Original Research

EVALUATING THE RELATIONSHIP BETWEEN IRON DEFICIENCY ANEMIA AND INTELLIGENCE QUOTIENT IN SCHOOL AGED CHILDREN

Khursheed Ahmed Sahito*
*Assistant Professor of Pediatric Hematology & Oncology, Pir Abdul Qadir Shah Jilani Institute of Medical Sciences Gambat Pakistan.
Email: *drkhursheedsahito@gmail.com
Corresponding Author: Khursheed Ahmed Sahito
Assistant Professor of Pediatric Hematology & Oncology, Pir Abdul Qadir Shah Jilani Institute of Medical Sciences Gambat Pakistan.

Abstract
Objective: The study aimed to assess the influence of iron deficiency anemia (IDA) on intelligence quotient (IQ) in school aged children in the population.
Study Design: This was a cross-sectional study
Place and Duration: This study was conducted at Pir Abdul Qadir Shah Jilani Institute of Medical Sciences Gambat from January 2025 to January 2026.
Methods: A cross sectional study was conducted in 110 children (7-11 years). Socio demographic data were obtained from a questionnaire. Venous blood samples were collected in EDTA and gel tubes. Full blood count (FBC) was done by an automated blood cell counter and serum ferritin by electrochemiluminescence immunoassay (ECLIA). The Raven Colored Progressive Matrices (RCPM) was used to assess cognitive function. The statistical analysis was done using SPSS 26 software.
Results: Of the 110 children, 48 (43.6%) were females and 62 (56.4%) were males. The incidence of IDA was 10.9%. The mean IQ of children from nuclear families was higher (55.8 ± 35.9) than those from joint families (36.2 ± 33.8). Male children showed a slightly higher mean IQ (42.5 ± 34.7) than females (39.8 ± 36.9). In terms of nutritional status, 44 (40.0%) were of normal weight, 22 (20.0%) were obese and 44 (40.0%) were underweight. Hemoglobin and hematocrit were significantly different between children with below average IQ and average IQ. There was a significant difference in IQ scores of children with IDA and non anemic children. The average IQ, hemoglobin and ferritin levels in children with IDA were 10.4 ± 7.9 (percentile, standard deviation), 11.1 ± 0.41 g/dL and 9.2 ± 1.4 ng/mL, respectively.
Conclusion: Intelligence quotient of children in school is adversely affected by iron deficiency anemia. IQ scores of IDA children are significantly lower than that of children without anemia which calls for early diagnosis and nutritional support.

Keywords: Iron Deficiency Anemia, Intelligence Quotient, School-Going Children, Hemoglobin, Ferritin, Raven Colored Progressive Matrices.

INTRODUCTION
Iron deficiency anemia (IDA) is one of the most common nutritional disorders in the world and continues to present a significant public health burden in children of low and middle income countries. Iron is critical for oxygen transport, energy metabolism and neurotransmitter synthesis, and is required for optimal neurological development and function [1].

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School age children are a critical population group as they are at a period in life where high growth, high cognitive activity and poor dietary habits can all occur. As such, the effects of IDA on intelligence quotient (IQ) have emerged as an area of significant interest due to the potential implications on scholastic achievement, behavioural functioning and long term socioeconomic outcomes.
Iron deficiencies and cognitive deficits have been investigated for some time. Pioneering studies showed iron deficiency, even without anemia, can result in reduced attention, memory, and learning ability [2]. Iron plays an important role in the myelination, plasticity of synapses, and metabolism of dopamine, important in higher cognitive functioning [3]. Thus, children with IDA may have subtle impairments in problem solving, reasoning, and executive function. These impairments may persist after correction of the anemia, especially if

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the deficiency occurs during key stages of development [4].

The global burden of IDA in school aged children is highly variable, ranging from 10% to more than 40% depending on dietary habits, socioeconomic factors, and health services [5]. Deficiency in many areas is attributed to low consumption of iron rich foods, parasitic infection and low dietary diversity [6]. Beyond the physical implications, IDA can affect attention, processing speed and academic performance of children compared to their non anemic counterparts [7]. Such cognitive deficits may have negative educational and economic consequences.

A number of studies have sought to establish the association of IDA with IQ. Studies from South Asia and Africa have demonstrated reduced IQ points in iron deficient children, with deficits ranging from 5 to 15 IQ points, depending on the severity of iron deficiency and its duration [8-10]. Halterman et al. found that children with IDA had much lower IQ scores on standardized tests, even when taking into account socioeconomic background [11]. Likewise, Lozoff et al proved long term cognitive impairment in children who suffered from chronic iron deficiency in early life [12]. Such studies highlight the need for early screening and treatment.

Despite the accumulating evidence, the link between IDA and IQ is affected by a number of confounding variables. Influential factors include parental education, family structure, socioeconomic background, dietary diversity and environmental enrichment [13]. For instance, children in nuclear families may be exposed to more intellectual stimulation than those in extended or joint families, which may affect IQ regardless of nutrition [14]. Further to this, obesity and undernutrition may also be accompanied by micronutrient deficiencies, which may furthr influence cognitive performance [15].

The current study seeks to add to this literature by assessing the impact of IDA on IQ in school aged children studied here. Through the measurement of hematological indices, ferritin concentrations and cognitive function using the Raven Coloured Progressive Matrices (RCPM), the present study aims to better understand the role of IDA on cognitive function. This association is important for guiding public health policies, school based screening and nutritional interventions, to enhance child development and school performance.

Given the strong body of evidence suggesting iron deficiency is associated with poor neurocognitive performance, it is important to explore this relationship in our population, where dietary, socioeconomic and cultural differences from previously studied populations may exist. Hence, this research contributes to the understanding of cognitive effects of IDA and underscores the need to take iron deficiencies into consideration in child development programs.

METHODOLOGY

We conducted a cross sectional study in 110 school children between the ages of 7-11 years. A multi stage sampling strategy was utilised to recruit children from a wide range of socioeconomic and family backgrounds. The study began with community meetings to explain and discuss the purpose of the study, the methods and the benefits of early detection of nutritional deficiencies with parents, teachers, and local co ordinators. Parents or guardians provided written informed consent, and children provided verbal assent, before enrolment.

Inclusion criteria included being in primary school (grade 1-5), aged 7-11 years, and free from chronic diseases that can impact on cognitive function. They were excluded if they had a known neurological condition, chronic systemic illness, had received a blood transfusion or were taking iron supplements. Those with recent infections were rescheduled for evaluation after recovery.

A socio demographic questionnaire was used to record information regarding age, sex, type of family (nuclear or joint), parents' education, family size and socioeconomic status. Further questions were asked on dietary practices, especially the consumption of iron rich foods like meat, egg, legumes and green vegetables. This data was used to interpret the nutritional and cognitive status.

Height and weight were measured using standardised techniques. Weight was recorded to the nearest 0.1 kg using a calibrated digital scale and height was recorded to the nearest 0.1 cm using a stadiometer. Body Mass Index (BMI) was calculated using the formula.

BMI percentiles were compared against age and sex specific charts for children 2-20 years of age. Children were classified as underweight, normal weight or obese according to these percentiles. These classifications were applied to investigate the link between nutrition and cognition.

Aseptically, 3mL of blood was drawn from each child by phlebotomists. The blood was aliquoted into EDTA tubes for hematological tests and gel tubes for biochemical tests. Blood was centrifuged at 4000 rpm for 10 minutes and stored at -40°C.

Peripheral blood smears were used to perform complete blood count (CBC) using an automated analyzer. The following parameters were measured: hemoglobin, hematocrit, mean corpuscular volume (MCV) and red cell indices. Serum ferritin concentrations were determined by electrochemiluminescence immunoassay (ECLIA), which is a highly sensitive and specific test for iron stores. Internal quality control measures were taken during the analysis to guarantee valid results.

Iron deficiency anemia (IDA) was defined as hemoglobin levels below age specific cut off levels and serum ferritin level <12 ng/mL. Iron deficiency without anemia (ID) was defined as low ferritin and normal hemoglobin and was included in the analyses when appropriate.

We used the Raven Colored Progressive Matrices (RCPM) to measure cognitive test performance, a well known, culture fair, non verbal test of intelligence and reasoning ability in children between 5.5 and 11.5 years of age. The task involves completing patterns, which involves visual perception, analogical reasoning and problem solving.

Children were tested in a well lit, distraction free room, and were tested one on one. Children were given standardised instructions, and were not under pressure to respond. Scores were standardized according to normative data, taking into account the child's age. IQ percentiles were divided into:

- Below average: 5th-10th percentile
- Average: 25th–50th percentile
- Above average: 75th-95th percentile

We used these groups to evaluate cognitive function among the hematological and nutritional groups.

Data were entered into a password protected database and verified. Continual variables like hemoglobin, ferritin and IQ percentiles were reported as the mean ± standard deviation (SD). Discrete variables, such as sex, family type, nutritional status and IDA were expressed as number and percentage.

The Shapiro–Wilk test was used to test for normality of continuous variables. If normally distributed, these were analysed using the Student's t test. When appropriate, the Mann Whitney U test was used. For categorical variables, the chi square test or Fisher's exact test was used to assess associations. A p value <0.05 was considered statistically significant.

We also performed exploratory analyses to assess correlations between IQ percentiles with regard to hemoglobin and ferritin levels. These analyses gave us an idea of the degree of association between iron status and cognitive function.

RESULTS

The study subjects were 110 school children from 7-11 years. Of these, 48 (43.6%) were females and 62 (56.4%) were males. The socio demographic profile of the participants is given in Table I. Of the various variables studied, family structure was found to have a significant association with IQ. The mean IQ score was significantly greater in children from nuclear families than joint families (55.8 ± 35.9 vs. 36.2 ± 33.8; $p < 0.05$). The other socio demographic variables (parental education, family income, number of siblings, and birth order) did not show significant differences in IQ.

Gender differences in hematological and cognitive parameters were compared among the children, but no differences were found in hemoglobin, hematocrit, ferritin, MCV or MCHC. But Mean Corpuscular Hemoglobin (MCH) was significantly different in males and females ($p < 0.05$), with higher levels in males. While not statistically significant, the mean IQ of males (42.5 ± 34.7) was slightly higher than females (39.8 ± 36.9), which is consistent with previous research.

Body mass index (BMI) classified 44 (40.0%) of 110 children as normal weight, 22 (20.0%) as obese and 44 (40.0%) as underweight. When we compared underweight with normal weight children, we found significantly lower IQ, hemoglobin, ferritin, hematocrit and MCH in underweight children ($p < 0.05$). This finding indicates that malnutrition may have a negative impact on the IQ of iron deficient children. However, comparison of obese children with normal weight children revealed that only MCV and MCH were significantly lower in obese children, with no significant differences seen in IQ, hemoglobin, ferritin and hematocrit.

IQ groups were also evaluated to determine whether there was a correlation between IQ and hematological indices. Children in the below average IQ (5th-10th percentile) group had significantly lower hemoglobin and hematocrit ($p < 0.05$) than children in the average IQ (25th-50th percentile) group. There was no significant difference in ferritin, MCV, MCH and MCHC between these two groups. On the other hand, comparing above average IQ children (75th-95th percentile) with average IQ children found no difference in hemoglobin, but IQ was significantly associated with MCV, MCH and MCHC ($p < 0.05$), which indicates that a higher IQ may be associated with better red cell indices.

The incidence of iron deficiency anemia (IDA) in this study was 10.9% (n = 12). Children with IDA showed a significant difference in IQ scores, with a significant decrease in mean IQ scores in IDA compared with non IDA. The mean IQ percentile of IDA children was 10.4 ± 7.9, compared with 44.6 ± 33.2 in non anemic children ($p < 0.001$). The IDA group also had significantly lower levels of hemoglobin and ferritin (11.1 ± 0.41 g/dL and 9.2 ± 1.4 ng/mL, respectively), consistent with the existence of iron deficiency. These results are shown in Table V.

Taken together, the findings show iron deficiency anemia has a significant detrimental effect on IQ scores, nutritional status and family factors are also important determinants of IQ. The hematological impact of the deficiency (low hemoglobin and ferritin) was strongly related with cognitive scores.

Table I. Socio-Demographic Characteristics and IQ Comparison (n = 110)

Variable	Category	N (%)	Mean IQ ± SD	P-Value

Sex	Male	62 (56.4)	42.5 ± 34.7	0.41
	Female	48 (43.6)	39.8 ± 36.9	
Family Structure	Nuclear	64 (58.2)	55.8 ± 35.9	0.03*
	Joint	46 (41.8)	36.2 ± 33.8	
Parental Education	Primary or less	38 (34.5)	38.1 ± 32.4	0.28
	Secondary	44 (40.0)	41.6 ± 35.1	
	Higher	28 (25.5)	47.2 ± 36.8	
Household Income	Low	52 (47.3)	39.4 ± 34.2	0.33
	Middle	42 (38.2)	43.7 ± 36.1	
	High	16 (14.5)	48.1 ± 37.5	

Table II. Comparison of Hematological Parameters between Genders

Parameter	Male (n = 62) Mean ± SD	Female (n = 48) Mean ± SD	P-Value
Hemoglobin (g/dL)	12.3 ± 0.7	12.1 ± 0.6	0.19
Hematocrit (%)	36.4 ± 2.1	35.9 ± 2.3	0.27
Ferritin (ng/mL)	21.8 ± 4.3	20.9 ± 4.6	0.31
MCV (fL)	80.1 ± 4.9	79.4 ± 5.2	0.44
MCH (pg)	26.7 ± 2.1	25.8 ± 2.0	0.04*
MCHC (g/dL)	32.9 ± 1.1	32.6 ± 1.2	0.22
IQ Percentile	42.5 ± 34.7	39.8 ± 36.9	0.48

Table III. Comparison of Nutritional Status with Hematological and Cognitive Parameters

Parameter	Normal Weight (N = 44)	Underweight (N = 44)	Obese (N = 22)	P-Value (Normal Vs Underweight)	P-Value (Normal Vs Obese)
IQ Percentile	48.2 ± 33.9	31.4 ± 29.8	44.1 ± 34.7	0.01*	0.52
Hemoglobin (g/dL)	12.4 ± 0.6	11.9 ± 0.7	12.2 ± 0.6	0.02*	0.33
Ferritin (ng/mL)	22.6 ± 4.2	19.8 ± 4.5	21.1 ± 4.0	0.03*	0.21
Hematocrit (%)	36.7 ± 2.0	35.1 ± 2.4	36.0 ± 2.1	0.01*	0.44
MCV (fL)	80.4 ± 4.8	79.1 ± 5.1	77.8 ± 4.9	0.19	0.04*
MCH (pg)	26.8 ± 2.0	25.4 ± 2.1	25.2 ± 2.0	0.01*	0.03*

Table IV. Comparison of IQ Categories with Haematological Parameters

Parameter	Below Average IQ (N = 28)	Average IQ (N = 46)	Above Average IQ (N = 36)	P-Value (Below Vs Average)	P-Value (Above Vs Average)
Hemoglobin (g/dL)	11.9 ± 0.6	12.4 ± 0.7	12.5 ± 0.6	0.01*	0.42
Hematocrit (%)	35.0 ± 2.3	36.7 ± 2.1	36.9 ± 2.0	0.02*	0.38
Ferritin (ng/mL)	20.1 ± 4.3	21.9 ± 4.4	22.4 ± 4.1	0.11	0.29
MCV (fL)	79.0 ± 5.0	80.1 ± 4.7	82.3 ± 4.6	0.28	0.03*
MCH (pg)	25.3 ± 2.1	26.4 ± 2.0	27.1 ± 1.9	0.07	0.04*
MCHC (g/dL)	32.5 ± 1.2	32.8 ± 1.1	33.3 ± 1.0	0.19	0.02*

Table V. Comparison between IDA and Non-IDA Children

Parameter	IDA (N = 12) Mean ± SD	Non-IDA (N = 98) Mean ± SD	P-Value
IQ Percentile	10.4 ± 7.9	44.6 ± 33.2	*
Hemoglobin (g/dL)	11.1 ± 0.41	12.4 ± 0.62	*
Ferritin (ng/mL)	9.2 ± 1.4	22.8 ± 4.1	*
Hematocrit (%)	34.9 ± 2.2	36.6 ± 2.1	0.01
MCV (fL)	78.4 ± 4.8	80.2 ± 4.9	0.12

MCH (pg)	25.1 ± 2.0	26.5 ± 2.1	0.06

DISCUSSION

Our study shows that iron deficiency anemia is associated with lower intelligence quotient (IQ) in school children. The rate of IDA in this study (10.9%) is similar to other studies which report rates between 10-20% in populations [16,17]. The reduced IQ scores in IDA children are consistent with the critical role of iron in brain and cognitive development.

Several studies have shown the adverse effects of iron deficiency on cognitive function. Sachdev et al. found lower IQ scores in iron deficient children, as in our study [8]. Soemantri also showed that iron supplementation led to improved cognitive performance, indicating a potentially reversible component [9]. Halterman et al. reported children with IDA had lower scores on standardised tests, even when accounting for socioeconomic status [11], further suggesting a direct link.

Our results are also consistent with studies from South Asia that show an association between IDA and suboptimal academic performance and attention [18,19]. Studies from Africa also report iron deficient children have slower information processing and memory [20]. The deficit in IQ shown in our study is comparable with the deficits observed by Idjradinata and Pollitt, who showed improved IQ scores with iron supplementation [10]. Our study also found that living in a nuclear family was associated with higher IQ, compared to joint families. This is in line with Gupta et al., who found that children in nuclear families are more likely to receive one-on-one cognitive stimulation [14]. We also found that children who were underweight had lower IQ scores, which is in line with reports that malnutrition affects cognitive performance [21,22].Our finding of lower hemoglobin and ferritin levels among children with low IQ scores is consistent with studies showing that the severity of hematological disorders is correlated with lower IQ [23,24]. Lozoff et al. showed long term cognitive deficits in children with chronic iron deficiency [12], implying early diagnosis is vital.

Although our results are in agreement with most of the previous studies, some others have reported low levels of association between IQ and IDA, which may be explained by confounding factors like socioeconomic background, parental education and stimulation [25,26]. However, severe and/or chronic iron deficiency was a strong predictor of poor cognitive performance in these studies.

In conclusion, the current study supports the considerable body of evidence on the association between IDA and cognitive function. The findings from this study, along with those from the studies reviewed above, are consistent across populations, and highlight the need for regular screening, nutrition programs and public health measures to prevent iron deficiency in children.

CONCLUSION

Our study shows that iron deficiency anemia has profound negative effects on intelligence in school aged children. IDA was shown to result in significantly lower IQ percentiles, hemoglobin and markedly lower ferritin levels in children than in non anemic children. Cognitive performance was also affected by nutritional status and family type, with lower scores observed in children who were underweight and those from joint families, when compared to their peers.

The study adds to the growing evidence of the critical role of iron in brain development and the need for timely screening and treatment of iron deficiency. Screening for anemia in school children and nutritional supplementation may reduce the risk of long term cognitive impairment, and promote improved academic and developmental performance.

In conclusion, the research highlights a need for comprehensive public health approaches that simultaneously tackle nutritional deficiencies and other socio environmental influences on children's development.

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