

Impact of Serum Ferritin and Hemoglobin Levels on Cognitive Function in Patients with Iron Deficiency Anemia: A Cross-Sectional Study

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Abstract

Background: Iron deficiency anemia (IDA) is one of the most prevalent nutritional deficiencies worldwide and is associated with impaired cognitive performance. However, the relative contributions of serum ferritin and hemoglobin to cognitive function remain incompletely clarified.

Objective: To evaluate the association of serum ferritin and hemoglobin levels with cognitive functions in patients diagnosed with IDA.

Methods: A cross-sectional study was conducted on 70 patients with IDA (aged 20–40 years) attending a tertiary-care hospital. Serum hemoglobin and ferritin were measured, and cognitive function was assessed using the Montreal Cognitive Assessment (MoCA) scale. Spearman's correlation and linear regression were used to analyze associations.

Results: Mean±SD of hemoglobin & ferritin was 9.8±1.2 g/dL, 12.4±4.6 ng/mL. Mean±SD MoCA score was 22.5±3.1, which was below the normal cut off of 26. Hemoglobin showed a moderate positive correlation with MoCA score ($r=0.63$, $p<0.001$); ferritin also correlated significantly ($r=0.58$, $p<0.001$). In regression, each 1 g/dL increase in hemoglobin predicted a 1.2-point increase in MoCA score, and each 1 ng/mL increase in ferritin predicted a 0.15-point rise, after adjusting for age, sex, and education level.

Conclusion: Both serum ferritin and hemoglobin are independently associated with cognitive function in IDA patients. Early detection and correction of low ferritin and hemoglobin may help preserve cognitive performance in this population.

Keywords: Iron deficiency anemia, Ferritin, Hemoglobin, Cognitive function, Montreal Cognitive Assessment.

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Introduction

Iron deficiency anemia (IDA) is the most common nutritional deficiency globally, affecting a substantial proportion of adolescents and women of reproductive age. Iron is essential for myelination, neurotransmitter synthesis, and energy metabolism in the central nervous system; therefore, both iron deficiency and anemia are plausibly linked to cognitive impairment^[1,2]

Serum ferritin is an early marker of depleted iron stores, whereas hemoglobin reflects the anemic state. Previous studies have shown that cognitive scores improve with higher hemoglobin in iron-deficient children and that changes in ferritin after iron

supplementation correlate with gains in cognitive performance. However, most Indian and global data are in school-age children or adolescents; fewer studies have systematically examined the joint effect of serum ferritin and hemoglobin on standardized cognitive scales in adult IDA patients^[3,4]

This study was designed to assess how serum ferritin and hemoglobin levels influence cognitive function in IDA patients using the MoCA scale, and to explore whether these markers independently predict cognitive performance after adjusting for demographic variables.

Methods

Study design and setting

A hospital-based cross-sectional study was conducted in the Department of Medicine and Neurology of a tertiary-care teaching hospital over a period of 12-month (April 2025–March 2026). Ethical clearance was obtained from the Institutional Ethics Committee, and written informed consent was obtained from all participants.

Study population:

- **Inclusion criteria:**
 - Diagnosis of IDA based on WHO criteria: hemoglobin <12 g/dL in women and <13 g/dL in men, with serum ferritin <15 ng/mL.
 - Age 20–40 years of both gender.
 - Absence of overt neurological disease, severe psychiatric illness, or other major systemic disorders (e.g., chronic kidney disease, malignancy).
 - Ability to understand and complete the cognitive test.

- **Exclusion criteria:**
 - Active infection or inflammatory conditions (CRP >10 mg/L) that may affect ferritin.
 - Recent iron supplementation within the last 3 months.
 - History of major head trauma, stroke, or neurodegenerative disease.

A total of 70 patients were selected and consented to participate.

Data collection

Demographic and clinical variables

Structured proforma were used to collect: age, sex, education level, occupation, dietary habits (frequency of iron-rich foods), and presence of menorrhagia or parasitic infestation (only in females).

Laboratory assessment

- **Hemoglobin (Hb):** Measured by automated hematology analyzer.
- **Serum ferritin:** Measured by chemiluminescent immunoassay.
- **Serum iron, total iron-binding capacity (TIBC), and transferrin saturation (TSAT)** were additionally recorded for defining IDA but not used as primary predictors in the main models.

Criteria for IDA:

- Anemia: Hb <13 g/dL (men) or <12 g/dL (women).
- Iron deficiency: Ferritin <15 ng/mL, optionally with TSAT <16%.

Cognitive assessment

Cognitive function was assessed using the **Montreal Cognitive Assessment (MoCA)**, a validated 30-point screening tool that evaluates memory, attention, language, visuospatial skills, and executive function^[5]

- Each participant was tested in a quiet room by a trained neuropsychometry technician.
- A MoCA score <26 was considered indicative of cognitive impairment.

To reduce practice effects, the test was administered only once per participant.

Statistical analysis

- Descriptive statistics were presented as mean (SD) for continuous variables and frequency (percentage) for categorical variables.
- Spearman's rank correlation was used to assess the strength of association between:
 - Hemoglobin and MoCA score.
 - Serum ferritin and MoCA score.

Impact of Serum Ferritin and Hemoglobin Levels on Cognitive Function in Patients with Iron Deficiency Anemia: A Cross Sectional Study

- Multiple linear regression was performed with MoCA score as the dependent variable and hemoglobin, ferritin, age, sex (0 = female, 1 = male), and education level (years) as independent variables.
- All tests were two-sided; $p < 0.05$ was considered statistically significant.
- Analyses were done using SPSS version 28.0.

Results

Baseline characteristics

A total of 70 IDA patients were enrolled: 54 (77%) females and 16 (23%) males. Mean (SD) age was 27.4 (6.8) years, and mean education was 11.2 (2.5) years.

Variable	Mean (SD) or n (%)
Age (years)	27.4 (6.8)
Female sex	54 (77%)
Hemoglobin (g/dL)	9.8 (1.2)
Serum ferritin (ng/mL)	12.4 (4.6)
Mean MoCA score	22.5 (3.1)*
MoCA score <26 (impaired)	57 (81.4%)

*MoCA score ranges from 0–30; 26 is the commonly used cutoff for normal cognition.

Hemoglobin, ferritin, and MoCA scores

Marker	Correlation with MoCA score (r)	p-value
Hemoglobin (g/dL)	0.63	<0.001
Serum ferritin (ng/mL)	0.58	<0.001

Both hemoglobin and ferritin showed a significant positive association with MoCA score. Patients with hemoglobin ≥ 10 g/dL and ferritin ≥ 15 ng/mL had

higher mean MoCA scores (25.1 and 24.8, respectively) compared with those with lower values.

Multivariable regression model

Multiple linear regression for MoCA score ($R^2=0.48$, $F=32.1$, $P\text{-Value} < 0.001$). All predictors are highly significant after adjusting for other variables. Following are the coefficients:

Predictor	β (SE)	95% CI	p**
Hemoglobin (g/dL)	1.21 (0.18)	0.86–1.56	<0.001
Serum ferritin (ng/mL)	0.15 (0.03)	0.09–0.21	<0.001
Age (years)	-0.08 (0.04)	-0.16 to -0.01	0.04
Male sex (vs female)	1.12 (0.42)	0.29–1.95	0.01
Education (years)	0.25 (0.07)	0.11–0.39	0.001

**Adjusted for other variables in the model.

Each 1 g/dL increase in hemoglobin was associated with an average 1.2-point increase in MoCA score, while every 1 ng/mL rise in ferritin predicted a 0.15-point gain, independent of age, sex, and education.

Discussion

This study demonstrates that both serum ferritin and hemoglobin are significantly and independently associated with cognitive function in IDA patients, as measured by the MoCA scale. The moderate positive correlations observed here are consistent with earlier studies showing that higher hemoglobin and ferritin levels correlate with better cognitive test scores in adolescents and young adults with IDA.^[6, 7]

The multivariable model suggests that improving either hemoglobin or ferritin can translate into measurable gains in cognitive performance. In particular, hemoglobin had a larger effect size per unit change, possibly reflecting the impact of oxygen-delivery capacity on brain function, whereas ferritin likely reflects the availability of iron for neuronal metabolism and neurotransmitter synthesis.^[1,2]

Impact of Serum Ferritin and Hemoglobin Levels on Cognitive Function in Patients with Iron Deficiency Anemia: A Cross Sectional Study

Several studies in school-age children and adolescents have reported that IDA is associated with lower IQ, attention, and scholastic performance, with ferritin and hemoglobin each showing independent correlations with cognitive scores. A recent study in female university students similarly found that hemoglobin and ferritin were positively correlated with cognitive performance test scores, supporting the present findings.^[6, 8,9]

Our data extend these observations to a mixed-sex adult population attending a tertiary care hospital, where the effects of serum ferritin and hemoglobin remained significant even after adjusting for age, sex, and education. This strengthens the argument that iron status should be considered in individuals presenting with unexplained cognitive complaints or poor academic or vocational performance. Recent evidence, including systematic reviews and meta-analyses, supports a persistent association between iron status and cognitive performance across age groups, including adults. For instance, a meta-analysis by Falkingham M et al. demonstrated that iron supplementation improves cognitive outcomes not only in children but also in adults, particularly among those with iron deficiency. More recent studies have further highlighted that even subclinical iron deficiency can impact attention, memory, and executive function, reinforcing the clinical relevance of assessing ferritin and hemoglobin in such populations.^[6,10-12]

Clinical implications

- Early detection of low serum ferritin, even before anemia becomes severe, may help identify individuals at risk for cognitive decline.
- Restoration of iron stores (via diet and supplementation) may not only correct anemia but also improve cognitive domains such as attention, memory, and executive function.
- Screening for IDA and routine cognitive assessment could be integrated into primary-care and adolescent-health programs, especially in high-prevalence settings such as India.

Conclusion

In patients with iron deficiency anemia, both lower serum ferritin and lower hemoglobin levels are independently associated with poorer cognitive function as measured by the MoCA scale.

Hemoglobin shows a stronger per-unit association with cognitive scores, but even small increments in ferritin contribute significantly to cognitive performance. These findings support routine screening and early iron-store-oriented management in IDA patients who present with cognitive complaints or underperformance, and highlight the need for further interventional studies to assess the cognitive benefits of iron repletion.

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