

Original Article

Association Between Age, Body Mass Index, and Iron Deficiency Anemia Among Libyan Children

Haloom Elhashmi^{1*}, Fatma Aldarat²¹Department of Pediatrics, Faculty of Medicine, University of Benghazi, Libya²Department of Laboratory Medicine, Clinical Hematopathology, Benghazi Medical Center, LibyaCorrespondence Email. haloum.elhashmi@uob.ly

Abstract

Nutritional deficiencies in children can be reflected in growth parameters, such as body weight, height, and Body Mass Index (BMI). Iron Deficiency Anemia (IDA) is the most common nutritional deficiency manifested in various BMI categories. Aim: The present study evaluated the association between age, BMI, and iron deficiency anemia among Libyan children. An observational retrospective study was conducted at the pediatric hematology clinic, Benghazi Medical Center, Libya, from December 1, 2019, to December 31, 2024. This study of 128 Libyan children aged 2-16 years with low iron status collected data including demographic parameters (age and sex), and hemoglobin and serum ferritin were recorded, and anthropometry (weight, height, and BMI), and three nutritional anthropometric categories (healthy weight, underweight, and overweight). We assess the association between age, IDA, and BMI. The data were analyzed using SPSS 27.0, and the statistical significance level was considered as 0.05. The rate of IDA is 66.4%, and age ≥ 12 years had the highest proportion of IDA, with a statistically significant association between age group and IDA ($\chi^2 = 14.155$, $p = 0.001$), and the majority (70%) of IDA children had normal BMI (healthy weight). However, there is no statistically significant association between BMI category and IDA ($\chi^2 = 1.274$, $p = 0.529$). A healthy weight was most common among 12- to 16-year-olds, with a statistically significant association between age group and BMI category ($\chi^2 = 10.300$, $p = 0.036$). Our study shows no association between BMI and IDA. Iron deficiency anemia is more common among healthy children. This study emphasizes the necessity of screening for IDA, irrespective of the nutritional status, especially in the risk age group, teenagers, preschoolers, and adolescents.

Keywords. Children, Iron Deficiency Anemia, Body Mass Index, Libya.

Introduction

Iron deficiency anemia (IDA) is the most common anemia globally, affected 30% of the population [1]. It poses a significant health challenge, particularly in developing nations. IDA accounts for about 50% of anemias [2]. It is frequently observed in children aged 6 to 59 months, who account for 40% of childhood iron deficiency anemia (IDA) [3]. Severe IDA results in poor cognitive, growth, and motor development in young children, and it decreases school performance in school-age children [4-7].

Iron deficiency anemia could be due to a poor iron diet, excessive or chronic bleeding, increased physiological demand, such as in the infant and adolescent age group [8]. Anthropometric parameters serve as indicators of nutritional status and encompass measurements such as weight, height, and body mass index, which are analyzed in relation to age and sex. BMI is an indicator of body fat percentage and a measure of an individual's weight relative to their height for age and sex [9]. Body Mass Index (BMI) is categorized into underweight, healthy weight, overweight, and obese.

Ideally, a normal child has a healthy weight; a shift of BMI out of the normal percentile range for age and sex is an indicator of a major health problem. Underweight: BMI is below the 5th percentile for age, gender, and height. Healthy weight: BMI is equal to or greater than the 5th percentile and less than the 85th percentile for age, gender, and sex. Overweight: BMI is at or above the 85th percentile but less than the 95th percentile for age, gender, and sex. Obese: BMI is at or above the 95th percentile for age, gender, and sex [10]. The prevalence of iron deficiency anemia is higher among underweight and overweight/obese people compared to those with normal BMI. Co-existence of iron deficiency and malnutrition, either undernutrition and overweight or obesity, has been reported, and they inflict a double burden on the affected children. They result in long-term sequelae and mortality among affected children. Iron deficiency anemia and body mass index (BMI) were indirectly associated. In an overweight or obese child, an elevated BMI is associated with increased hepcidin production, a master hormone of iron regulation, which controls iron delivery to the bloodstream. An increase in hepcidin inhibits iron absorption and recycling of iron by macrophages, eventually leading to iron deficiency anemia [11].

An obese patient has an excess of adipose tissue, which is associated with inflammation, resulting in low iron status observed in obese adults [12, 13]. Increased adipose tissue leads to macrophage infiltration and inflammatory cytokines, such as interleukin-6, which stimulate the synthesis of ferritin and hepcidin, an inflammatory marker; hepcidin is the master regulator of iron [12]. Hepcidin prevents intestinal iron absorption and macrophage iron release, resulting in low serum iron levels [13]. The underweight children, especially the preschool and teenage age groups, are at risk of iron deficiency with subsequent iron deficiency anemia [14,15].

In adolescents, age as well as their abnormal body mass index are the main predisposing risk factors for IDA [16,17], and overweight or obese children and adolescents also have high BMI, which leads to abnormally low iron status and thus increased risk of anemia [18,19]. Nutritional deficiencies, including iron, zinc, and vitamins, were commonly associated with undernutrition in children and young people. Overnutrition increased the risk of ID, with an inverse relationship observed between iron status and body weight [20]. Our study aimed to evaluate the association between age, BMI, and iron deficiency anemia among Libyan children.

Methods

Study design and participants

This is a retrospective study of 128 children aged 2- 16 years with low iron status, followed up at the pediatric hematology clinic at Benghazi Medical Centre, Benghazi, Libya, from December 2019 to December 2024. The collected study data in follow-up form included age, gender, weight, height, Hemoglobin (Hb), and serum ferritin.

Study Population and Sample Size

A total of 128 Libyan children aged 2–16 years with latent iron deficiency (ID) were enrolled and followed up at the pediatric hematology clinic. Eligibility was restricted to children within the specified age range who had documented iron deficiency and were under regular follow-up at BMC between January 2019 and August 2024.

Exclusion Criteria

Children were excluded if they presented with infection, chronic disease, inflammation, hematological disorders other than latent iron deficiency or iron deficiency anemia, incomplete or missing data, febrile illness with elevated C-reactive protein (CRP), or if they did not meet the inclusion criteria (e.g., age <2 years or >16 years, absence of iron deficiency).

Classification of Iron Status

All enrolled children with low serum ferritin levels were classified as having iron deficiency (ID). Those with concomitant low hemoglobin levels, adjusted for age, were categorized as iron deficiency anemia (IDA).

Definitions and Cut-Offs

Iron deficiency was defined according to World Health Organization (WHO) guidelines: plasma ferritin <12 µg/L or <30 µg/L in the presence of inflammation for children <5 years, and <15 µg/L or <70 µg/L in the presence of inflammation for children ≥5 years [21].

Anemia was diagnosed and graded based on WHO hemoglobin thresholds for age and sex [22]:

- Children 6–23 months: <10.5 g/dl
- Children 24–59 months: <11.0 g/dl
- Children 5–11 years: <11.5 g/dl
- Children 12–14 years (boys and non-pregnant girls): <12.0 g/dl

Accordingly, the study population was stratified into two groups: iron deficiency (ID) and iron deficiency anemia (IDA).

The anthropometric measurements

The anthropometric measurements, including weight, height, and body mass index, were estimated using the formula: body mass (kg)/height (m²) in line with the World Health Organization.

Measures were plotted using the WHO growth charts for ages 2–20. Organization's (WHO) criteria for the classification of underweight, healthy, overweight, and obesity. Under-weight: BMI is below the 5th percentile for age, gender, and height. Healthy weight: BMI is equal to or greater than the 5th percentile and less than the 85th percentile for age, gender, and sex. Overweight: BMI is at or above the 85th percentile but less than the 95th percentile for age, gender, and sex. Obese: BMI is at or above the 95th percentile for age, gender, and sex [23].

Statistical Analysis

Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 27[24]. Descriptive statistics were used to summarize participants' characteristics. Categorical variables such as age group, sex, BMI category, and iron deficiency status, including iron deficiency(ID) and iron deficiency anemia (IDA), were presented as frequencies and percentages. The association between categorical variables and ID status was assessed using the chi-square (χ^2) test. When appropriate, Fisher's exact test was considered for 2×2 tables. A p-value of less than 0.05 was considered statistically significant.

Crude odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to estimate the strength and direction of the association between independent variables (age group and sex) and iron deficiency status

categories, using reference categories for comparison. The odds ratios were computed from 2×2 contingency tables.

Results

A total of 128 children were included in the study, with ages ranging from 2 to 16 years (mean = 6.87 ± 4.09 years). Nearly half of the participants (44.5%) were aged 5–11 years, while 39.1% were between 2–4 years and 16.4% were between 12–16 years. More than half of the children were females, representing 53.5% of the sample, while males accounted for 46.5% (Table 1).

Table 1. Demographic Characteristics of the Study Children

Variable	Category	Frequency (n)	Percentage (%)
Age Group (years)	2–4	50	39.1
	5–11	57	44.5
	≥12	21	16.4
Sex	Female	69	53.5
	Male	60	46.5

Table 2 shows the distribution of participants by age group and sex. In the 2–4 years age group (n = 50), males were slightly more represented (56.0%) than females (44.0%). In contrast, females were more represented in the 5–11 age group (57.9%) compared to males (42.1%). The highest proportion of females was observed in the ≥12 years age group, where females accounted for 66.7% and males 33.3%.

Table 2. Distribution of Participants by Age Group and Sex

Age Group	Female n (%)	Male n (%)	Total n (%)
2–4 years	22 (44.0%)	28 (56.0%)	50 (39.1%)
5–11 years	33 (57.9%)	24 (42.1%)	57 (44.5%)
≥12 years	14 (66.7%)	7 (33.3%)	21 (16.4%)
Total	69 (53.9%)	59 (46.1%)	128 (100%)

The mean body weight was 24.24 ± 12.41 kg, and the mean height was 120.59 ± 23.27 cm. The average body mass index (BMI) was 15.76 ± 3.35 kg/m² (Table 3).

Table 3. Descriptive Statistics of Anthropometric

Variable	Minimum	Maximum	Mean	Standard Deviation (SD)
Weight (kg)	9	66	24.24	12.41
Height (cm)	89	161	120.59	23.27
BMI (kg/m ²)	11	37	15.76	3.35

As presented in Table 4, the majority of children (62.5%) had a healthy weight according to BMI classification. However, a considerable proportion (32.0%) were underweight, indicating a notable burden of undernutrition in the study population. Only a small percentage of children were classified as overweight (5.5%) (Table 4).

Table 4. Distribution of Body Mass Index (BMI) Categories Among Children

BMI Category	Frequency (n)	Percentage (%)
Healthy weight	80	62.5
Underweight	41	32.0
Overweight	7	5.5
Total	128	100.0

The prevalence of IDA differed across age groups: Age ≥12 years had the highest proportion of IDA (85.7%), followed by Age 2–4 years (78.0%), while Age 5–11 years had the lowest prevalence (49.1%). A Pearson Chi-square test showed a statistically significant association between age group and IDA status ($\chi^2 = 14.155$, $p = 0.001$) (Table 5).

Table 5. Association Between Age Group and IDA Status

Age	IDA n (%)	ID n (%)	Total n (%)	χ^2	p-value
2–4 years	39 (78.0%)	11 (22.0%)	50 (39.1%)	14.155	0.001
5–11 years	28 (49.1%)	29 (50.9%)	57 (44.5%)		
≥12 years	18 (85.7%)	3 (14.3%)	21 (16.4%)		
Total	85 (66.4%)	43 (33.6%)	128 (100%)		

The prevalence of IDA was higher among females (71.0%) compared to males (61.0%). However, a Pearson Chi-square test showed that this difference was not statistically significant ($\chi^2 = 1.425$, $p = 0.233$) (Table 6).

Table 6. Association Between Sex and IDA Status

Sex	IDA n (%)	ID n (%)	χ^2	p-value
Female	49 (71.0%)	20 (29.0%)	1.425	0.233
Male	36 (61.0%)	23 (39.0%)		
Total	85 (66.4%)	43 (33.6%)		

Of the 128 children included in the study, 85 children (66.4%) were diagnosed with iron deficiency anemia (IDA), while 43 children (33.6%) had iron deficiency (ID) without anemia (Table 7).

Table 7. Distribution of Iron Deficiency Status

Diagnosis	Frequency (n)	Percentage (%)
Iron Deficiency (ID)	43	33.6
Iron Deficiency Anemia (IDA)	85	66.4
Total	128	100.0

The prevalence of IDA varied significantly across age groups, with the ≥12 years (85.7%) and 2–4 years (78.0%) showing higher proportions than the 5–11 years group (49.1%). The association between age group and IDA was statistically significant ($\chi^2 = 14.155$, $p = 0.001$). In contrast, although females had a higher prevalence of IDA (71.0%) compared to males (61.0%), the association between sex and IDA was not statistically significant ($\chi^2 = 1.425$, $p = 0.233$). This indicates that the age group is significantly associated with IDA status, whereas sex is not significantly associated with IDA in this study (Table 8).

Table 8. Association Between Age, Sex, and Iron Deficiency Status

		IDA n (%)	ID n (%)	χ^2	p-value
Age	2–4 years	39 (78.0%)	11 (22.0%)	14.155	0.001
	5–11 years	28 (49.1%)	29 (50.9%)		
	≥12 years	18 (85.7%)	3 (14.3%)		
Sex	Female	49 (71.0%)	20 (29.0%)	1.425	0.233
	Male	36 (61.0%)	23 (39.0%)		

Among the study population with a healthy weight, 56 (70.0%) had iron deficiency anemia (IDA), while 24 (30.0%) had ID. In the underweight group, 25 (61.0%) had IDA and 16 (39.0%) had only ID. Similarly, among overweight students, 4 (57.1%) had IDA, whereas 3 (42.9%) had ID. Overall, 85 (66.4%) of the total participants had IDA, and 43 (33.6%) had ID. The chi-square test showed no statistically significant association between BMI category and IDA ($\chi^2 = 1.274$, $p = 0.529$), indicating that the prevalence of IDA did not significantly differ across BMI categories in this study (Table 9).

Table 9. Association Between BMI Categories and Iron Deficiency Status

BMI Category	ID n (%)	IDA n (%)	χ^2	p-value
Healthy weight	24 (30.0%)	56 (70.0%)	1.274	0.529
Underweight	16 (39.0%)	25 (61.0%)		
Overweight	3 (42.9%)	4 (57.1%)		
Total	43 (33.6%)	85 (66.4%)		

Among the 128 participants, the association between age, sex, and iron deficiency anemia (IDA) was examined using crude odds ratios. Using the 2–4 age group as the reference category, children aged 5–11 years had lower odds of IDA (OR = 0.56, 95% CI: 0.23–1.37), while those aged 12–16 years had nearly similar odds (OR = 0.99, 95% CI: 0.38–2.56). Regarding sex, females had 1.57 times higher odds of having IDA compared to males (OR = 1.57, 95% CI: 0.74–3.31). Since all confidence intervals include 1, neither age nor sex showed a statistically significant relationship with IDA in this study (Table 10).

Table 10. Odds Ratios for the Association Between Age, Sex, and IDA Status

Variable	Category	OR	95% CI
Age (Years)	2–4 (Ref)	1.00	—
	5–11	0.56	0.23 – 1.37
	12–16	0.99	0.38 – 2.56
Sex	Male (Ref)	1.00	—
	Female	1.57	0.74 – 3.31

Among females, 69.6% were of a healthy weight, 26.1% were underweight, and 4.3% were overweight, whereas among males, 54.2% were of a healthy weight, 39.0% were underweight, and 6.8% were overweight. Although underweight was more common among males and healthy weight among females, the Pearson Chi-square test showed that this difference was not statistically significant ($\chi^2 = 3.191$, $p = 0.203$) (Table 11).

Table 11 Association Between BMI Category and Sex

BMI	Female n (%)	Male n (%)	Total n (%)	χ^2	p-value
Healthy weight	48 (60.0%)	32 (40.0%)	80 (62.5%)	3.191	0.203
Underweight	18 (43.9%)	23 (56.1%)	41 (32.0%)		
Overweight	3 (42.9%)	4 (57.1%)	7 (5.5%)		
Total	69 (53.9%)	59 (46.1%)	128 (100%)		

Healthy weight was most common among 12–16-year-olds (85.7%), followed by 5–11-year-olds (61.4%) and 2–4-year-olds (54.0%). Underweight was most prevalent in the age group 2–4 years (44.0%), while overweight was relatively more common in the age group 5 to 11 years (8.8%). The Pearson Chi-square test showed a statistically significant association between age group and BMI category ($\chi^2 = 10.300$, $p = 0.036$) (Table 12).

Table 12. Association Between Age Group and BMI Category

BMI	2–4 years n (%)	5–11 years n (%)	12–16 years n (%)	Total n (%)	χ^2	p-value
Healthy weight	27 (54.0%)	35 (61.4%)	18 (85.7%)	80 (62.5%)	10.30	0.036
Underweight	22 (44.0%)	17 (29.8%)	2 (9.5%)	41 (32.0%)		
Overweight	1 (2.0%)	5 (8.8%)	1 (4.8%)	7 (5.5%)		
Total	50 (39.1%)	57 (44.5%)	21 (16.4%)	128 (100%)		

Discussion

IDA is a major health issue worldwide, especially in developing countries such as Libya. It can be a double burden problem coexisting with other malnutritional problems, such as being overweight or underweight. This study investigated the associations between age, BMI, and IDA in Libyan children. The current study of our low iron status children shows that the prevalence of IDA anemia was 66.4 %, while 43.6% had ID. This indicates the IDA is more common than latent ID in our population study, explained by low educational level regarding IDA and absence of screening, and improper management programs, which make IDA a significant health problem in our society. The highest prevalence of IDA (85.7%) was among children aged ≥ 12 years, followed by (78.0%) in 2–4-year-old children. This indicates children aged ≥ 12 years were more likely to be anemic than the younger age group, with a significant association of IDA with age (It is inconsistent with a recent study in Nepal, a past study in Rwanda, and in Kenya, which reported that younger children were more likely to develop anemia than older children [25 - 27]).

In the current study, the older adolescent children are more prone to developing IDA. This can be elucidated by age-related risk factors associated with IDA, as individuals aged 12 years and older are in puberty, a stage characterized by heightened physiological iron requirements for muscle building, hemoglobin synthesis, and the pubertal growth spurt [28]. A low iron and vitamins diet for these children is a causative factor of nutritional deficiencies, including IDA. Furthermore, menstrual bleeding serves as an additional

contributing factor to IDA in adolescent females, resulting in iron deficiency and finally IDA.[29]. Our study also shows that female children are slightly more likely than males to be anemic, with no significant association of IDA with gender.

Among the study population a significant proportion, nearly 2/3 (70.0%) of our healthy weight study group had iron deficiency anemia (IDA), followed by (61.0%) of underweight and overweight (57.1%), which shows an insignificant difference between the frequencies of IDA in healthy and undernourished children, and with no significant association between BMI and IDA in Libyan children ($p = 0.529$). Our finding, supported by Kamruzzaman M's (2021) study, and Ripa Chakma, et al, studies which finding no association between BMI and anemia among the children [30] [31], and study in Jordan, which revealed that 60.7% of anemic adolescent girls had a normal BMI, and no significant association was found between BMI categories and anemia [32]and is consistent with findings in Kuwait, where overweight/obesity did not play a major role in anemia among adolescents [33]. This finding is inconsistent with Tazeen Khan et al.'s (2018) study, which found that abnormal body mass index, either underweight or overweight/obesity, has a risk of iron deficiency anemia. While a normal body mass index (healthy weight) has a positive correlation between the body mass index (BMI) and hemoglobin concentration [34]. Our study shows that (61.0%) underweight children had IDA, which is consistent with Agho, K.E et al (2024) study, and Tatala, S et al. (2008) study, which found that underweight children had an increased risk of developing anemia [35,36].

Limitations

This is a retrospective study of only iron-deficient children who follow up at the hematology clinic; it is only in a single health center with a small number of patients. This research was conducted among children with iron deficiency who attended the hematology clinic, thus limiting it to a single health center and a limited number of patients.

Conclusion

Iron deficiency anemia is a significant public health dilemma in our country, more common among healthy children. This study heigh light to the necessity of screening for IDA, even in otherwise healthy children, especially in the risk age group, teenagers, preschoolers, and adolescents. Health care providers need targeted public health programs, including education, screening, supplementation, and food fortification, for all children regardless of their nutritional status, especially risk groups, to improve children's health and prevent short and long-term sequelae.

Author Contributions

Haloom Abdel Salam Elhashmi conceived & design of the study, contributed data or analysis tools, performed the analysis/ interpretation of data, drafted the manuscript, revised for important intellectual context, and approved the final version of the manuscript. Fatma Aldarat collected the data, contributed data or analysis tools, and provided approval of the final version of the manuscript.

Ethics

Ethical approval for this retrospective study was obtained from the Faculty of Medicine, University of Benghazi, ethics committee. The patient consent was waived as this was a retrospective chart review.

Conflicts of Interest: The authors declare no conflict of interest.

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