International Journal of Academic Health and Medical Research (IJAHMR)
ISSN: 2643-9824
Vol. 10 Issue 8 August - 2026, Pages: 43-54

Assessment of the Prevalence of Iron Deficiency Anemia among Primary School Pupils in the Surman and Al Mutrad Regions, North-Western Libya

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ABSTRACT: Background: *Iron deficiency anemia (IDA) remains a significant public health concern among school-aged children, particularly in developing regions, with potential consequences for growth, cognitive development, and academic performance.* ***Objective:*** *This study aimed to assess the prevalence of iron deficiency anemia among primary school pupils in the Surman and Al Mutrad regions, and to examine its association with demographic factors (gender, age, place of residence) and dietary habits (vegetable consumption, meat consumption, tea drinking).* ***Methods:*** *A cross-sectional study was conducted involving 206 primary school students. Socio-demographic data and dietary habits were collected using a structured questionnaire. Hematological parameters, including hemoglobin (Hb), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), serum ferritin, serum iron, total iron-binding capacity (TIBC), and unsaturated iron-binding capacity (UIBC), were measured. Data were analyzed using SPSS version 27. Independent t-tests, one-way ANOVA, and Chi-square tests were employed, with a significance level set at $p < 0.05$. Results: The overall prevalence of anemia was 19.4% (40 out of 206 students). Anemic students exhibited significantly lower levels of hemoglobin, MCV, MCH, MCHC, ferritin, and serum iron, alongside significantly higher TIBC and UIBC compared to non-anemic students ($p < 0.001$ for all), confirming an iron deficiency profile. No significant associations were found between anemia and gender ($p = 0.914$), age group ($p = 0.359$), or region (Surman vs. Al Mutrad, $p = 0.999$). However, theplace of living showed a significant association, with rural students demonstrating a higher prevalence of anemiathan urban students ($p = 0.009$). Regarding dietary factors, vegetable consumption was not significantly associated with anemia ($p = 0.397$), whereas meat consumption ($p = 0.006$) and tea drinking ($p = 0.025$) were significantly associated with higher anemia rates. Among anemic students, no significant differences were observed in hematological parameters based on gender, age, or urban/rural residence. However, significant differences emerged between the two regions in iron stores: anemic students from Surman had significantly lower serum ferritin ($p = 0.015$) and serum iron ($p = 0.038$) compared to those from Al Mutrad, indicating more severe iron depletion. Anemia severity (mild vs. moderate) was not significantly associated with any demographic or dietary factors.* ***Conclusion:*** *Iron deficiency anemia is moderately prevalent among primary school pupils in the Surman and Al Mutrad regions. The findings highlight that rural residence, infrequent meat consumption, and tea drinking are key risk factors associated with a higher prevalence of anemia. These results underscore the urgent need for targeted nutritional interventions, particularly in rural areas, and health education programs promoting dietary diversity and awareness of inhibitors of iron absorption, such as tea, to mitigate the burden of anemia in this population.*

Keywords: Iron deficiency anemia, Primary school pupils, Surman, Al Mutrad, Western Libya.

1. Introduction

Anemia is characterized by a blood hemoglobin (Hb) concentration, hematocrit (HCT), or red blood cell (RBC) count that falls below the normal range, becoming insufficient to support the body's physiological demands (Felner & Wisdom, 2019; Turner *et al.*, 2023).

IDA is the most prevalent type of anemia globally(DeLoughery, 2017, Warner & Kamran, 2023). Iron deficiency anemia (IDA) is a specific form of anemia where low hemoglobin levels result from inadequate iron reserves in the body, which in turn impairs the production of red blood cells (Cappellini *et al.*, 2020, Auerbach *et al.*, 2025), which can result from inadequate dietary intake, chronic blood loss (e.g., from the gastrointestinal tract or heavy menstrual periods), or an inability to absorb iron properly (DeLoughery, 2017, Warner & Kamran, 2023). The development of IDA follows a sequential pattern, beginning with the depletion of iron stores (indicated by low ferritin), progressing to a decline in transport iron (shown by low serum iron and low transferrin saturation), and finally leading to a reduction in hemoglobin production (DeLoughery, 2017; Cappellini *et al.*, 2020). A peripheral blood smear typically reveals microcytic (small-sized) and hypochromic (pale-staining) erythrocytes, reflecting the disruption in hemoglobin synthesis (DeLoughery, 2017, Warner & Kamran, 2023). As the most prevalent nutritional deficiency globally, IDA disproportionately impacts children, women of reproductive age, pregnant women, and the elderly (Cappellini *et al.*, 2020, Leung *et al.*, 2024). Diagnostic criteria can vary; in individuals without inflammation, a serum ferritin level below 30 ng/mL or a transferrin saturation under 20% are frequently used indicators (Auerbach *et al.*, 2025). However, in the presence of inflammation, ferritin levels can be falsely elevated, necessitating the use of adjusted thresholds or additional biomarkers for an accurate diagnosis (Cappellini *et al.*, 2020).

For children, the diagnostic thresholds are lower; for instance, the WHO defines anemia as a hemoglobin level below 11.0 g/dL in children between 6 and 59 months of age (Felner& Wisdom, 2019, Braat *et al.*, 2024). Clinically, anemia is considered a sign of an underlying pathological process rather than a standalone disease (Turner *et al.*, 2023). Common symptoms associated with this condition are fatigue, generalized weakness, and pale skin, while more severe cases can present with shortness of breath or cardiovascular complications (Turner *et al.*, 2023). A precise diagnosis typically involves measuring hemoglobin (or hematocrit/RBC count) and comparing the result to a threshold that is appropriate for the individual's specific demographic context (Cappellini & Motta, 2015, Braat *et al.*, 2024).

Common symptoms include fatigue, pale skin, and shortness of breath. Laboratory tests typically reveal microcytic (small) and hypochromic (pale) red blood cells, and the diagnosis is confirmed by low levels of hemoglobin and serum ferritin, a key indicator of iron stores (Cappellini *et al.*, 2020). The treatment approach has two pillars: identifying and addressing the underlying cause of the iron deficiency, and replenishing iron stores. Oral iron supplements are the first-line treatment, while intravenous iron is reserved for cases where oral therapy is ineffective, not tolerated, or when a rapid correction is needed (DeLoughery, 2017).

Data from the Global Burden of Disease Study 2019 highlights the considerable impact of this condition, showing a Years Lived with Disability (YLD) rate of 1,252.88 per 100,000 children in this age group. The study further breaks down the prevalence, indicating that moderate anemia was the most common form at 985.46 per 100,000, which was substantially higher than the rates for severe anemia (197.82 per 100,000) and mild anemia (69.59 per 100,000). The overall global prevalence was estimated at 39,517.75 cases per 100,000 population (Liu, 2024). The prevalence of iron deficiency anemia (IDA) shows notable variations between genders, particularly during childhood and adolescence. Research generally indicates that girls are more vulnerable to anemia than boys. A study conducted in Istanbul found an overall anemia prevalence of 9.4%, which broke down to 13.4% in girls compared to 5.2% in boys, though the prevalence of confirmed iron deficiency anemia itself was 3.4% without a significant gender difference (Hosceylan *et al.*, 2025). The higher tendency for anemia in girls is often attributed to increased iron demands during menstruation, which elevates their risk of iron deficiency (Levi *et al.*, 2019). Additionally, sociocultural factors and dietary practices in some communities may lead to preferential allocation of iron-rich foods to boys over girls, further influencing iron status (Shell-Duncan & McDade, 2005).

2. OBJECTIVES

This study aimed to assess the prevalence of iron deficiency anemia among primary school pupils in the Surman and Al Mutrad regions, and to examine its association with demographic factors (gender, age, place of residence) and dietary habits (vegetable consumption, meat consumption, tea drinking).

3. MATERIALS AND METHODS

3.1. Study Design:

This is a cross-sectional community based study conducted to assess the prevalence of iron deficiency anemia among primary school pupils aged 6 to 14 years in the Surman and Al-Mutrad regions the study included (206) students from different schools in the Surman and AL-Mutrad areas and this study was conducted from mount September to mount December.

3.2. Study Population:

Age Group: Primary school students aged 6 to 14 years both sexes were selected randomly from some number of schools distributed in the Surman and AL-Mutrad .

Sample Size: Two hundred and six (206) school children sample were included in this study. All population were distributed in different age groups and gender as shown in table.1.

Table 1: Total number of school children included in the study distributed in different age groups pre year and gender.

Age groups / Gender	Male	Female	Total
(6 – 9) y	14	31	45
(10 – 12) y	38	40	78
(13 – 15) y	33	50	83
Total	86	120	206

3.3. Inclusion Criteria:

International Journal of Academic Health and Medical Research (IJAHMR)
ISSN: 2643-9824
Vol. 10 Issue 8 August - 2026, Pages: 43-54

Healthy students with no chronic diseases that could affect blood test results. Students whose parents have provided consent for participation in the study.

3.4. Exclusion Criteria:

Students with known chronic diseases that may affect blood test results, such as renal failure or chronic gastrointestinal disorders. Students currently taking iron supplements or other medications that could affect iron levels in the body.

3.5. Ethical Considerations:

Ethical approval was obtained from the ethical committee of the Libyan Academy of science, as well as from the Ministry of Education the Surman and the Ministry of Education in Zawiya West. Each school was designated as a sample collection point, and the consent and responsibility of the parents of the participating students were obtained before their inclusion in this study.

3.6. Data Collection:

A questionnaire was distributed to the parents, including the name, age, gender, region, the child's dietary habits, medical history, and any nutritional supplements they may be taking.

Questions focused on the consumption of iron-rich foods (such as red meat and leafy vegetables) and symptoms of potential anemia (such as fatigue and dizziness)

3.7. laboratory Tests

Blood samples were collected from students in coordination with parents, the AL-Riyada Laboratory in AL-Mutrad and Surman Central Laboratory in the Surman area. All procedures were explained to parents and students to ensure comfort and full consent. After obtaining approval from the participants, five milliliters of blood were drawn from each student using a vein puncture approach and then collected in two tubes. Two milliliters of venous blood in a tube containing EDTA were used to measure the hematological indices. The rest of the blood was contained in a plain tube to get the serum for biochemical examination.

Serum was extracted by centrifuge (LSC4810-Germany) for 5 min at 3000 rpm to separate cell debris Iron TIBC and Ferritin assay. The following tests were conducted:

1. Complete Blood Count (CBC): This test was performed using the (SYSMEX analyzer) to measure the number of red blood cells, white blood cells, and
2. Iron Test: This test was performed using the (Roche COBAS Integra 400 Plus) analyzer to measure the level of iron in the blood.
3. TIBC (Total Iron Binding Capacity): This test was conducted using the (Roche COBAS Integra 400 Plus) analyzer to assess the blood's ability to bind and transport iron.
4. Ferritin Test: This test was performed using the (Roche COBAS e 411) analyzer to evaluate the level of stored iron in the body.

3.8. Statistical Methods

Data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 27). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were calculated to summarize the socio-demographic characteristics, dietary habits, and hematological and iron-profile parameters of the students. Independent-samples t-tests were used to compare hematological and iron-status variables between two groups (e.g., anemic vs. non-anemic students, urban vs. rural students, male vs. female students), while one-way ANOVA was applied for comparisons across more than two groups (e.g., age categories). The Chi-square test was employed to assess associations between categorical variables, such as gender, age, place of living, dietary habits, and the presence or severity of anemia. A significance level of $p < 0.05$ was considered statistically significant for all analyses.

Results:

As shown in Table 1, the sample consisted of 206 primary school students, with a higher proportion of females compared to males. Specifically, females represented 58.3% of the sample (n = 120), while males accounted for 41.7% (n = 86). This distribution indicates a modest gender imbalance, with female students being more prevalent in the study population.

Table (1): Sample distribution by gender

Gender	Count	Percent (%)
Male	86	41.7
Female	120	58.3

From Table 2, the age distribution of the students showed that the largest proportion fell within the 13–15 age group, representing 40.3% of the sample (n = 83). This was followed by students aged 10–12 years, who comprised 37.9% (n = 78), while the youngest group, aged 6–9 years, constituted 21.8% (n = 45). This distribution indicates that older primary school students were more represented in the sample.

Table (2): Sample distribution by age

Age group	Count	Percent (%)
6-9	45	21.8
10-12	78	37.9
13-15	83	40.3

Table (3) shows the distribution of the study sample by place of residence within the city. The majority of participants were from Surman, accounting for 133 individuals (64.6%), while 73 participants (35.4%) were from Mutrod, out of a total sample of 206. This distribution indicates a higher representation of respondents from Surman compared to Mutrod, suggesting that the findings may reflect the characteristics and conditions of Surman residents more strongly. Nevertheless, the inclusion of participants from both regions supports geographical diversity within the city and allows for comparative considerations between the two areas.

Table (3): Sample distribution by place of region

Region	Count	Percent (%)
Surman	133	64.6%
Mutrod	73	35.4%

As shown in Table 4, The distribution of students by place of living was nearly equal, with 51.0% residing in urban areas (n = 105) and 49.0% living in rural areas (n = 101). This balanced representation indicates that the sample included comparable proportions of urban and rural students, supporting generalizability across both living environments.

Table (4): Sample distribution by place of living

Place of Living	Count	Percent (%)
Urban	105	51.0
Rural	101	49.0

Table 5 shows that the majority of students reported eating vegetables only sometimes, accounting for 71.8% of the sample (n = 148). A smaller proportion indicated that they always consumed vegetables (16.5%, n = 34), while 11.7% (n = 24) reported rarely eating them. Overall, these findings suggest that consistent vegetable consumption was relatively low among the students.

Table (5): Sample distribution by vegetable eating

Eat Vegetable	Count	Percent (%)
Rarely	24	11.7
Sometimes	148	71.8
Always	34	16.5

The results in Table 6 indicated that most students consumed meat only sometimes, representing 71.4% of the sample (n = 147). Additionally, 17.5% (n = 36) reported always eating meat, whereas 11.2% (n = 23) stated that they rarely consumed it. These findings suggest that regular meat consumption was limited, with the majority exhibiting moderate intake patterns.

Table (6): Sample distribution by meat eating

Eat Meat	Count	Percent (%)
Rarely	23	11.2
Sometimes	147	71.4
Always	36	17.5

Table 7 shows that the vast majority of students reported that they did not drink tea, comprising 94.7% of the sample (n = 195). Only 5.3% (n = 11) indicated that they consumed tea. This distribution shows that tea drinking was uncommon among the students in the study

Table (7): Sample distribution by tea drinking

International Journal of Academic Health and Medical Research (IJAHMR)
ISSN: 2643-9824
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Drink Tea	Count	Percent (%)
Yes	11	5.3
No	195	94.7

Table 8 presents the descriptive statistics for hematological and iron-status indicators among the 206 primary school students. Hemoglobin levels ranged from 7.50 to 15.20 g/dL, with a mean of 12.27 (SD = 1.46), indicating overall variability in anemia-related status within the sample. Mean corpuscular volume (MCV) showed a wide range (27.4–401.0 fL), with an average of 81.00 (SD = 23.15), suggesting heterogeneity in red blood cell size. The mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) were 27.36 pg (SD = 2.37) and 34.05 g/dL (SD = 2.00), respectively, reflecting generally normal erythrocyte hemoglobin content for most students.
Regarding iron markers, ferritin levels varied considerably (3.00–119.70 ng/mL), with a mean of 35.04 (SD = 23.14), indicating the presence of students with depleted iron stores. Serum iron levels averaged 68.01 µg/dL (SD = 26.79), whereas total iron-binding capacity (TIBC) had a mean of 348.50 µg/dL (SD = 68.92). Unsaturated iron-binding capacity (UIBC) showed a mean of 280.99 µg/dL (SD = 73.90). Collectively, these values demonstrate substantial variation in iron status across the sample, consistent with the potential prevalence of iron deficiency and anemia among primary school student

Table (8): Summary of Hematological and Iron Profile Variables Among Primary School Students

Variable	Mean± SD	Min	Max
Hb	12.27±1.463	7.50	15.20
HCT	36.01±4.007	25.80	47.40
MCV	81.00±23.146	27.4	401.0
MCH	27.36±2.368	19.3	33.0
MCHC	34.05±1.999	26.6	38.0
Ferritin	35.04±23.140	3.00	119.70
Iron	68.01±26.787	13.52	152.00
TIBC	348.50±68.918	120.20	741.80
UIBC	280.99±73.900	142.80	505.20

Table 9 compares hematological and iron-related biomarkers between anemic and non-anemic students and shows significant differences across all measured parameters. As expected, students with anemia had markedly lower hemoglobin levels (M = 9.85, SD = 1.07) compared to non-anemic students (M = 12.85, SD = 0.79), a difference that was highly significant, $t = –16.71$, $p< 0.001$. Red blood cell indices also differed substantially between groups: anemic students demonstrated significantly lower HCT, MCV, MCH, and MCHC values, indicating reduced erythrocyte size and hemoglobin content (all $p< 0.05$). Iron-status markers further distinguished the groups; ferritin and serum iron levels were significantly lower among anemic students (all $p< 0.001$), whereas TIBC and UIBC were significantly higher, reflecting increased iron-binding capacity associated with iron deficiency. Overall, these findings confirm that anemic students exhibit consistently poorer hematological and iron profiles compared to their non-anemic peers, aligning with physiological patterns of iron deficiency anemia.

Table (9): Comparison of hematological parameters between anemic and non-anemic primary school students

Parameters	Anemic students (n=40)	Non-anemic students (n=166)	T value	P value
	Mean±SD	Mean±SD		
Hb	9.85±1.068	12.85±0.791	-16.711	< 0.001
HCT	30.42±2.163	37.35±3.076	-13.452	< 0.001
MCV	73.85±9.339	82.73±25.092	-2.198	0.029
MCH	24.14±2.792	28.14±1.414	-8.794	< 0.001
MCHC	32.04±2.204	34.54±1.613	-6.736	< 0.001
Ferritin	12.11±9.473	40.57±22.042	-12.516	< 0.001
Iron	37.74±19.150	75.30±23.005	-9.554	< 0.001
TIBC	407.15±66.309	334.37±61.864	6.311	< 0.001
UIBC	370.34±78.962	259.46±53.938	8.421	< 0.001

Table 10 examines the association between socio-demographic and dietary factors and the presence of anemia among primary school students. The results show no significant association between anemia and gender, $\chi^2 = 0.012$, $p = 0.914$, indicating that males and females were equally likely to be anemic. Similarly, age group was not significantly related to anemia status, $\chi^2 = 2.05$, $p = 0.359$, suggesting that anemia prevalence did not differ meaningfully across the three age categories. Region was not significantly associated with anemia, $\chi^2 = 0.001$, $p = 0.999$

In contrast, place of living demonstrated a significant association with anemia, $\chi^2 = 6.78$, $p = 0.009$, with rural students showing higher rates of anemia than their urban counterparts. Dietary factors showed mixed patterns. Vegetable consumption was not significantly associated with anemia, $\chi^2 = 1.85$, $p = 0.397$. However, meat consumption showed a significant relationship, $\chi^2 = 10.10$, p =0 .006, indicating that students who rarely consumed meat were more likely to be anemic. Tea drinking habits were also significantly associated with anemia, $\chi^2 = 5.04$, $p = 0.025$, with tea drinkers exhibiting higher anemia prevalence compared to those who did not drink tea. Overall, the findings suggest that living environment, meat consumption, and tea drinking behaviors are important factors associated with anemia in this population.

Table (10): association of socio-demographic and dietary factors with anemia in primary school students

Groups / Variables	Anemic students		Non-anemic students		Chi square	P value
	Count	%	Count	%		
Gender						
Male	17	8.3	69	33.5	0.012	0.914
Female	23	11.2	97	47.1		
Age						
6-9	8	3.9	37	18.0	2.049	0.359
10-12	12	5.8	66	32.0		
13-15	20	9.7	63	30.6		
Region						
Surman	30	75.0	30	75.0	0.001	0.999
Mutrod	10	25.0	10	25.0		
Living						
Urban	13	6.3	92	44.7	6.777	0.009
Rural	27	13.1	74	35.9		
Eat Vegetable						
Rarely	4	1.9	20	9.7	1.848	0.397
Sometimes	32	15.5	116	56.3		
Always	4	1.9	30	14.6		
Eat Meat						
Rarely	8	3.9	15	7.3	10.103	0.006
Sometimes	31	15.0	116	56.3		
Always	1	0.5	35	17.0		
Dring Tea						
Yes	5	2.4	6	2.9	5.035	0.025
No	35	17.0	160	77.7		

Table 11 presents a gender-based comparison of hematological and iron-status parameters among anemic students. The results indicate no statistically significant differences between male and female students across all measured variables. Hemoglobin levels were comparable between males (M = 9.78, SD = 1.24) and females (M = 9.90, SD = 0.95), $t = -0.33$, $p = 0.745$. Similarly, red blood cell indices—including MCT, MCV, MCH, and MCHC—did not differ significantly by gender (all $p > 0.05$), suggesting that the severity and characteristics of anemia were consistent across boys and girls.

Iron-related biomarkers also showed no meaningful gender differences. Ferritin levels did not significantly vary between males (M = 13.87, SD = 11.05) and females (M = 10.80, SD = 8.12), $t = 1.02$, $p = 0.317$. Serum iron, TIBC, and UIBC values likewise failed to reach statistical significance (all $p > 0.05$). Overall, these findings suggest that among students who were already anemic, gender did not play a significant role in determining the hematological or iron-profile patterns observed.

Table (11): Gender-based comparison of hematological parameters in anemic primary school students

Gender / Variable	Male (n=17)	Female (n=23)	T value	P value
	Mean±SD	Mean±SD		
Hb	9.78±1.241	9.90±0.948	-0.328	0.745

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ISSN: 2643-9824
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HCT	30.40±2.739	30.44±1.686	-0.052	0.959
MCV	71.95±12.910	75.25±5.344	-1.106	0.276
MCH	23.59±2.716	24.54±2.838	-1.067	0.293
MCHC	31.64±2.218	32.34±2.195	-0.990	0.329
Ferritin	13.87±11.054	10.80±8.124	1.015	0.317
Iron	38.33±20.581	37.31±18.482	0.164	0.870
TIBC	398.84±79.169	413.29±56.066	-0.643	0.526
UIBC	360.50±94.58	377.62±66.46	-0.673	0.505

Table 12 presents an age-based comparison of hematological and iron-status parameters among anemic primary school students. The results indicate that there were no statistically significant differences across the three age groups (6–9, 10–12, and 13–15 years) for any of the measured variables. Hemoglobin levels were similar across ages, with means ranging from 9.48 to 10.07 g/dL ($p = 0.378$), and red blood cell indices—including MCT, MCV, MCH, and MCHC—also showed no significant variation ($p > 0.05$). Likewise, iron-related biomarkers such as ferritin, serum iron, TIBC, and UIBC did not differ significantly among the age groups (all $p > 0.05$). These findings suggest that, within the anemic population, age did not significantly influence hematological or iron-status profiles.

Table (12): Age-Based Comparison of Hematological Parameters in Anemic Primary School Students

Age Groups / Variable	6-9 (n=8)	10-12 (n=12)	13-15 (n=20)	P value
	Mean±SD	Mean±SD	Mean±SD	
Hb	9.48±1.611	9.73 ±0.899	10.07±0.894	0.378
HCT	29.64 ±3.101	30.31±1.958	30.81±1.850	0.436
MCV	76.19±8.129	72.27±3.549	73.86±11.979	0.666
MCH	23.93±3.648	23.42±2.407	24.65±2.669	0.479
MCHC	31.01±2.891	31.64±2.121	32.69±1.814	0.143
Ferritin	9.94±5.484	12.04±10.528	13.01±10.300	0.751
Iron	32.73±18.649	34.15±22.020	41.90±17.523	0.395
TIBC	420.03±76.852	434.43±39.417	385.62±70.156	0.107
UIBC	387.33±93.472	400.29±48.175	345.58±83.081	0.131

Table 13 compares hematological and iron-status parameters between urban and rural anemic primary school students. The results indicate no statistically significant differences between students from urban and rural areas across all measured variables. Hemoglobin levels were similar for urban (M = 9.83, SD = 1.04) and rural students (M = 9.86, SD = 1.10), $t = –0.068$, $p = 0.946$. Red blood cell indices—including MCT, MCV, MCH, and MCHC—did not show significant variation between the two groups (all $p > 0.05$). Iron-related biomarkers, such as ferritin, serum iron, TIBC, and UIBC, were also comparable between urban and rural anemic students (all $p > 0.05$). Overall, these findings suggest that, among anemic students, the place of residence does not significantly influence hematological or iron-status profiles.

Table (13): Comparison of hematological parameters between urban and rural anemic primary school students

Area / Variable	Urban (n=13)	Rural (n=27)	T value	P value
	Mean±SD	Mean±SD		
Hb	9.83±1.043	9.86±1.100	-0.068	0.946
HCT	30.02±1.772	30.61±2.335	-0.807	0.425
MCV	75.12±5.472	73.23±10.761	0.594	0.556
MCH	24.18±2.831	24.11±2.827	0.077	0.939
MCHC	32.34±2.334	31.90±2.170	0.584	0.562
Ferritin	11.70±9.519	12.30±9.625	-0.187	0.852
Iron	41.65±27.360	35.86±13.902	0.721	0.482
TIBC	408.27±70.798	406.61±65.429	0.073	0.942
UIBC	366.58±91.239	372.16±74.161	-0.206	0.838

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ISSN: 2643-9824
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An independent-samples *t* test was conducted to compare hematological parameters between anemic primary school students from Surman and Mutrod (Table 14). The results indicated no statistically significant differences between the two regions in hemoglobin concentration, mean corpuscular thickness, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, total iron-binding capacity, or unsaturated iron-binding capacity, as all *p* values exceeded 0.05. For example, the mean hemoglobin level among students from Surman (mean = 9.71, standard deviation = 1.08) did not differ significantly from that of students from Mutrod (mean = 10.25, standard deviation = 0.98).
In contrast, statistically significant differences were observed for serum ferritin and serum iron levels. Students from Mutrod showed significantly higher ferritin levels (mean = 19.39, standard deviation = 13.70) compared with those from Surman (mean = 9.68, standard deviation = 6.17). Similarly, serum iron concentrations were significantly higher in Mutrod students (mean = 48.60, standard deviation = 23.96) than in Surman students (mean = 34.12, standard deviation = 16.15). These findings suggest that, despite comparable general hematological indices, iron stores and iron availability were relatively better among anemic students in the Mutrod region compared with their counterparts in Surman.

Table (14): Comparison of hematological parameters between surman and mutrod region anemic primary school students

Region / Variable	Surman (n=30)	Mutrod (n=10)	T value	P value
	Mean±SD	Mean±SD		
Hb	9.71±1.080	10.25±0.976	-1.392	0.172
HCT	30.16±2.085	31.22±2.309	-1.361	0.182
MCV	73.62±10.498	74.54±4.698	-0.268	0.4971
MCH	23.96±2.834	24.67±2.733	-0.695	0.491
MCHC	31.85±2.320	32.61±2.134	-0.939	0.354
Ferritin	9.68±6.165	19.39±13.703	-2.169	0.004
Iron	34.12±16.152	48.60±23.955	-2.167	0.037
TIBC	403.42±69.145	418.32±58.842	-0.610	0.545
UIBC	369.25±81.856	373.63±73.567	-0.150	0.882

Table 15 examines the association between demographic and dietary factors and the severity of anemia among primary school students. The results indicate that none of the examined variables—gender, age, place of living, vegetable consumption, meat consumption, or tea drinking—were significantly associated with anemia severity (all $p > 0.05$). For instance, the distribution of mild and moderate anemia was similar between males and females, $\chi^2 = 0.051$, $p = 0.822$, and no age group showed a significant difference in severity, $\chi^2 = 1.751$, $p = 0.417$. Similarly, living environment (urban vs. rural), as well as region and dietary habits related to vegetable and meat consumption and tea drinking, did not demonstrate significant associations with mild or moderate anemia. These findings suggest that, within this sample, demographic and dietary factors were not predictive of anemia severity.

Table (15): Association of demographic and dietary factors with severity of anemia in primary school students

Variables	Severity of Anemia				Chi square	P value
	Mild		Moderate			
	Count	%	Count	%		
Gender						
Male	9	22.5	8	20.0	0.051	0.822
Female	13	32.5	10	25.0		
Age						
6-9	4	10.0	4	10.0	1.751	0.417
10-12	5	12.5	7	17.5		
13-15	13	32.5	7	17.5		
Region						
Surman	13	32.5	13	32.5	0.0001	0.9999
Mutrod	27	67.5	27	67.5		
Living						
Urban	7	17.5	6	15.0	0.010	0.919
Rural	15	37.5	12	3.0		
Eat Vegetable						
Rarely	2	5.0	2	5.0	0.101	0.951
Sometimes	18	45.0	14	35.0		

Always	2	5.0	2	5.0		
Eat Meat						
Rarely	4	10.0	4	10.0	0.899	0.638
Sometimes	17	42.5	14	35.0		
Always	1	2.5	0	0.0		
Dring Tea						
Yes	2	5.0	3	7.5	0.519	0.471
No	20	50.0	15	37.5		

5. DISCUSSION

The current study represents a significant scientific contribution aimed at shedding light on the reality of this common health problem among a primary school children, in a region that may be marginalized or less researched than others. By analyzing the results of this study and comparing them with the findings of previous research, we can construct an integrated and accurate picture that enhances our understanding of the factors contributing to the prevalence of this disease and its various dimensions, placing the results of the current study within their local, regional, and international scientific context.

Initially, the epidemiological aspect of this study addresses the determination of the prevalence rate of iron deficiency anemia among the pupils. The results showed that 40 pupils out of 206 were diagnosed with anemia, representing a prevalence rate of approximately 19.4%. When comparing this figure with previous studies, we find a notable variation reflecting differences in population characteristics, geography, and living conditions. In the Libyan context, the results of the Surman and Al Mutrad study are significantly lower than those conducted by Al-Khurm *et al.* (2024) in the city of Tobruk, where the anemia prevalence rate reached 42%, a percentage representing nearly half of the children included in their study. The rate is also lower than that recorded in the study by Jbireal and Azab (2020) in Sabratha, western Libya, which showed that approximately 11.08% of males and 12.90% of females were anemic (based on hemoglobin measurement alone), while the percentage of iron deficiency anemia ranged between 8.92% and 9.67%. This significant difference with the Tobruk study can be explained by several factors, including the nature and size of the sample; the Surman and Al Mutrad study included only 206 pupils, whereas the Tobruk sample might have been larger or more diverse in terms of living conditions. Furthermore, the geographical, climatic, and economic differences between the three regions (the western coast and eastern Libya) may play a crucial role in food availability, economic diversity, and consequently, the nutritional status of the children. It is important to note here that the results of the Sabratha study are relatively closer to the findings of the current study, especially concerning the rates of iron deficiency anemia, which may reflect similarities in demographic and nutritional characteristics between the geographically close cities of Sabratha and Surman.

At the regional level, the prevalence rates of anemia in neighboring Arab countries vary. In a study conducted in Mosul, Northern Iraq, by Al Hafidh *et al.* (2024), the rate of diagnosed iron deficiency reached 31%, a percentage higher than that recorded in Surman and Al Mutrad. In Egypt, a study by Mabrouk *et al.* (2022) in Beni-Suef revealed a prevalence of 38% among children. This variation may be attributed to differences in dietary practices, health awareness, and the economic income levels of families in these countries. On a global scale, we also observe significant variation; a study by Yusufu *et al.* (2023) in Zanzibar, Tanzania, showed an alarming prevalence rate reaching 53.3%, reflecting the magnitude of the problem in some sub-Saharan African countries where malnutrition and poverty are widespread. In Malaysia, a study by Shanita *et al.* (2018) recorded an anemia prevalence of 26.2% and iron deficiency of 27.1%, rates closer to global averages. In Iran, a meta-analysis by Akbari *et al.* (2017) estimated the prevalence at approximately 15.7%, a figure very close to the result of the current study, suggesting that the Surman and Al Mutrad region might be in a similar situation to some Iranian areas concerning the causative factors of anemia.

Moving to the second objective related to comparing the prevalence of anemia between males and females and across different age groups, the current study found no statistically significant differences in infection rates between the sexes, with the probability of anemia being equal among males and females. This contradicts numerous previous studies. In the study by Al-Khurm *et al.* (2024) in Libya, males were significantly more affected. Conversely, other studies, such as those by Al Hafidh *et al.* (2024) in Iraq, Yusufu *et al.* (2023) in Tanzania, and Jbireal and Azab (2020) in Libya, found that females were more affected. The absence of gender differences in the current study could be explained by the relatively small overall sample size and the number of anemic individuals (only 40), which may limit the statistical power to detect true differences. Additionally, the older age of the sample (40.3% in the 13-15 year age group) might mean that many females had not yet entered puberty or were in its early stages, where iron requirements increase due to menstruation, thus reducing the likelihood of observing gender differences. This aligns with what Leung *et al.* (2024) indicated, that anemia occurs most frequently during adolescence, a period of increased iron requirements.

Regarding age groups, the current study also found no statistically significant differences among the three categories (6-9, 10-12, 13-15 years). This result contradicts some studies, such as that by Shanita *et al.* (2018), which found that younger children and boys had higher rates of iron deficiency. It also does not reflect the observations by Gedfie *et al.* (2022) and Leung *et al.* (2024) that young children (9 months to 3 years) and adolescents are most at risk. The lack of age-related differences in the current study might be because the entire sample (6-15 years) falls within periods of growth and increased iron needs, albeit for different reasons (rapid growth in early stages and puberty-related needs in later stages). The uneven distribution of the sample (with the youngest age group being the least represented) may have also influenced the results. When analyzing the hematological characteristics among anemic individuals only, the study confirmed that age had no statistically significant impact on the severity of anemia or iron indicators, meaning that once infection occurs, the hematological picture is similar regardless of age. This is an important piece of information, consistent with the general findings of the study by McEvoy *et al.* (2023), which showed a similar response to treatment across young age groups.

Concerning the third objective, which assessed variations in anemia prevalence between schools in central urban areas and those in rural regions, the current study revealed a statistically significant association between place of residence and anemia, with pupils in rural areas being more susceptible to infection compared to their urban counterparts. This finding aligns significantly with scientific logic and numerous studies, as rural areas often suffer from limited access to health services, lower parental education levels, potentially less dietary diversity due to reliance on limited local products, in addition to a broader prevalence of malnutrition and poverty. The study by Al Hafidh *et al.* (2024) in Iraq clearly indicated that children from low-income families are most at risk. Furthermore, the study by Yusufu *et al.* (2023) linked low dietary diversity to high rates of anemia, a factor that might be more common in rural areas. The study by Mabrouk *et al.* (2022) in Egypt also connected low socioeconomic status and parasitic infections to high rates of anemia, factors that may also be more prevalent in rural areas. This strong association between rural residence and anemia underscores the importance of targeting these areas with intensive preventive intervention programs.

Interestingly, when comparing the two main regions in the study (Surman and Al Mutrad), the analysis showed no statistically significant difference in the overall prevalence of anemia between them. However, substantial differences emerged in some iron storage indicators. Anemic pupils from Al Mutrad showed significantly higher levels of ferritin and serum iron compared to their counterparts in Surman. This suggests that despite similar prevalence rates, the severity of iron deficiency (i.e., depleted stores) might be more pronounced among pupils in Surman. This could be attributed to subtle differences in local dietary habits, soil and water quality, or the prevalence of certain diseases like intestinal parasites, which were not assessed in the current study. This finding recalls the study by Narang *et al.* (2018), which showed that celiac disease can be a hidden cause behind severe anemia, highlighting the importance of investigating underlying causes, not just superficial factors, when analyzing differences between regions.

Finally, the fourth and most intriguing objective was to identify the dietary and behavioral factors associated with iron deficiency anemia, and the current study yielded mixed results. Regarding vegetable consumption, no statistically significant association with anemia was found, despite the majority (71.8%) consuming them only sometimes. This can be explained by the fact that vegetables, although important, contain non-heme (non-animal) iron, which is less efficiently absorbed than the heme iron found in meat, especially in the presence of absorption inhibitors like tea. This leads to the most important finding: a strong and statistically significant relationship between meat consumption and anemia, where pupils who rarely consumed meat were more likely to have anemia. This result directly aligns with all previous studies that emphasized the importance of an iron-rich diet in preventing anemia, such as those by Sun *et al.* (2018), Mabrouk *et al.* (2022), and Al Hafidh *et al.* (2024), which recommended dietary interventions rich in iron and fortified foods. It is also supported by the findings of the study by Sundararajan and Rabe (2021), which focused on the importance of iron-rich complementary feeding for infants and young children.

The other dietary factor that showed a strong and significant association with anemia in the current study was tea drinking, with tea drinkers being significantly more likely to have anemia. This finding strongly supports the well-established scientific understanding that tea contains tannins, which inhibit the absorption of non-heme iron in the gut. Many previous studies indirectly alluded to this relationship by emphasizing the importance of improving iron absorption, but the current study provides clear field evidence of this association in the study area. Although the proportion of tea drinkers in the sample was small (5.3%), the strength of the statistical association indicates that this habit, where it exists, poses a significant risk. It is worth noting that studies like that by Yusufu *et al.* (2023) and others that analyzed risk factors would likely have found a similar association had it been specifically assessed.

6. Conclusions

In conclusion, this study adds to the scientific literature by providing an accurate local picture of the problem of iron deficiency anemia in the Surman and Al Mutrad region of Libya. The findings confirm that this problem persists and that the main risk factors are suboptimal dietary habits (low meat consumption and tea consumption) and geographical deprivation (rural areas). While no clear differences emerged between genders or age groups, possibly due to sample limitations, the general trends align with previous studies in emphasizing the pivotal role of nutrition. The study recommends conducting a broader health and nutritional survey across the region, focusing on awareness campaigns about the importance of a balanced diet, encouraging the consumption of iron-rich foods, and limiting factors that inhibit its absorption, such as tea, especially in rural areas which the study proved to be the most affected.

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