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Sex-based Differences in Hematological and Iron-Status Biomarkers, Nutritional Factors, and Anemia Status among Adolescents at the Higher Institute of Health Sciences, Al-Marj, Libya

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ABSTRACT:

Background: Adolescence is a nutritionally vulnerable period in which rapid growth, expansion of blood volume, increasing lean body mass, and—after menarche—recurrent menstrual blood loss raise iron requirements. Iron deficiency may develop before overt anemia and may affect fatigue, exercise capacity, attention, and academic performance. A combined assessment of hemoglobin, red-cell indices, ferritin, transferrin saturation, and soluble transferrin receptor can therefore characterize iron status more completely than hemoglobin alone.

Objective: To compare hematological and biochemical iron-status markers between adolescent girls and boys at the Higher Institute of Health Sciences, Al-Marj, Libya, and to describe anemia status, nutrition knowledge, food-related iron awareness, nutritional-status categories, and physical activity.

Methods: An institution-based cross-sectional study included 75 adolescents assessed from October 2024 through May 2025. The sample comprised 50 girls (66.7%) and 25 boys (33.3%). Descriptive variables were summarized as frequency and percentage. Hematological and iron-status markers were summarized as mean ± standard deviation. The investigator-provided anemia classification and p values were retained, while arithmetic percentages were independently checked for internal consistency.

Results: Forty of 75 participants were classified as anemic (53.3%) and 35 as not anemic (46.7%). Anemia affected 31/50 girls (62.0%) and 9/25 boys (36.0%), with a significant sex association (Pearson χ^2 $p=0.033$). Low nutrition knowledge was reported in 58.7%, 50.7% lacked awareness of iron-boosting foods, and 62.7% lacked awareness of iron-inhibiting foods. Girls had lower Hb, Hct, MCV, MCH, serum iron, transferrin saturation, and ferritin and higher transferrin, sTfR, and sTfR/log ferritin index than boys. Mean ferritin was 14.01 ± 13.26 ng/mL in girls versus 73.81 ± 44.37 ng/mL in boys (reported $p<0.0001$).

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Conclusion: The study demonstrates a high anemia burden and a coherent female-predominant pattern of lower iron stores and iron-restricted erythropoiesis. The findings support combined laboratory screening together with menstrual and nutrition assessment, while highlighting the need for verification of individual diagnostic thresholds and collection of raw participant-level data for adjusted analyses.

1. INTRODUCTION

Adolescence is a biologically dynamic stage characterized by accelerated linear growth, expansion of lean tissue, endocrine maturation, and increasing blood volume. These changes markedly increase the requirement for iron, which is essential for hemoglobin synthesis, mitochondrial energy production, enzymatic reactions, and normal neurocognitive function. When iron supply does not keep pace with growth and physiological losses, iron stores are depleted first; only later does hemoglobin fall sufficiently to meet diagnostic criteria for anemia. For this reason, iron deficiency and iron-deficiency anemia represent related but distinct stages of the same physiological continuum [1-3,18,19].

The consequences of inadequate iron status during adolescence extend beyond the complete blood count. Iron deficiency can contribute to fatigue, reduced exercise tolerance, impaired concentration, diminished learning efficiency, and lower physical performance even when anemia is not yet severe. These functional consequences are particularly important in students because adolescence is a period of high academic demand and rapid cognitive development. Global guidance therefore emphasizes prevention, early recognition, and correction of iron deficiency in nutritionally vulnerable adolescent groups [16,20,21].

Sex differences become more pronounced after puberty. Boys typically develop higher hemoglobin concentrations and greater red-cell mass during later puberty, partly in association with androgen-driven erythropoiesis. Girls, in contrast, acquire an additional pathway of iron loss after menarche. Recurrent menstrual blood loss can progressively reduce iron stores, and heavy menstrual bleeding may accelerate the transition from latent iron deficiency to overt anemia. Clinical guidance for adolescents with heavy menstrual bleeding recommends evaluation not only of hemoglobin but also of ferritin and, where clinically indicated, investigation for an underlying bleeding disorder [17,22].

Dietary quality is another central determinant of iron balance. Heme iron from animal-source foods is generally more bioavailable than non-heme iron from plant sources. Vitamin C can enhance absorption of non-heme iron, whereas phytates and polyphenol-rich beverages such as tea and coffee can reduce absorption when consumed with or soon after meals. Meal skipping, restrictive diets, limited access to iron-rich foods, and insufficient knowledge of these dietary interactions may therefore contribute to deficiency. Nutrition education is particularly relevant in institutional settings because awareness can be modified through targeted health-promotion programs [4,5,20].

A complete blood count provides the first hematological evidence of iron-restricted erythropoiesis. Declining mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) indicate progressively smaller red cells containing less hemoglobin, while an increase in red-cell distribution width (RDW) may reflect the coexistence of older relatively normal cells and newly produced microcytic cells. However, microcytosis is not specific for iron deficiency; thalassemia trait and other causes of microcytic anemia remain important differential diagnoses, particularly in Mediterranean and North African populations [18,23].

Biochemical markers strengthen interpretation. Ferritin is the most widely used indicator of storage iron and is recommended by the World Health Organization for assessment of iron status [2]. A low ferritin concentration strongly supports depleted iron stores, but ferritin is also an acute-phase reactant and can be falsely normal or elevated during inflammation. Serum iron is more variable and is influenced by diurnal rhythm, recent intake, and inflammatory states. Transferrin and transferrin saturation (TSAT) provide complementary information regarding transport capacity and circulating iron availability [2,18,19].

Soluble transferrin receptor (sTfR) reflects cellular demand for iron and erythropoietic activity and is generally less affected by inflammation than ferritin. Combining sTfR with ferritin in the sTfR/log ferritin index can improve discrimination between depleted iron stores and inflammatory patterns when conventional markers are difficult to interpret [7,8,14]. Thus, a pattern of low ferritin and TSAT together with higher transferrin and sTfR is biologically more convincing than any isolated marker.

Hematological indices can also be influenced by systemic physiological and disease-related factors beyond nutritional deficiency. In a Libyan-related clinical context, Saad Elabidi and colleagues evaluated blood indices together with erythropoietin levels in

cystic kidney disease, illustrating the broader importance of interpreting hematological measurements alongside mechanisms that regulate erythropoiesis and systemic disease [15]. Although that clinical population differs from healthy adolescents, the study reinforces the principle that blood indices should be interpreted within their biological context rather than in isolation.

Available Libyan studies suggest that anemia and iron deficiency remain relevant problems in school-age and adolescent populations, although estimates differ by age, sex, region, and diagnostic criteria. Data from Tripoli, Tobruk, and Nalut have reported an appreciable burden among adolescent girls and have highlighted menstrual and nutritional factors as potentially important contributors [9-13]. These regional data support the need for institution-specific assessment in eastern Libya, where dietary patterns, health awareness, and access to preventive services may differ from other settings.

The present study was therefore designed to integrate three complementary perspectives: overall anemia status, sex-specific hematological and iron-biomarker patterns, and descriptive nutritional/lifestyle characteristics. By examining these domains together among adolescents at the Higher Institute of Health Sciences in Al-Marj, the study aims to provide a clearer basis for local screening, nutrition education, menstrual-health assessment, and future participant-level analytical research.

2. Aim and Objectives

The primary aim was to evaluate anemia and iron status among adolescents at the Higher Institute of Health Sciences, Al-Marj, with particular emphasis on sex differences and potentially modifiable nutritional factors.

- Compare Hb, Hct, RBC count, MCV, MCH, MCHC, RDW-SD, and RDW-CV between girls and boys.
- Compare serum iron, transferrin, transferrin saturation (TSAT), ferritin, sTfR, and the sTfR/log ferritin index between sexes.
- Describe the distribution of anemia status, nutrition-knowledge categories, awareness of iron-boosting and iron-inhibiting foods, nutritional-status categories, physical activity, and the supplied menstrual-period variable.
- Assess the association between sex and anemia status using the supplied 2×2 counts.
- Identify practical laboratory, dietary, and menstrual-health targets for future screening and preventive programs at the institute.

3. MATERIALS AND METHODS

3.1 Study design, setting, and period

An institution-based cross-sectional study was conducted among adolescents assessed at the Higher Institute of Health Sciences, Al-Marj, Libya. Data collection covered the period from October 2024 through May 2025. The cross-sectional design was selected to describe the burden of anemia and nutritional characteristics at the study setting and to compare hematological and iron-status profiles between female and male participants at the same general study period.

3.2 Study population and sample

The analytical sample consisted of 75 adolescents: 50 girls (66.7%) and 25 boys (33.3%). All counts and percentages in the revised manuscript were checked against this denominator unless a sex-specific denominator was explicitly required. The source material supplied for revision did not provide the exact age range, mean age, response rate, sampling frame, or recruitment technique; these items should be inserted from the original study log before journal submission and were not invented in this manuscript.

3.3 Data domains and study variables

The study dataset contained three principal domains. First, hematological measures included hemoglobin (Hb), hematocrit (Hct), red blood cell count (RBC), MCV, MCH, MCHC, RDW-SD, and RDW-CV. Second, biochemical iron-status measures included serum iron, transferrin, TSAT, ferritin, sTfR, and the sTfR/log ferritin index. Third, descriptive questionnaire or classification variables included anemia status, nutrition knowledge, awareness of iron-boosting foods, awareness of iron-inhibiting foods, nutritional status, physical activity, and a supplied menstrual-period variable.

3.4 Nutrition knowledge and dietary awareness

Nutrition knowledge was categorized in the source dataset as good, enough, or low. Awareness of foods that increase dietary iron intake or support iron availability was recorded as yes/no, as was awareness of foods or practices considered to inhibit iron absorption. The revised analysis preserved these source categories exactly. Because the original questionnaire, scoring rubric, number of items, and validation procedure were not supplied, no new cut points or questionnaire scores were created. Future reports should append the original questionnaire and define the scoring thresholds used for each knowledge category.

3.5 Nutritional-status and physical-activity variables

Nutritional status was provided in three categories—underweight, normal, and overweight—while physical activity was categorized as low or high. These categories were analyzed descriptively as supplied. The source file did not specify whether nutritional status was based on BMI-for-age z scores, another anthropometric reference, or clinical classification, and did not provide the instrument or duration threshold used to classify physical activity. Accordingly, the manuscript reports the observed categories without attributing them to a specific standard that was not documented.

3.6 Menstrual variable

A binary variable labeled "menstrual-period variable" was present in the supplied aggregate table (yes=5; no=70). Because the wording, eligibility denominator, and clinical meaning of this variable were not documented, it was retained as a source variable but was not interpreted as the prevalence of menstruation, menarche, irregular menses, or heavy menstrual bleeding. For future participant-level work, menstrual history should be collected only among relevant participants and should document age at menarche, cycle length, duration, flooding, large clots, frequent sanitary-product changes, and school absence, consistent with adolescent heavy-menstrual-bleeding assessment principles [17,22].

3.7 Blood sampling and laboratory measurements

Venous blood was assessed for complete blood count indices and biochemical markers of iron status. The source dataset provided group summary values but did not specify the hematology analyzer, iron/ferritin assay platform, specimen-processing protocol, calibration schedule, internal quality-control material, or timing of collection. These technical details are essential for reproducibility and should be inserted from the laboratory records. Ferritin interpretation should consider concurrent inflammation because ferritin can rise as part of the acute-phase response [2,18,19]. Where available, C-reactive protein (CRP) and, in population surveys, alpha-1-acid glycoprotein (AGP) can strengthen interpretation of ferritin in inflammatory settings.

3.8 Operational interpretation of anemia and iron status

The final source classification identified 40 participants as anemic and 35 as not anemic. This classification was retained as the primary categorical outcome. Current WHO guidance recommends age- and sex-appropriate hemoglobin thresholds rather than a single universal cutoff [1]. Because the individual ages, hemoglobin values linked to each participant, and exact diagnostic rule used to generate the classification were not available in the aggregate dataset, the present manuscript does not reclassify participants independently. Similarly, mean ferritin values were used to compare groups but not to calculate the prevalence of iron deficiency, which requires participant-level measurements and appropriate cutoffs [2].

3.9 Statistical analysis and data-quality checks

Categorical variables are presented as frequency and percentage. Percentages were independently recalculated from the supplied frequencies using n/75 as the overall denominator, with sex-specific percentages based on n=25 males and n=50 females when appropriate. The association between sex and anemia status was verified from the 2×2 table using Pearson's chi-square test without continuity correction ($p=0.033$). Continuous laboratory variables are presented as mean ± standard deviation, and their p values were retained exactly from the investigator-provided analytical table because the raw participant-level dataset was not available for complete reanalysis. A two-sided $p<0.05$ was interpreted as statistically significant. Derived absolute and relative mean differences were used only as descriptive transformations and did not generate new inferential claims.

3.10 Ethical considerations

The final journal version should state the approving ethics committee, approval number, consent/assent procedure, confidentiality protections, and whether participation was voluntary. These details were not present in the supplied aggregate material and were therefore left for completion from the approved study protocol rather than being inferred.

4. RESULTS

4.1 Participant overview and anemia status

The study included 75 adolescents, of whom 50 (66.7%) were girls and 25 (33.3%) were boys. Forty participants were classified as anemic (53.3%) and 35 as not anemic (46.7%). The corrected percentage for the not-anemic group is therefore 35/75 = 46.7%.

Table 1. Overall participant and anemia profile

Characteristic	Frequency (n)	Percentage (%)
Female	50	66.7
Male	25	33.3
Anemic	40	53.3
Not anemic	35	46.7

4.2 Nutrition knowledge and food awareness

Low nutrition knowledge was the most common category, affecting 44 participants (58.7%). Only 12 participants (16.0%) were classified as having good knowledge. Awareness was also incomplete: 38 participants (50.7%) reported no awareness of iron-boosting foods, while 47 (62.7%) reported no awareness of iron-inhibiting foods or dietary practices.

Table 2. Nutrition knowledge and iron-related dietary awareness

Characteristic	Frequency (n)	Percentage (%)
Knowledge: good	12	16.0
Knowledge: enough	19	25.3
Knowledge: low	44	58.7
Awareness of iron-boosting foods: yes	37	49.3
Awareness of iron-boosting foods: no	38	50.7
Awareness of iron-inhibiting foods: yes	28	37.3
Awareness of iron-inhibiting foods: no	47	62.7

4.3 Nutritional status, physical activity, and supplied menstrual variable

Underweight was the largest supplied nutritional-status category (50/75; 66.7%), whereas 11 participants (14.7%) were classified as normal and 14 (18.7%) as overweight. Low physical activity was recorded in 50 participants (66.7%). The menstrual-period variable was positive in 5 participants (6.7%) and negative in 70 (93.3%); because its operational meaning was not documented, it is presented descriptively without further interpretation.

Table 3. Nutritional-status, physical-activity, and supplied menstrual-variable categories

Characteristic	Frequency (n)	Percentage (%)
Nutritional status: underweight	50	66.7
Nutritional status: normal	11	14.7
Nutritional status: overweight	14	18.7
Physical activity: low	50	66.7
Physical activity: high	25	33.3
Menstrual-period variable: yes	5	6.7
Menstrual-period variable: no	70	93.3

4.4 Anemia status by sex

Anemia was more frequent among girls than boys. Thirty-one of 50 girls (62.0%) were anemic compared with 9 of 25 boys (36.0%). Conversely, 64.0% of boys and 38.0% of girls were not anemic. The 2×2 distribution showed a statistically significant association between sex and anemia status (Pearson χ^2 p=0.033).

Table 4. Anemia status by sex among the 75 adolescents

Sex	Anemic	Not anemic	Total	P value
Male	9 (36.0%)	16 (64.0%)	25 (33.3%)	0.033*
Female	31 (62.0%)	19 (38.0%)	50 (66.7%)	

**Pearson chi-square test, no continuity correction. Percentages in the anemia/not-anemia columns are within sex.*

4.5 Hematological and biochemical iron-status comparisons

Girls showed a consistent pattern of lower hematological indices and poorer iron status. Mean Hb, Hct, MCV, MCH, serum iron, TSAT, and ferritin were lower in girls, while transferrin, sTfR, and the sTfR/log ferritin index were higher. RBC count and RDW-SD showed no statistically significant sex difference in the investigator-provided analysis.

Table 5. Comparison of hematological and biochemical parameters between adolescent girls and boys

Parameter	Girls, mean ± SD	Boys, mean ± SD	p value
Hb (g/dL)	11.62 ± 1.66	12.82 ± 1.59	0.0009
Hct (%)	34.99 ± 4.41	38.17 ± 3.79	0.002
RBC ($\times 10^6/\mu L$)	4.643 ± 0.55	4.694 ± 0.50	0.84
MCV (fL)	76.35 ± 6.52	81.22 ± 6.06	0.006
MCH (pg)	24.94 ± 2.89	27.34 ± 2.76	0.002
MCHC (g/dL)	32.64 ± 1.49	33.47 ± 1.66	0.05
RDW-SD (fL)	40.39 ± 4.85	39.42 ± 4.27	0.53
RDW-CV (%)	14.96 ± 1.83	13.94 ± 2.06	0.02
Iron (µg/dL)	34.23 ± 26.04	53.04 ± 39.33	0.04

Parameter	Girls, mean ± SD	Boys, mean ± SD	p value
Transferrin (mg/dL)	277.34 ± 54.87	234.45 ± 60.20	0.003
Transferrin saturation (%)	8.43 ± 5.98	15.37 ± 10.10	0.0006
Ferritin (ng/mL)	14.01 ± 13.26	73.81 ± 44.37	<0.0001
sTfR (µg/mL)	1.66 ± 0.99	1.07 ± 0.36	0.0005
sTfR/log ferritin	2.51 ± 2.93	0.62 ± 0.21	<0.0001

Abbreviations: Hb, hemoglobin; Hct, hematocrit; RBC, red blood cell count; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; RDW, red-cell distribution width; TSAT, transferrin saturation; sTfR, soluble transferrin receptor. P values are retained from the investigator-provided analysis.

Table 6. Selected magnitude of sex differences in key iron-related markers

Parameter	Girls - Boys	Girls as % of boys	Interpretation
Hb	-1.20 g/dL	90.6%	Lower mean hemoglobin in girls
MCV	-4.87 fL	94.0%	More microcytic profile in girls
Iron	-18.81 µg/dL	64.5%	Lower circulating iron
TSAT	-6.94 points	54.8%	Lower iron availability
Ferritin	-59.80 ng/mL	19.0%	Markedly lower mean iron stores
sTfR	+0.59 µg/mL	155.1%	Higher cellular iron demand
sTfR/log ferritin	+1.89	404.8%	Strong combined iron-deficiency signal

Derived differences are descriptive transformations of the reported group means and do not represent additional inferential tests.

4.6 Figures derived from the descriptive and laboratory tables

Figures 1-6 visualize the descriptive variables from Tables 1-4. Figures 7-10 summarize the principal laboratory sex differences from Tables 5-6. No new participants or measurements were introduced in producing these figures.

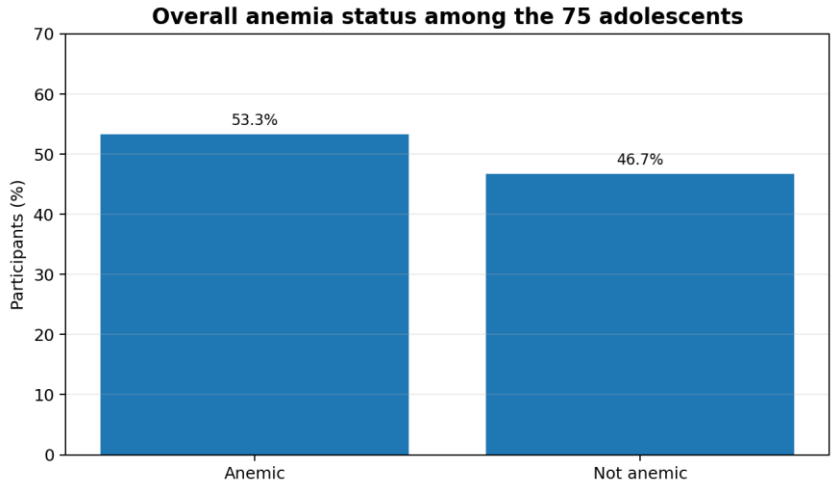

Figure 1. Overall anemia status among the 75 adolescents.

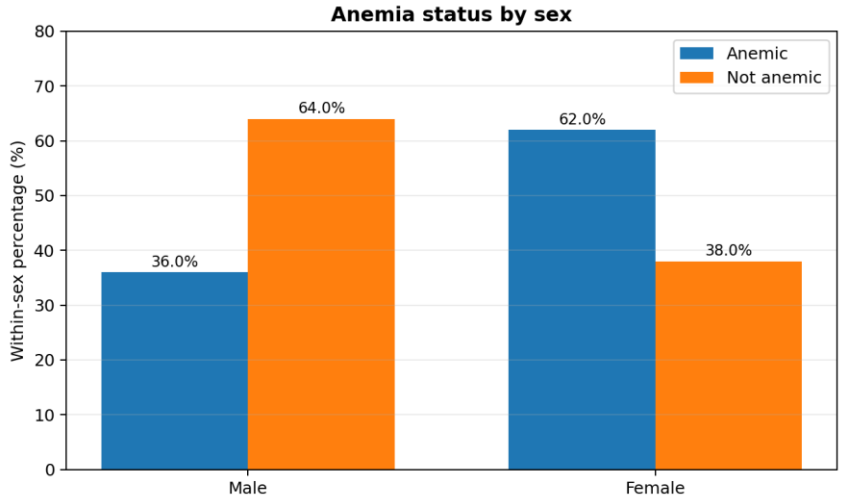

Figure 2. Anemia and not-anemia proportions within each sex. The sex association was significant (Pearson χ^2 p=0.033).

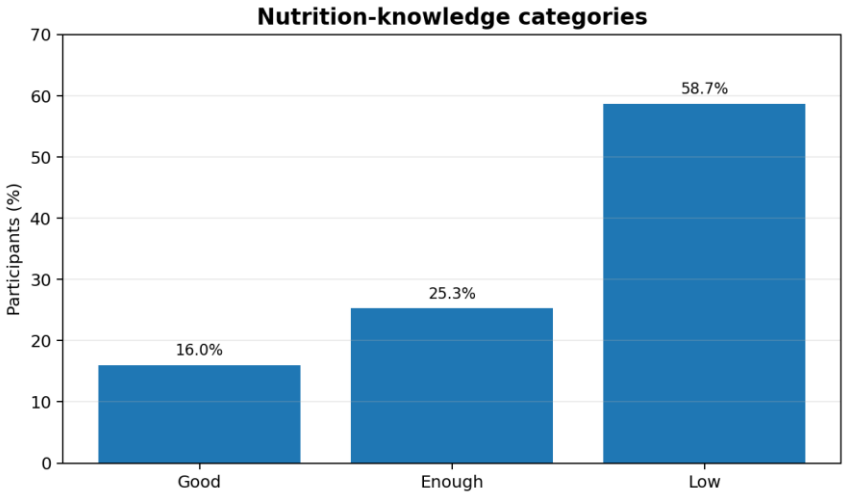

Figure 3. Distribution of nutrition-knowledge categories.

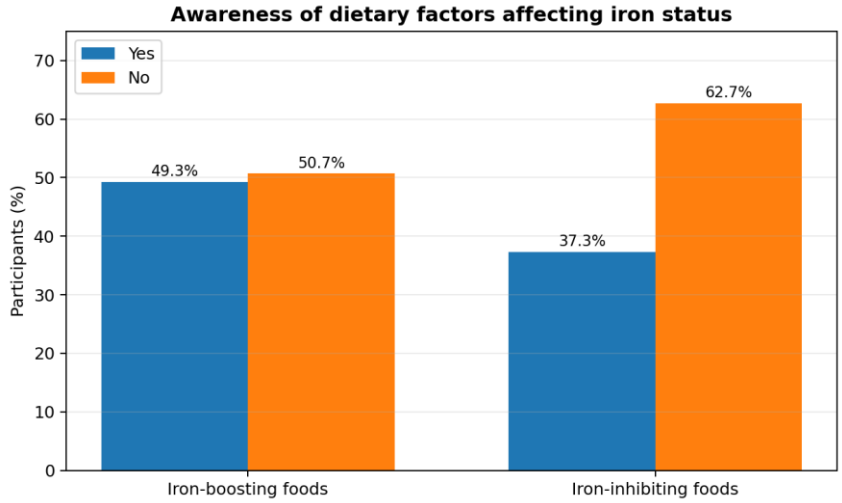

Figure 4. Awareness of iron-boosting and iron-inhibiting foods or dietary practices.

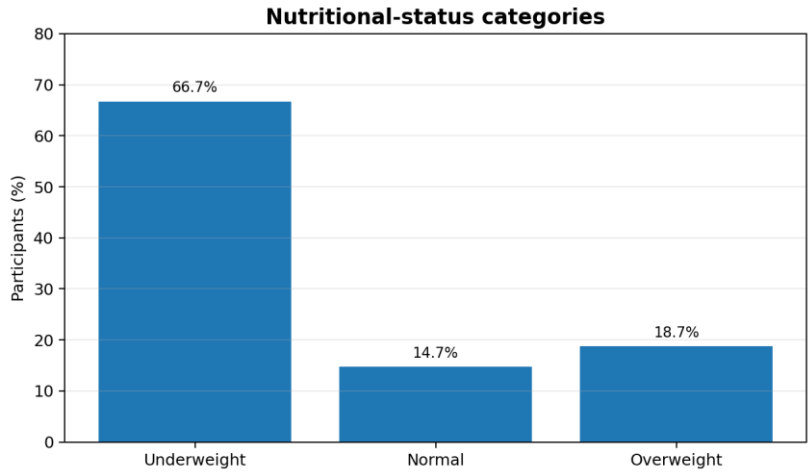

Figure 5. Distribution of nutritional-status categories as supplied in the source dataset.

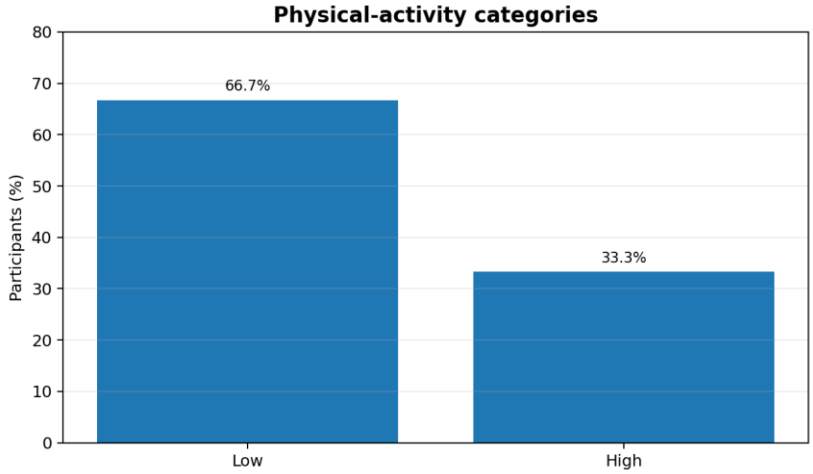

Figure 6. Physical-activity categories among the 75 adolescents.

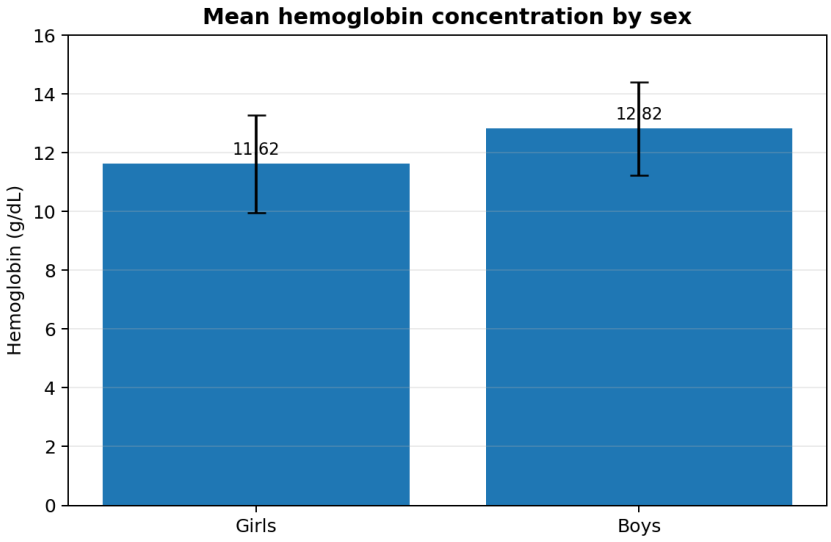

Figure 7. Mean hemoglobin concentration (mean ± SD) among adolescent girls and boys.

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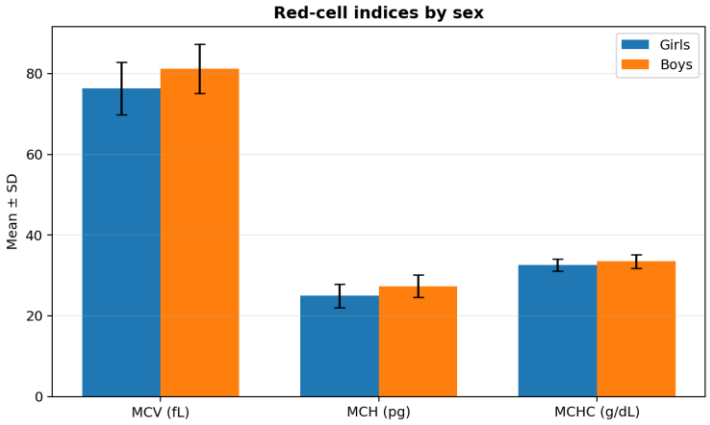

Figure 8. Comparison of MCV, MCH, and MCHC (mean ± SD) between adolescent girls and boys.

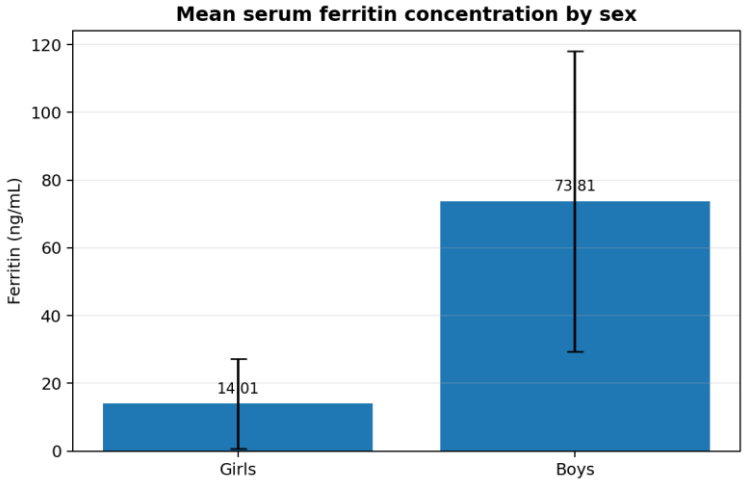

Figure 9. Mean serum ferritin concentration (mean ± SD) among adolescent girls and boys.

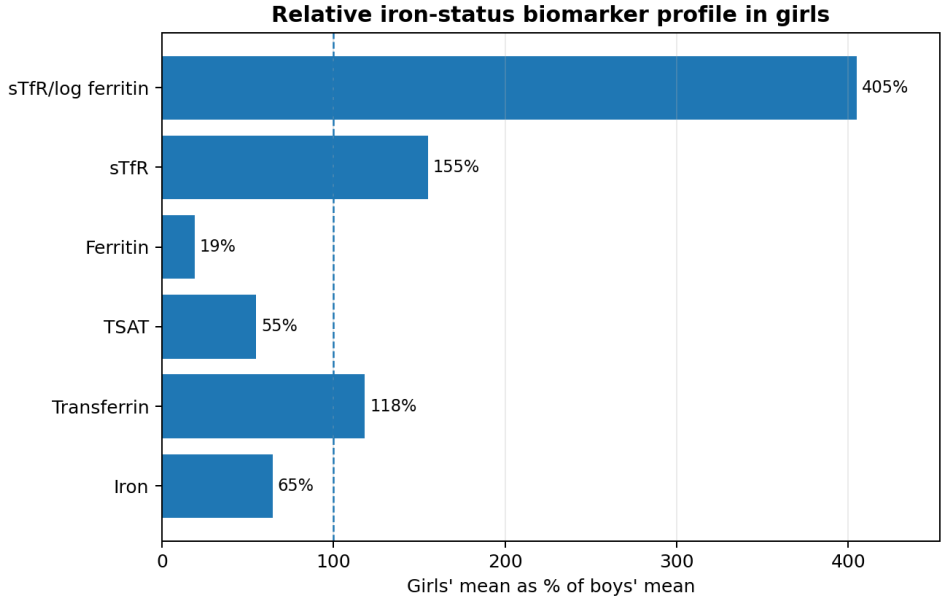

Figure 10. Iron-status biomarkers expressed as the girls' mean relative to the boys' mean (boys = 100%).

5. DISCUSSION

The principal finding of this study is that anemia and adverse iron-status markers were substantially more prominent among girls than boys. More than half of all participants were classified as anemic, and the within-sex prevalence was 62.0% in girls compared with 36.0% in boys. This categorical difference is supported by a coherent laboratory pattern: girls had lower Hb, Hct, MCV, MCH, serum iron, TSAT, and ferritin together with higher transferrin, sTfR, and sTfR/log ferritin index. The agreement across storage, transport, and erythropoietic-demand markers makes the female disadvantage biologically persuasive.

The red-cell findings suggest iron-restricted hemoglobinization rather than a simple reduction in red-cell number. RBC count was almost identical between sexes, while MCV and MCH were lower in girls and RDW-CV was higher. This pattern is typical of evolving microcytic, hypochromic erythropoiesis. Nevertheless, microcytosis is not unique to iron deficiency, and thalassemia trait should remain in the differential diagnosis when microcytosis persists after iron repletion or when ferritin is not low [18,23].

Ferritin showed the largest separation between sexes. Mean ferritin in girls was only 14.01 ng/mL compared with 73.81 ng/mL in boys, corresponding to a mean value approximately 81% lower. Because ferritin reflects storage iron, this difference strongly suggests substantially reduced average iron reserves among girls. However, group means cannot determine the proportion of individuals whose ferritin falls below a diagnostic cutoff, and inflammation can raise ferritin independently of iron stores [2,18,19]. Future participant-level analysis should therefore combine individual ferritin values with appropriate cutoffs and, where possible, CRP or another inflammatory marker.

The concurrent fall in serum iron and TSAT and rise in transferrin and sTfR reinforces the ferritin finding. Lower TSAT indicates reduced circulating iron available for erythropoiesis, whereas increased transferrin is a common compensatory response to reduced iron supply. Higher sTfR reflects increased cellular demand for iron and is less dependent on the acute-phase response than ferritin. The approximately four-fold higher sTfR/log ferritin index in girls provides an especially strong combined signal of depleted stores plus increased tissue iron demand [7,8,14].

The sex difference is clinically plausible during adolescence because menstrual losses are superimposed on rapid growth and high iron requirements. Heavy menstrual bleeding is a recognized cause of iron deficiency in adolescents, and guidance recommends assessment of ferritin in addition to hemoglobin when bleeding is clinically important [17,22]. The current dataset does not contain a sufficiently defined menstrual-history variable to test this pathway directly, but future studies should incorporate a structured menstrual assessment so that laboratory iron status can be linked to bleeding burden rather than inferred from sex alone.

The descriptive nutrition data identify important potentially modifiable gaps. Nearly three fifths of participants were classified as having low nutrition knowledge, about half lacked awareness of iron-boosting foods, and nearly two thirds lacked awareness of iron-inhibiting foods. These findings support the inclusion of nutrition education in adolescent anemia prevention. Educational messages should emphasize regular intake of iron-rich foods, combining plant sources of iron with vitamin C, and avoiding tea or coffee close to iron-rich meals. WHO guidance on adolescent nutrition and iron supplementation supports preventive nutrition strategies in settings with a substantial anemia burden [16,20,21].

The high proportion categorized as underweight and the high prevalence of low physical activity deserve additional investigation. Because the original classification method was not documented, the present study cannot determine whether the nutritional-status categories were based on BMI-for-age or another standard. Nonetheless, these descriptive patterns suggest that future data collection should include measured height, weight, BMI-for-age z score, dietary intake, socioeconomic variables, and validated physical-activity questions so that relationships with anemia can be examined analytically rather than descriptively.

The findings are broadly consistent with previous Libyan reports from Tripoli, Tobruk, and Nalut showing that anemia and iron deficiency are relevant adolescent health problems, often with a higher burden among girls [9-13]. Differences in prevalence between studies are expected because age structure, pubertal stage, dietary patterns, diagnostic thresholds, inflammation, sampling procedures, and local socioeconomic conditions can all alter estimates. The current Al-Marj data therefore add a useful eastern-Libyan institutional perspective, particularly because they include an extended iron-biomarker panel rather than hemoglobin alone.

From a screening perspective, the data argue against reliance on hemoglobin alone. CBC plus ferritin is a practical first-line combination, while TSAT and sTfR may clarify cases in which ferritin is discordant or inflammation is suspected. In participants

with persistent microcytosis after iron stores are corrected, a hemoglobinopathy work-up should be considered. At the public-health level, laboratory screening is most likely to be effective when paired with menstrual assessment, dietary counseling, and referral pathways for clinically significant anemia or heavy bleeding.

The results should nevertheless be interpreted within the limits of the available dataset. The cross-sectional design cannot establish causality. Individual ages, raw laboratory values, validated questionnaire scores, detailed menstrual data, inflammation markers, assay platforms, sampling methodology, and full ethics details were not supplied for this revision. In addition, the p values for the continuous laboratory markers were taken from the investigator-provided analytical table and could not be independently reproduced without raw data. These limitations do not negate the strong descriptive pattern, but they define the analyses that should be completed before final journal submission.

6. CONCLUSION

Among 75 adolescents assessed at the Higher Institute of Health Sciences, Al-Marj, from October 2024 through May 2025, 53.3% were classified as anemic. Anemia was significantly more frequent among girls than boys, and girls also demonstrated lower mean hemoglobin, red-cell indices, serum iron, transferrin saturation, and ferritin with higher transferrin and sTfR-related indices. The combined pattern is strongly compatible with lower iron stores and greater iron-restricted erythropoiesis among girls. Low nutrition knowledge and incomplete awareness of dietary factors affecting iron were common, identifying modifiable targets for intervention. Future participant-level analysis should link laboratory findings to age, menstrual blood loss, diet, nutritional status, inflammation, and socioeconomic factors to define the causes of anemia more precisely.

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