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Impaired pulmonary function in school-aged children with iron deficiency anemia: a comparative observational study

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ABSTRACT

Background and objectives. Iron deficiency anemia is a common disorder that may affect teenagers. Low hemoglobin impairs tissue oxygenation and organ function, including the respiratory system. This study aimed to evaluate the possible role of iron deficiency anemia in impaired respiratory function in school-aged children.

Materials and methods. This comparative observational study was conducted in Basrah, Iraq. Participants were categorized into two groups. Group 1 included 30 patients (15 males and 15 females) with iron deficiency anemia (mean age 13.97 ± 0.93 years). Group 2 included 50 healthy individuals (24 males and 26 females) as a control group (mean age 14.28 ± 1.11 years). Complete blood count was measured using a hematology analyzer. Pulmonary function was assessed by spirometry following standard procedures, measuring forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio. Statistical analysis was conducted using independent-samples t tests and bivariate correlation analysis; $p < 0.05$ was considered statistically significant.

Results. Children with iron deficiency anemia showed significantly lower red blood cell count, hemoglobin concentration, mean corpuscular volume, and mean corpuscular hemoglobin concentration compared with controls (all $p < 0.05$). Spirometric assessment demonstrated significantly reduced FEV_1 (3.11 ± 0.39 vs. 3.33 ± 0.38 L, p = 0.017) and FVC (3.60 ± 0.50 vs. 3.97 ± 0.40 L, p = 0.001) in the anemic group. The FEV_1/FVC ratio also differed significantly between groups (p = 0.016). In the anemic group, hemoglobin and red blood cell count showed significant positive correlations with FEV_1 and FVC, indicating an association between anemia severity and reduced pulmonary function.

Conclusion. Iron deficiency anemia in school-aged children is associated with significant impairment of spirometric parameters, suggesting a detrimental effect on respiratory function. Early detection and correction of anemia may help preserve pulmonary health in this population.

Keywords: iron deficiency anemia, spirometry, pulmonary function, adolescents, school-aged children

INTRODUCTION

Global health recognizes iron deficiency as a serious health problem, affecting 20%–50% of the worldwide population, making it the most prevalent nutritional deficiency [1,2]. Anemia affects all age groups; however, it is more prevalent in adolescents and pregnant women [3,4]. It may impair immune responses and alter pathogen metabolism and growth. Low hemoglobin levels impede tissue oxygenation and organ function, which may increase susceptibility to respiratory tract infections [5].

Approximately 50% of anemia in developing countries is iron deficiency anemia [1], and it is among the most prevalent conditions in children and adolescents [2]. Iron is an essential trace element for children's health, playing a critical role in cellular respiration and oxygen transport. It is required for DNA synthesis, protein metabolism, and immune function [6]. Furthermore, iron deficiency anemia may impair growth and development and reduce immunity, cognitive abilities, and academic achievement [5,7]. Children with iron deficiency anemia may

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be more susceptible to acute infections such as acute respiratory tract infection, urinary tract infection, and gastroenteritis [7,8].

The association between acute respiratory tract infection and iron deficiency may be attributed to inflammatory mediators such as tumor necrosis factor alpha (TNF-α), interferon gamma (IFN-γ), interleukin-1β (IL-1β), and IL-6. These mediators activate monocytes and neutrophils to synthesize iron metabolism proteins such as hepcidin, siderocalin, haptoglobin, and hemopexin, which reduce duodenal iron absorption [2,9].

Altered iron homeostasis has been implicated in the pathophysiology of multiple systems, including the respiratory system [10]. However, the relationship between iron deficiency anemia and impaired respiratory function remains unclear in children and adolescents. Therefore, this study was conducted to evaluate the impact of iron deficiency anemia on respiratory function tests in school-aged children.

PATIENTS AND METHODS

Patients

This comparative observational study was conducted in Basrah, Iraq, and was approved by the local ethics committee of the College of Medicine, University of Basrah. Participants were intermediate school students selected randomly from those attending the school health care unit. Age- and sex-matched healthy children were included as a control group.

Participants were aged 13–16 years. Group 1 (anemic group) included 30 patients (15 males and 15 females) with iron deficiency anemia, as recorded in the school health care unit medical files (mean age 13.97 ± 0.93 years). Group 2 (control group) included 50 healthy individuals (24 males and 26 females) (mean age 14.28 ± 1.11 years).

Individuals with physical abnormalities, obesity, allergic diseases, bronchial asthma, chronic diseases, or a history of major surgery were excluded. Information was collected using a questionnaire, and written informed consent was obtained from the parents of each participant.

Methods

Spirometric parameters were recorded using a spirometer (MIR Spirolab III Diagnostic Spirometer, England). The device was calibrated daily. Spirometry was performed for all participants in the morning (8:00–11:00 AM) in the sitting position after recording age, sex, height, weight, and ethnic group. The test was repeated at least three times for each participant, and the best result was used for analysis. The American Thoracic Society (ATS) and European Respiratory Society (ERS) guidelines were followed. All maneuvers were performed by the same physician. Parameters included FEV1 (forced expiratory volume in 1 second), FVC (forced vital capacity), and FEV1/FVC (%).

A 2 mL venous blood sample was drawn from each participant and collected in an EDTA tube for blood parameter measurements. Complete blood count was performed using a hematology analyzer (Ruby, Germany). Iron deficiency anemia was defined according to WHO criteria: hemoglobin <12 g/dL in females and <13 g/dL in males.

Statistical analysis

SPSS (version 20) was used for analysis. Normality of continuous variables was assessed using the Shapiro–Wilk test. Group differences in means were tested using the independent-samples t test, and differences in proportions were tested using the chi-square (χ^2) test. Correlations between hematological indices and spirometric parameters were evaluated using bivariate correlation analysis. Statistical significance was defined as $p < 0.05$.

RESULTS

TABLE 1. Demographic characteristics of the participitants

Parameter	Anemic group (n = 30)	Control group (n = 50)	p-value
Age (year), mean ± SD	13.97 ± 0.92	14.28±1.11	0.17*
Sex, n (%)			1.00**
Male	15 (50%)	24 (48%)	
Female	15 (50%)	26 (52%)	
Weight (kg), mean ± SD	46.10 ± 5.26	47.90 ± 4.74	0.13*

**Independent-samples T test*
***Chi square test*

As shown in Table 1, age, sex distribution, and body weight did not differ significantly between the anemic and control groups (p = 0.17, p = 1.00, and p = 0.13), indicating that the groups were well matched.

The anemic group had significantly lower red blood cell count (2.72 ± 0.49 vs. 3.83 ± 0.84 × 10^6/mm^3, p < 0.001), hemoglobin concentration (7.53 ± 1.03 vs. 10.86 ± 1.20 g/dL, p < 0.001), mean corpuscular volume (73.43 ± 4.98 vs. 76.32 ± 4.47 fL, p = 0.012), and mean corpuscular hemoglobin concentration (25.92 ± 3.28 vs. 29.39 ± 2.31 g/dL, p < 0.001) compared with the control group. No significant differences were observed in mean corpuscular hemoglobin (27.20 ± 1.68 vs. 27.56 ± 2.27 pg, p = 0.430), total white blood cell count (4.23 ± 1.76 vs. 4.36 ± 1.42 × 10^3/mm^3, p = 0.717), or lymphocyte count (1.65 ± 0.78 vs. 1.56 ± 0.65 × 10^3/mm^3, p = 0.633). In contrast, monocyte (0.42 ± 0.22 vs. 0.57 ± 0.25 × 10^3/mm^3, p = 0.006) and neutrophil counts (2.66 ± 0.81 vs. 3.79 ±

TABLE 2. Blood parameters of the studied groups

Parameter	Anemic group (n = 30)	Control group (n = 50)	p-value*
RBC (×10^6/mm^3)	2.72 ± 0.49	3.83 ± 0.84	<0.001
Hb (g/dL)	7.53 ± 1.03	10.86 ± 1.20	<0.001
MCV (fL)	73.43 ± 4.98	76.32 ± 4.47	0.012
MCH (pg)	27.20 ± 1.68	27.56 ± 2.27	0.430
MCHC (g/dL)	25.92 ± 3.28	29.39 ± 2.31	<0.001
WBC (10^3/mm^3)	4.23 ± 1.76	4.36 ± 1.42	0.717
Lymphocytes (×10^3/mm^3)	1.65 ± 0.78	1.56 ± 0.65	0.633
Monocytes (×10^3/mm^3)	0.42 ± 0.22	0.57 ± 0.25	0.006
Neutrophils (×10^3/mm^3)	2.66 ± 0.81	3.79 ± 1.11	<0.001

**Independent-samples T test*

TABLE 3. Comparisom of spirometric parameters between the studied groups

Parameter	Anemic group (n = 30)	Control group (n = 50)	p-value*
FEV_1 (L)	3.11 ± 0.39	3.33 ± 0.38	0.017
FVC (L)	3.60 ± 0.50	3.97 ± 0.40	0.001
FEV_1/FVC%	86.64 ± 4.81	83.94 ± 4.33	0.016

Abbreviations: *FEV_1, forced expiratory volume in the first second; FVC, forced vital capacity*
**Independent-samples T test*

1.11 × 10³/mm³, p < 0.001) were significantly lower in the anemic group.

Spirometric parameters

Children with iron deficiency anemia demonstrated significantly reduced spirometric values compared with controls. Forced expiratory volume in one second (FEV_1) was lower in the anemic group (3.11 ± 0.39 vs. 3.33 ± 0.38 L, p = 0.017), as was forced vital capacity (FVC) (3.60 ± 0.50 vs. 3.97 ± 0.40 L, p = 0.001). The FEV_1/FVC ratio also differed significantly between groups (86.64 ± 4.81 vs. 83.94 ± 4.33%, p = 0.016) (Table 3).

Correlation analysis

Within the anemic group, hemoglobin concentration showed significant positive correlations with both FEV_1 (r = 0.35, p = 0.001) and FVC (r = 0.46, p < 0.001), while red blood cell count was also positively correlated with FEV_1 and FVC (r = 0.31 for both; p = 0.005 for both) (Table 4). Mean corpuscular hemoglobin concentration demonstrated significant positive correlations with FEV_1 (r = 0.25, p = 0.023) and FVC (r = 0.30, p = 0.006). Mean corpuscular volume was positively correlated with FEV_1 (r = 0.25, p = 0.021) but not with FVC (p = 0.058). A significant negative correlation was observed between hemoglobin concentration and the FEV_1/FVC ratio (r = −0.28, p = 0.01). No significant correlations were identified between spirometric parameters and mean corpuscular hemoglobin.

TABLE 4. Correlation of blood parameters with spirometric results in anemic group (n = 30)

Parameter		FEV_1	FVC	FEV_1/FVC, %
Hb	r value	0.350	0.460	-0.280
	p-value*	0.001	<0.001	0.010
RBC	r value	0.310	0.310	-0.030
	p-value*	0.005	0.005	0.744
MCV	r value	0.250	0.210	0.070
	p-value*	0.021	0.058	0.496
MCH	r value	-0.050	-0.010	-0.090
	p-value*	0.607	0.886	0.394
MCHC	r value	0.250	0.300	-0.170
	p-value*	0.023	0.006	0.124

**Bivariate correlation test*

DISCUSSION

Anemia is one of the most common conditions affecting human health, socioeconomic development, and overall well-being, and it remains a major public health concern, particularly among women and children [11]. One of the most prevalent causes of anemia is inadequate nutrition. Iron deficiency anemia is especially common among children and adolescents [9,12]. Low hemoglobin levels have been linked to impaired tissue oxygenation and may adversely affect pulmonary function [12,13]. Pulmonary function tests play an important role in the diagnosis and management of respiratory and systemic illnesses [14].

In the present study, iron deficiency anemia was associated with impaired spirometric parameters in school-aged children. The anemic and control groups were comparable in age and sex distribution, and the anemic group showed lower pulmonary function indices, which may be explained by reduced oxygen-carrying capacity due to decreased hemoglobin concentration. Serum iron is essential for hemoglobin synthesis and normal metabolism; therefore, hemoglobin-mediated oxygen transport can directly influence respiratory performance [15].

In this study, spirometric parameters (FEV_1, FVC, and FEV_1/FVC%) were significantly reduced in anemic students. This finding is consistent with the study by Zahra et al., which reported significant reductions in spirometric parameters in patients with microcytic anemia [16]. Similarly, Mohamed et al. concluded that children and adolescents with iron deficiency anemia were more likely to develop respiratory disorders [17]. These observations support the concept that iron deficiency, through impaired hemoglobin synthesis, may negatively influence overall physiological status, including respiratory function [18].

In children, iron deficiency may lead to behavioral and learning impairment and may alter heat production, muscle metabolism, and catecholamine levels. Additionally, iron deficiency can reduce immune function, predisposing individuals to several conditions, including respiratory disease [10,12]. Bronchial asthma and other atopic disorders are important public health conditions in children and are influenced by both genetic and environmental factors. Infection, allergen exposure, and medications are among recognized triggers. Some studies have suggested that bronchial asthma may be associated with dietary restriction and low serum iron in children; therefore, anemic patients may be more susceptible to asthma exacerbations and chest infections [10,12].

Several mechanisms may explain the association between anemia and asthma. Chronic inflammatory diseases are frequently accompanied by anemia [19]. In asthma, persistent inflammation may contribute to anemia through disruption of hepcidin regulation. Inflammatory mediators, including cytokines, can reduce iron availability and influence ferritin production. Cytokines such as TNF-α, IFN-γ, and IL-6 may reduce red blood cell production and survival or increase phagocytosis. IL-6 stimulates hepatic hepcidin production, thereby disturbing iron homeostasis [19–23]. In a case-control study, Bener et al. reported that anemia was more frequent among asthmatic children than among non-asthmatic controls [24]. Other studies have also indicated that low iron levels may occur in the context of respiratory tract infections [6,7]. In addition, Roma et al. concluded that anemia is an important risk factor for acute lower respiratory tract infection in children under five years of age and was more frequent among affected children [25]. These findings are consistent with the results reported by Ramakrishnan et al. in children younger than 16 years, where anemia was present in 74% of children with respiratory tract infection compared with 33% of healthy controls [7,26].

Regarding correlations between spirometric and hematological parameters, we observed significant positive correlations of FEV_1 and FVC with hemoglobin concentration, RBC count, and MCHC. In contrast, no significant correlation was observed between spirometric parameters (FEV_1, FVC, and FEV_1/FVC%) and MCH (Table 4). These findings suggest that reduced hemoglobin and related indices may contribute to impaired pulmonary function. Hemoglobin supports oxygen and carbon dioxide transport, participates in nitric oxide transport and regulation, and contributes to buffering; therefore, reduced hemoglobin may impair normal physiological function and activity [22]. Our findings are consistent with an Egyptian study reporting that anemia, particularly iron deficiency anemia, remains common in children and is significantly associated with acute lower respiratory tract infections. Early detection and management of anemia may help reduce lower respiratory infections and recurrence of chest infections, thereby improving respiratory function [27,28].

Limitations of the study

This study has limitations, including the relatively small sample size and the restricted geographic area from which participants were recruited. However, the inclusion of a healthy control group strengthens the comparative interpretation of the findings. Future research is recommended to include:

a) longitudinal cohort studies assessing progression over time;
b) randomized trials evaluating the effect of iron supplementation on lung function; and
c) assessment of inflammatory markers and oxidative stress in iron deficiency anemia–related pulmonary dysfunction.

CONCLUSION

Iron deficiency anemia is associated with significant impairment of respiratory function tests in school-aged children. Reduced hemoglobin levels may negatively affect pulmonary performance by limiting oxygen delivery to tissues. Early identification and appropriate management of iron deficiency anemia may help preserve respiratory function and reduce the risk of respiratory morbidity in this population.

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Conflict of interest:

The authors declare no conflicts of interest related to this study.

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