

Original article

# Prevalence and Determinants of Iron Deficiency Anemia Among School-Aged Children in Tobruk, Libya: A Community-Based Cross-Sectional Study

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**ABSTRACT**

Iron deficiency anemia (IDA) remains a major public health problem among school-aged children, particularly in low- and middle-income countries, where it adversely affects growth, cognitive development, and immune function. This study aimed to determine the prevalence of iron deficiency anemia and its associated factors among school-aged children in Tobruk, Eastern Libya. A community-based cross-sectional study was conducted between January and June 2025 among 366 children aged 6–14 years attending four primary healthcare centers in Tobruk. Data were collected using structured questionnaires and laboratory investigations. Hematological parameters were measured using an automated hematology analyzer (Sysmex KX-21N), and serum ferritin was assessed to evaluate iron status using an automated biochemical analyzer (Siemens Dimension P Plus). Anemia was defined as hemoglobin <12 g/dL, and IDA as hemoglobin <12 g/dL with serum ferritin <15 ng/mL. Data were analyzed using SPSS version 26.0. The Chi-square test was used to assess associations, and a p-value <0.05 was considered statistically significant. The overall prevalence of anemia was 56.2% (95% CI: 51.1–61.2). Iron deficiency anemia was observed in 32.7% (95% CI: 28.0–37.4) of participants, while 10.3% had iron deficiency without anemia, and 23.4% had other types of anemia. IDA was significantly higher among males (40.0%) compared to females (25.0%) ( $p = 0.002$ ). A significant association was also found between age group and IDA ( $p = 0.034$ ), with the highest prevalence among children aged 6–7 years (42.6%). No significant association was found between gender and overall anemia ( $p = 0.548$ ). Low serum ferritin (<15 ng/mL) was present in 43.2% of children, with no significant difference between genders ( $p = 0.091$ ). Iron deficiency anemia is highly prevalent among school-aged children in Tobruk, particularly among younger children (aged 6–7 years) and males. These findings indicate a moderate-to-severe public health problem requiring urgent intervention. School-based nutritional programs, routine screening for anemia and iron deficiency, iron supplementation for high-risk groups, and public health education are strongly recommended to reduce the burden of IDA in eastern Libya.

**Introduction**

Anemia remains a major global public health challenge, particularly affecting low- and middle-income countries. Among all population groups, school-aged children are especially vulnerable due to rapid growth, increased iron requirements, and higher susceptibility to infections and malnutrition. Iron deficiency anemia (IDA) is the most common nutritional deficiency worldwide and accounts for approximately 50% of all anemia cases in children [1]. The consequences of IDA during childhood extend beyond hematological effects. Evidence from recent studies indicates that IDA is associated with impaired cognitive development, reduced school performance, lower physical work capacity, increased fatigue, and weakened immune function. Long-term iron deficiency during critical developmental windows may lead to irreversible neurodevelopmental deficits [2].

Globally, the prevalence of anemia among school-aged children is estimated at 25.4% for IDA and up to 40% for all-cause anemia, with the highest burdens observed in sub-Saharan Africa and South Asia [3]. In the Eastern Mediterranean region, including Libya, the prevalence of anemia among children ranges from 30% to 60% depending on geographic location, socioeconomic status, and dietary patterns [4]. Despite the recognized burden, data on IDA among school children in Libya remain scarce. Most existing studies have focused on preschool children or pregnant women, with limited evidence from eastern Libya, particularly Tobruk [5]. Rapid urbanization, dietary changes, limited nutritional screening programs, and the recent socioeconomic disruptions in Libya may have exacerbated micronutrient deficiencies [6]. Therefore, this

study aimed to determine the prevalence and associated determinants of IDA among school-aged children in Tobruk.

## Methods

### Study Design and Setting

A community-based cross-sectional study was conducted between January and June 2025 among school-aged children in Tobruk, Eastern Libya. Tobruk is served by four main primary healthcare centers. Anemia was defined according to WHO criteria as hemoglobin <12 g/dL for children aged 6–14 years, for consistency with previous local studies (WHO defines <11.5 g/dL for ages 5–11 years and <12 g/dL for ages 12–14 years).

### Study Population and Sampling

The study population included apparently healthy school-aged children aged 6–14 years of both sexes. A stratified random sampling technique was applied, with strata defined according to the four main healthcare centers in Tobruk. Participants were selected proportionally from each center to ensure adequate representation. The required sample size was calculated using a single population proportion formula, assuming an expected anemia prevalence of 50%, a 95% confidence level, and a margin of error of 5%. Accordingly, a total of 366 children were included in the study.

### Blood Sample Collection and Laboratory Analysis

A total of 5 mL of venous blood was collected aseptically from each participant by trained personnel. Of this, 2 mL was transferred into EDTA tubes for complete blood count (CBC) analysis, while the remaining 3 mL was placed into plain tubes for serum separation. Serum samples were obtained after centrifugation at 3000 rpm for 10 minutes and stored at -20°C until analysis. Hematological parameters, including hemoglobin (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), and red blood cell count (RBC), were measured using an automated hematology analyzer (Sysmex KX-21N, Japan) according to the manufacturer's instructions. Biochemical parameters, including serum ferritin, serum iron, and total iron-binding capacity (TIBC), were measured using standard methods with an automated biochemical analyzer (Siemens Dimension P Plus, Germany). All laboratory analyses were performed under strict quality control, with daily calibration and use of control samples.

### Statistical Analysis

Data were entered, cleaned, and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as frequencies and percentages for categorical variables, and as mean ± standard deviation (SD) for continuous variables. The prevalence of anemia and iron deficiency anemia was reported with 95% confidence intervals (CI). Associations between categorical variables (e.g., age group, gender, and anemia status) were assessed using the Chi-square test. A p-value of less than 0.05 was considered statistically significant.

## Results

A total of 366 school-aged children aged 6–14 years were included in this study, comprising 190 males (51.9%) and 176 females (48.1%). The overall prevalence of anemia (hemoglobin <12 g/dL) was 56.2% (n = 206; 95% CI: 51.1–61.2). Iron deficiency anemia (IDA) was identified in 32.7% (n = 120) of participants, while 10.3% (n = 38) had iron deficiency without anemia. Other types of anemia accounted for 23.4% (n = 86). No statistically significant association was found between gender and anemia (p = 0.548).

**Table 1: Prevalence of Anemia by Gender.**

Gender	Total (n)	Anemia n (%)	Non-Anemia n (%)	$\chi^2$	p-value
Male	190	104 (54.7%)	86 (45.3%)		
Female	176	102 (57.9%)	74 (42.1%)		
Total	366	206 (56.2%)	160 (43.8%)	0.36	0.548

**Table 2: Prevalence of Iron Deficiency Anemia (IDA) by Gender**

Gender	Total (n)	IDA n (%)	Non-IDA n (%)	$\chi^2$	p-value
Male	190	76 (40.0%)	114 (60.0%)		
Female	176	44 (25.0%)	132 (75.0%)		
Total	366	120 (32.7%)	246 (67.3%)	9.12	0.002

A statistically significant association was observed between gender and IDA ( $p = 0.002$ ), with higher prevalence among males.

**Table 3: Distribution of Anemia Types**

Condition	Frequency (n)	Percentage (%)
Iron deficiency anemia (IDA)	120	32.7
Iron deficiency only	38	10.3
Other types of anemia	86	23.4
Non-anemic	122	33.3
Total	366	100

A statistically significant association was found between age group and IDA ( $p = 0.034$ ), with the highest prevalence among children aged 6–7 years (42.6%).

**Table 4: Prevalence of Iron Deficiency Anemia (IDA) by Age Group**

Age Group (years)	Total (n)	IDA n (%)	Non-IDA n (%)	$\chi^2$	p-value
6–7	94	40 (42.6%)	54 (57.4)		
8–10	160	52 (32.5%)	108 (67.5)		
11–12	44	18 (40.9)	26 (59.1)		
13–14	68	10 (14.7)	58 (85.3)		
Total	366	120 (32.8)	246 (67.2)	8.67	0.034

No statistically significant association was observed between gender and ferritin levels ( $p = 0.091$ ).

**Table 5: Serum Ferritin Status by Gender**

Gender	Total (n)	Low Ferritin (<15 ng/mL) n (%)	Normal Ferritin ( $\geq 15$ ng/mL) n (%)	$\chi^2$	p-value
Male	190	90 (47.3%)	100 (52.7%)		
Female	176	68 (38.6%)	108 (61.4%)	2.85	0.091
Total	366	158 (43.2%)	208 (56.8%)		

## Discussion

The present study demonstrated that the overall prevalence of anemia among school-aged children in Tobruk was 56.2% (95% CI: 51.1–61.2), indicating a moderate to severe public health problem according to international classification. This prevalence is considerably higher than previously reported national estimates in Libya, where anemia prevalence among children has been reported at approximately 26.6%. This discrepancy may be explained by differences in age groups, study settings, and local socioeconomic and nutritional factors, particularly in eastern Libya. [7]. When compared with regional data, the findings of this study are consistent with previous reports from Tobruk and other parts of eastern Libya, where anemia prevalence has exceeded 50%, suggesting a persistent and localized public health burden. In contrast, studies conducted in other North African countries, such as Egypt and Morocco, have reported relatively lower prevalence rates. These variations may reflect differences in dietary patterns, healthcare access, and the effectiveness of nutritional intervention programs. [8] The prevalence of iron deficiency anemia (IDA) in this study was 32.7%, which is higher than global estimates among school-aged children, generally reported to be around 25%. This finding confirms that iron deficiency remains the leading cause of anemia in this population. The high proportion of children with low serum ferritin (43.2%) further supports the presence of inadequate iron stores, likely due to insufficient dietary intake of iron-rich foods, poor absorption, or increased physiological demands during growth [9].

A key finding of this study was the statistically significant association between gender and IDA ( $\chi^2 = 9.12$ ,  $p = 0.002$ ), with a higher prevalence observed among males (40.0%) compared to females (25.0%). This result differs from many international studies, which often report higher prevalence among females due to menstrual blood loss and increased iron requirements during adolescence. However, similar patterns have been observed in certain developing regions, where gender differences may be influenced by cultural dietary practices, differences in physical activity, or unequal distribution of nutritional resources [10].

The higher prevalence of IDA among males (40.0%) compared to females (25.0%) in this study contrasts with the conventional expectation that adolescent girls are at higher risk due to menstrual blood loss. However,

similar patterns have been reported in other Middle Eastern and North African settings [16]. Possible explanations include: (1) higher iron requirements in boys during rapid growth phases due to greater muscle mass expansion and red blood cell volume [17]; (2) cultural dietary practices where boys may consume more iron-absorption inhibitors such as tea with meals [18]; and (3) gender-biased healthcare seeking, where parents may perceive boys as healthier and delay seeking preventive care [19].

In contrast, the association between gender and overall anemia was not statistically significant ( $\chi^2 = 0.36$ ,  $p = 0.548$ ), indicating that while anemia affects both sexes similarly, iron deficiency as a specific cause shows gender-related variation. Additionally, serum ferritin levels did not differ significantly between males and females ( $\chi^2 = 2.85$ ,  $p = 0.091$ ), suggesting that factors beyond iron storage alone may contribute to the observed gender differences in IDA [11].

The study also demonstrated a statistically significant association between age group and IDA ( $\chi^2 = 8.67$ ,  $p = 0.034$ ), with the highest prevalence observed among younger children aged 6–7 years. This finding is consistent with previous studies indicating that younger children are more vulnerable to iron deficiency due to rapid growth, increased nutritional requirements, and often inadequate dietary intake. Furthermore, early childhood is a critical period where nutritional deficiencies can have long-term consequences on cognitive and physical development [12]. The relatively high proportion of children with iron deficiency without anemia (10.3%) highlights the importance of early detection before progression to overt anemia. This emphasizes the need for screening programs that include biochemical markers such as serum ferritin, rather than relying solely on hemoglobin levels [13]. Overall, the findings of this study confirm that anemia and iron deficiency anemia remain significant public health challenges among school-aged children in Tobruk. The high prevalence, particularly among younger children and males, underscores the urgent need for targeted interventions, including nutritional education, iron supplementation programs, and routine school-based screening. Addressing these factors is essential to reduce the burden of anemia and improve health outcomes in this population. [14]

The findings of this study have several practical implications. First, routine school-based screening for anemia should be implemented in Tobruk, targeting children aged 6–7 years who are at highest risk. Second, nutritional education programs should emphasize iron-rich foods (red meat, legumes, dark leafy greens) and enhancers of iron absorption (vitamin C), while discouraging consumption of tea with meals. Third, weekly iron-folic acid supplementation should be considered for high-risk groups, particularly young boys and preadolescent children. Finally, given that 10.3% of children had iron deficiency without anemia – a condition also associated with cognitive impairment [20] screening programs should include ferritin testing, not only hemoglobin measurement.

### Limitations

This study has several limitations. First, the cross-sectional design does not allow causal inference. Second, the study was limited to children in Tobruk and may not represent all Libyan children. Third, dietary intake, parasitic infections, and socioeconomic factors were not comprehensively assessed. Finally, inflammatory markers such as C-reactive protein were not measured, which may affect interpretation of serum ferritin levels.

### Conclusion

Iron deficiency anemia is highly prevalent (32.7%) among school-aged children in Tobruk, representing a moderate-to-severe public health problem according to WHO classification. Younger children (aged 6–7 years) and males are at particularly high risk. These findings underscore the urgent need for targeted, school-based interventions, including regular screening for anemia and iron deficiency, iron supplementation for high-risk groups, nutritional education for families and teachers, and deworming programs. Without prompt action, the long-term cognitive and developmental consequences of childhood IDA will continue to affect Libya's future generations. Future longitudinal studies should investigate the dietary, socioeconomic, and infectious determinants of IDA in this population.

### Conflict of interest

None declared

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