg /L)	6.006±0.443	78.401±15.005	***P. Value*** <0.05	15-150 µg /L
TIBC (µg/dL)	464.236±8.137	359.714±11.852	***P. Value*** <0.05	240-425 µg/dL
TSat (%)	6.148±0.469	26.542±1.667	***P. Value*** <0.05	15%-50%.
UIBC (µg/dL)	435.863±8.114	266.530±12.188	***P. Value*** <0.05	135-395 µg/dL

S.E.: Standard Error, TIBC: Total iron binding capacity, TSat: Transferrin saturation, Unsaturated iron binding capacity.

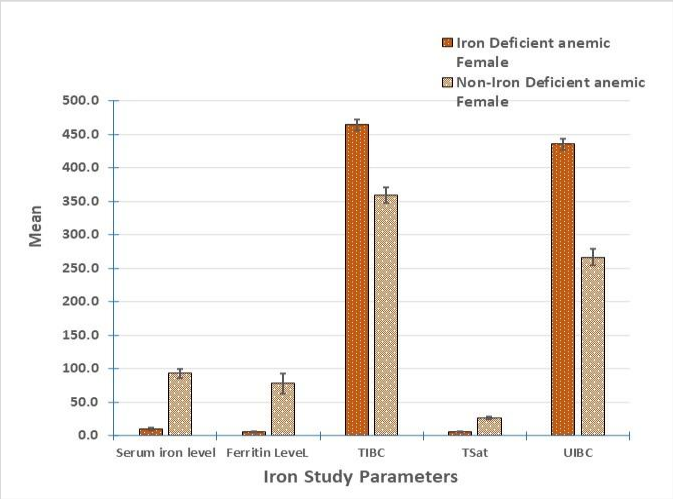

Figure 3: Iron study parameters iron-deficient and non-iron-deficient female cases.

4. Discussion

Anemia prevalence in male and non-pregnant females with low MCV and MCH levels has not been thoroughly studied in the Kalar district of Garmian province in Iraqi Kurdistan. However, there remains a dearth of information concerning its prevalence in this group and its potential links to sociodemographic and clinical factors. This issue is of significant concern in the region because of its substantial scale.

The study found that among the 140 female cases with low MCV and MCH levels, only 12.95% had an average hemoglobin level of 12 g/dL In comparison, among the 30 male cases with low MCV and MCH levels, 40% had an average hemoglobin level of 13 g/dL or higher. Therefore, depending on the hemoglobin level, these data reveal that approximately 87.14% of the females and 60% of the males in the study had anemia. The prevalence and severity of anemia are significantly higher in females than in males, consistent with previous research that has highlighted this gender-based differences, reporting 53% anemia prevalence among females and 23% among males aged 15 to 49, as well as 55.6% among females and 27.7% among males within a similar age group[19, 20].

In the study, among the female cases, the percentages of mild, moderate, and severe anemia were 25.7%, 55.0%, and 6.4%, respectively. In contrast, in the male cases, 50% were mildly anemic, 10% were moderately anemic, and none were severely anemic. These findings align with a previous study in which the majority (70.8%) of female participants were found to be anemic. Among them, 24.16% had mild anemia, 37.5% had moderate anemia, and 9.16% had severe anemia[21]. However, another study by Little *et al*. reported proportions of 18%, 35.9%, and 3.4% for mild, moderate, and severe anemia, which differed slightly from the current study's results[22]. This gender-based differences in anemia prevalence could be attributed to women not consuming significantly more iron than men, despite their higher iron requirements. In addition, a more Significant proportion of women than men did not meet the recommended dietary iron intake specific to their gender[23, 24].

The gender-based differences in hemoglobin levels, with women having approximately 12% less hemoglobin than men, are attributed to sex hormones such as estrogen and androgens. These hormones affect the kidneys and blood vessels, causing differences in hemoglobin levels. This is related to variations in erythropoietin, a hormone involved in red blood cell production[25, 26, 24].

The study confirmed the presence of anemia among the participants, particularly concerning gender. It found significant differences in serum hemoglobin (Hb), HCT, RBC, and MCV levels between females (10.532 ± 0.116 g/dl, 33.336 ± 0.405 mg/dl, 4.986 ± 0.054 mg/dl, 67.531 ± 0.528 mg/dl) and males (12.673 ± 0.250 g/dl, 40.183 ± 0.791 g/dl, 5.999 ± 0.143 mg/dl, 66.763 ± 1.028 g/dl) respectively. Female levels were lower in all parameters except MCV. Notably, most previous studies focused on pregnant women, teenagers, and children, with few involving adult men and women[27, 17]. A study addressed gender differences in CBC parameters, but the results were not comparable to the current study, possibly due to inconsistency in characteristics of sample[28]. This may also be attributed to low hemoglobin levels, as we mentioned before[23, 24], which also affects other RBC parameters. Low hemoglobin levels content of RBC also leads to low levels of MCV, MCH, HCT, and RBC count[9].

Globally, anemia is the most common nutritional disorder, affecting an estimated 1.6–2 billion people. IDA is the most common type of anemia, accounting for 30%–50% of all cases, indicating a significant burden of this particular form of anemia[29, 30].

According to the results of the current study, none of the anemic male cases (0.0%) out of 30 cases were found to be iron-deficient. In contrast, 60 (42.9%) of the 140 anemic female cases were classified as iron-deficient based on the criteria set by the WHO (**Error! Reference source not found.**). These criteria include low ferritin levels (<15mg/L for non-pregnant females and <20mg/L for males), low transferrin saturation (<15% for females and <20% for males), and low hemoglobin levels (<12g/dL for non-pregnant females and <13g/dL for males).

The findings of this study demonstrate a significantly higher prevalence of IDA in females than in males. These results affirm that IDA is indeed a concern that predominantly affects women in this particular region. These findings align with those of previous studies[31].

The study findings align with previous research regarding the prevalence of IDA and gender differences[32, 33]. Women of reproductive age can be affected by IDA because of various factors such as diet, infections, menstrual patterns, gastrointestinal problems, medications, and blood donations. Identifying the most critical factors within a population would aid in implementing effective interventions to address these root causes[34].

This study compared the iron study parameters between individuals with and without anemic iron deficiency. The findings revealed a significant, substantial difference in the severity of iron deficiency between the two groups, as indicated in Figure 3. Similar differences were also observed when examining the red blood cell parameters in the mentioned groups.

The Mentzer index was calculated using the following formula: MCV (in fL) divided by the RBC count (in millions per microliter). If the calculated Mentzer index is above 13, it indicates the likelihood of IDA, whereas a value below 13 suggests the possibility of thalassemia. In a recent study, the Mentzer index proved to be a reliable tool in differentiating between the two, showing a sensitivity of 90% and specificity of 85% for iron deficiency anemia (IDA), and a sensitivity of 85% and specificity of 90% for beta thalassemia trait, respectively[35].

The present study demonstrated a statistically significant high Mentzer index among female cases with IDA compared to females without IDA in the same age groups (Error! Reference source not found.B). In addition, the same results were found for the RDW index for both groups. These indices can predict IDA diagnosis when Hg, RBC, HCT, MCV, and MCH levels are. These findings are approximately consistent with those of a study conducted in the same area[35]. These results can be attributed to IDA.

The results of this study demonstrated a decrease in various red blood cell parameters, including the Mentzer index, RDW index, RBC, hemoglobin (Hb), and hematocrit (HCT). The probable explanation is that a deficiency of iron impairs hemoglobin synthesis, resulting in smaller RBCs and a decrease in RBC count. Consequently, this leads to higher values for the Mentzer and RDW indices, indicating anisocytosis and increased red cell volume variability. Additionally, limited iron availability diminishes hemoglobin levels, resulting in reduced oxygen-carrying capacity. The lower RBC count and decreased hematocrit reflect the impairment in RBC production and mass due to iron deficiency. Collectively, these changes demonstrate the significant impact of iron deficiency on RBC size, production, and oxygen transport capacity in IDA[36, 37].

Regarding the sociodemographic data (**Error! Reference source not found.**), the findings of the current study indicate that only age and sex exhibited a significant association with the severity of anemia. These findings align somewhat with those of previous studies, albeit with minor differences[32, 38]. However, the results were not entirely consistent with most of the studies reported in the existing literature regarding age and marital status(*p-value* 0.07 *p-value* 0.04), respectively[39, 40]. Possible explanations include distinct population characteristics, regional or temporal variations, differences in study methodology, or limited/conflicting evidence in the literature.

Concerning the signs and symptomatic complications of IDA within the study population (**Error! Reference source not found.**), the current study revealed that only shortness of breath and easy fatigability exhibited a significant association with iron deficiency. These results were not exactly compatible with previous studies findings[41, 42]. The study also noted that these results were not exactly compatible with previous studies, which found that other symptoms, such as pale skin, headache, and dizziness, are also associated with IDA. The potential interpretation of the variance in findings between this study and previous studies lies in the greater diversity of the study population and the heightened rigor of the study methods. Further investigation is required to pinpoint the precise factors contributing to the observed disparities.

Conclusions

In conclusion, our results confirm a high prevalence of anemia in the studied regions of Kalar district, Kurdistan region of Iraq, in both men and women with low MCV and MCH levels. IDA is a significant health problem in apparently non-pregnant women of reproductive age from the same region. The study found that low levels of specific blood cell parameters, including Hb, HCT, RBC count, and MCHC, along with high values of RDWI and Mentzer Index among the iron-deficient cases, can serve as predictors of IDA, especially among women with symptoms such as shortness of breath and easy fatigability.

Recommendation

Further studies are recommended to investigate the causes of IDA and the role of inflammation in the study area. In addition, there is an urgent need to develop effective strategies to address iron deficiency and IDA in this population.

Conflict of interest

All authors have no conflict of interest to declare.

Author Contribution and Funding Information

The first author primarily contributed to the experimental work and writing. The second and third authors contributed to supervision and revision. No funding was received for this research.

Data availability statement

The data used to support the findings of this study are available upon request, from the corresponding author: Diyar Akbar Hasan Al-Jaf; diyar.akbar.2022@st.tu.edu.iq

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