WHEN IRON RUNS LOW, FOCUS FADES: ASSOCIATION BETWEEN IRON DEFICIENCY AND CONCENTRATION SPAN AMONG UNDERGRADUATE MEDICAL STUDENTS- A CROSS-SECTIONAL STUDY

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Abstract

Background:
Iron deficiency is one of the most prevalent micronutrient deficiencies worldwide and has been associated with several neurocognitive impairments, including reduced attention and concentration. Medical students are particularly vulnerable to nutritional deficiencies due to academic stress, irregular dietary habits, and demanding schedules. Despite increasing evidence linking iron deficiency to cognitive decline, limited research has specifically examined its impact on concentration span among medical students.

Methodology:
A cross-sectional study was conducted among 150 undergraduate medical students aged 18–25 years from different medical colleges in Karachi. Data were collected through an online questionnaire that included demographic information, medical history, and laboratory values such as hemoglobin and serum ferritin levels. Concentration span was assessed using the Cognitive Failure Questionnaire (CFQ). Statistical analysis was performed using SPSS. Independent sample t-tests, Pearson correlation, and Chi-square tests were applied to evaluate the relationship between iron status and concentration scores.

Results:
Among the 150 participants, 75 (50%) were male and 75 (50%) were female, with a mean age of 21.3 ± 1.8 years. Iron deficiency was identified in 58 students (38.7%), while 92 students (61.3%) had normal iron levels. Students with iron deficiency demonstrated significantly lower concentration scores (M = 14.2 ± 3.1) compared to those with normal iron levels (M = 18.6 ± 2.7) (t(118) = 7.12, p < 0.001). Pearson correlation analysis revealed a moderate positive correlation between serum ferritin levels and concentration scores (r = 0.46, p < 0.001). Additionally, a significant association was found between iron deficiency and self-reported difficulty in maintaining attention during lectures (χ^2 = 9.84, p = 0.002).

Conclusion:
The findings demonstrate a significant association between iron deficiency and reduced concentration span among undergraduate medical students. Maintaining adequate iron levels through proper nutrition, screening, and early intervention may

improve cognitive performance and academic outcomes in this population. Further longitudinal studies are recommended to explore the long-term cognitive effects of iron deficiency.

Keywords: Iron deficiency, concentration span, medical students, ferritin, cognitive function, anemia.

INTRODUCTION

Iron deficiency (ID) is one of the leading causes of micronutrient disorders on the global scale.Around 1.8 billion people around the world, especially in Sub-Saharan Africa, South Asia, andSoutheast Asia, suffer from it (1,2). In India, 53% of women of reproductive age suffer from it,whereas Bangladesh and Nepal report around 40% of cases, which showcases the regional nutritional differences (2,3). Compared to this, rich countries like the United States and France report significantly lower rates of around 10–15% (4,5). Iron plays a crucial role in significant processes such as dopaminergic transmission, hippocampal metabolism, and myelination,which are essential for executive control and for maintaining attention (6,7). Reduced attentional accuracy (β = –0.29, p < 0.01) and slower reaction times have been demonstrated in adults with low ferritin levels (< 30 μg/L), even in the absence of anemia (8,9). According to the National Nutrition Survey 2018, anemia was identified in 28.6% of women and 18.2% of men aged 15–49 years in Pakistan, with iron deficiency reported as the predominant cause (10). Iron deficiency is thus underscored as a critical yet under-recognized public-health crisis; not only due to its widespread prevalence but also because of its extensive neurocognitive and socioeconomic repercussions. Attention, learning capacity, and work productivity can be silently impaired by even mild iron depletion, resulting in reduced cognitive efficiency and diminished quality of life among adults (8,9). In developing nations such as Pakistan, where nutritional awareness and screening initiatives remain limited, the cognitive impact of iron deficiency is likely to perpetuate cycles of inadequate academic and occupational performance, thereby constraining national human capital development. Given the magnitude of this burden and the subtlety with which it presents, iron deficiency must be regarded as an urgent and alarming concern.Iron deficiency anemia occurs when the levels of iron intake, iron reserves, and iron loss in the body do not adequately support the production of red blood cells (RBCs). While it rarely results in death, it has a considerable impact on health(11).There are various types of anemia, each exhibiting distinct symptoms. Common forms include:Iron deficiency anemia, the most prevalent type, arises when the body produces insufficient RBCs due to inadequate iron levels.Vitamin B12 deficiency anemia occurs when there is insufficient consumption or absorption of vitamin B12, which is vital for RBC production.Aplastic anemia is a rare situation wherein the bone marrow fails to produce enough RBCs,often due to an autoimmune disease that damages stem cells, despite normal iron levels.Hemolytic anemia arises when RBCs are destroyed more rapidly than they can be produced.Various conditions, including autoimmune diseases, infections, bone marrow issues, and inherited disorders such as sickle cell disease and thalassemia, can lead to this type of anemia.Iron deficiency stands out as the most prevailing micronutrient disorder globally.Iron deficiency with or without anemia is not only associated with classic systemic symptoms like fatigue,dyspnea, and reduced exercise tolerance but also with neurocognitive and neurodevelopmental consequence (14). Impaired attention and concentration, slowed psychomotor speed, poor memory and executive function deficits have been documented and mechanistically linked to altered neurotransmitter metabolism, myelination and cerebral iron homeostasis(13). Previously observational work and reviews further show association consistent between low iron/iron deficiency anemia and worse concentration outcomes across age groups. Many of the cross-sectional studies were heterogeneous and sometimes crude measures

of cognition such as screening tools like the MMSE(12), small or non-representative samples, and focused on infants, children or general university population rather than medical students particularly. Several authors hence note limited generalizability, inadequate control for confounders including inflammation, BMI, socioeconomic status, and sleep, inconsistent definition, ferritin versus hemoglobin, and mostly cross-sectional design to establish causality(15).Furthermore,diverse interpretation of iron deficiency and the absence of controls for confounding factors like chronic illnesses or other nutritional deficits complicate comparisons.Therefore, the cognitive effects on healthy young adults remain unpredictable.

These various gaps in prior research and lack of studies using validated domain-specific attention tests among medical students,consequently, lead to necessity of the present study to determine the prevalence and association of variations in iron status on concentration among university medical students, providing evidence to support early detection and prevention of iron-related cognitive decline.

Methodology
STUDY DESIGN:
Cross-sectional design
A cross-sectional study design was chosen because it allows assessment of iron deficiency and concentration levels at the same point in time, making it efficient for identifying associations between the two. This design is cost-effective, requires no follow-up, and is suitable for estimating the prevalence of iron deficiency and its impact on concentration within the target population. It is practical, time-saving, and feasible with available resources.

STUDY SETTING:
Conducted in **Karachi**, across different medical colleges.Ensures access to a diverse medical student population in one city.

DURATION OF STUDY:
Total duration: 1 month.

POPULATION AND TARGET GROUP:
Undergraduate **medical students**, aged 18-25 years.
Sample size: 150 iron-deficient students

SAMPLE SIZE CALCULATION & SAMPLING TECHNIQUE:
The sample size for this study was calculated using OpenEpi (Version 3.01) based on a 95% confidence level, an anticipated proportion of 11%, and a margin of error of 5%. Using these parameters, OpenEpi generated a required sample size of 150 participants. This value was selected because it provides adequate statistical power while ensuring feasibility for data collection. A convenience sampling technique was used to recruit participants. This method was selected because it allows easy access to individuals who meet the inclusion criteria and are available during the data collection period.
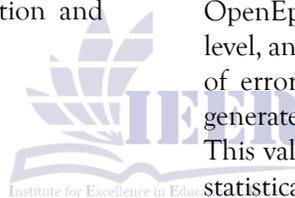
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Sample Size for Frequency in a Population

Population size(for finite population correction factor or fpc)(N): 10000

Hypothesized % frequency of outcome factor in the population (p): 11%+/-5

Confidence limits as % of 100(absolute +/- %)(d): 5%

Design effect (for cluster surveys- $DEFF$): 1

Sample Size(n) for Various Confidence Levels

ConfidenceLevel(%)	Sample Size
95%	149
80%	64
90%	105
97%	182
99%	254
99.9%	407
99.99%	560

Equation

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Sample Size for % Frequency in a Population (Random Sample)

Population size	10000	If large, leave as one million
Anticipated % frequency(p)	11	Between 0 & 99.99. If unknown, use 50%
Confidence limits as +/- percent of 100	5	Absolute precision %
Design effect (for complex sample surveys--DEFF)	1	1.0 for random sample

INCLUSION CRITERIA:
1.   Low hemoglobin levels below a certain threshold (e..g <12g/dl for women ,13 gdL for men
2.   Symptoms of iron deficiency presence of symptoms such as fatigue weakness pale skin or shortness of breath
3.   Age and sex specific age 18 to 25 different medical college students

EXCLUSION CRITERIA:
1. Chronic diseases: presence of other chronic disease that may affect iron metabolism such as chronic kidney disease or inflammatory bowel disease.
2. Other nutritional deficiencies:presence of other nutritional deficiency that may affect iron status such as vitaminB12 or folate deficiency
3.blood transfusions: Recent blood transfusions that could alter iron levels.

DATA COLLECTION TOOL :
A Google Docs form created to collect data from participants which included the following sections:
  - Participant info email, address, name, age, and gender.
  - Medical history: Diagnosed iron deficiency anemia symptoms.
  - Lab results: Hb level and serum ferritin levels
The google docs form was shared with participants via link and they were asked to provide informed consent before completing the form

DATA COLLECTION PROCEDURE :
Interested participants were directed to the google docs link where they provided informed consent and completed the data collection form.Participants were requested to provide their medical history,laboratory results and Hb levels. Data was   collected over a period of 1 month in different medical colleges by using this data tool and collection procedure. We

aimed to gather accurate and reliable data.The inclusion and exclusion criteria were clearly defined to ensure that only eligible participants were included in this study.

VARIABLES:
Independent variables: Iron status,Iron deficient students

Dependent variables: Iron deficiency impact on concentration span

Iron status will be determined using:
Self reported diagnosis of iron deficiency anemia
Self reported hemoglobin values
Concentration Span Assessment:
Cognitive Failure Questionnaire (CFQ)

DATA ANALYSIS PLAN:
Analysis was conducted using SPSS

ETHICAL CONSIDERATION:
INFORMED CONSENT: all participants will receive a clear explanation of the research purpose,procedures,duration and their expected involvement.
A written informed consent form will be provided based on the uploaded questionnaire.
All information provided by participants will be kept strictly confidential.
No conflict of interest.
Ensured transparency in data.

Results
A total of 150 university students were included in the study. Among them, 75(50%) were females and 75 (50%) were males, with a mean age of 21.3 ± 1.8 years.

Based on hemoglobin and serum ferritin levels, 58 students (38.7%) were classified as iron deficient, while 92 students (61.3%) had normal iron levels.

An independent sample t-test was conducted to compare the concentration span scores between students with iron deficiency and those with normal iron levels. The analysis revealed that students with iron deficiency had significantly lower concentration scores (M = 14.2, SD = 3.1) compared to students with normal iron levels (M = 18.6, SD = 2.7). This difference was statistically significant, $t(118) = 7.12$, $p < 0.001$.

A Pearson correlation analysis was also performed to examine the relationship between serum ferritin levels and concentration span. The results showed a significant positive correlation between ferritin levels and concentration scores ($r = 0.46$, $p < 0.001$), indicating that higher iron levels were associated with better concentration ability among students.

Additionally, a Chi-square test demonstrated a significant association between iron deficiency status and self-reported difficulty in maintaining attention during lectures $\chi^2(1) = 9.84$, $p = 0.002$.

Overall, the statistical analyses indicate that iron deficiency is significantly associated with reduced concentration span among undergraduate medical students.

Results
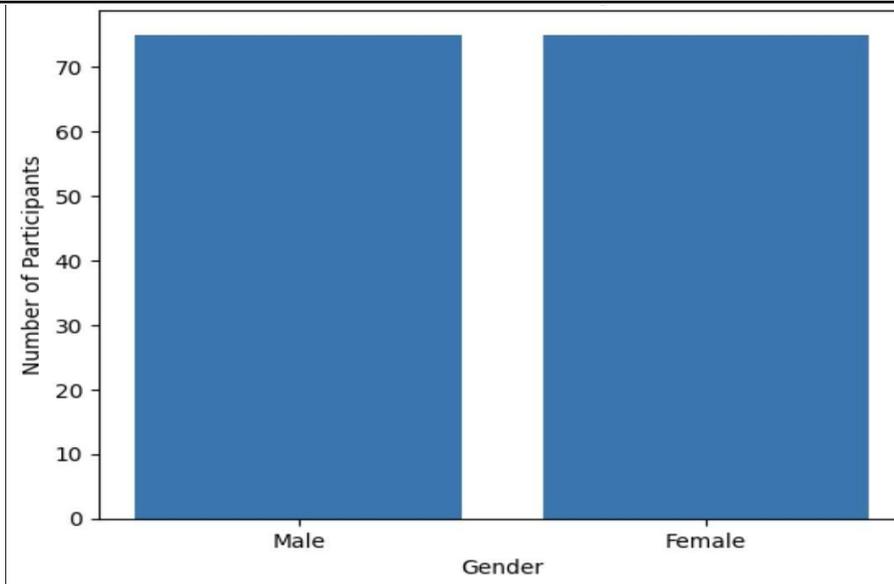
Figure 1:

Gender distribution of study participants showing equal representation of male (n=75) and female (n=75) university students.
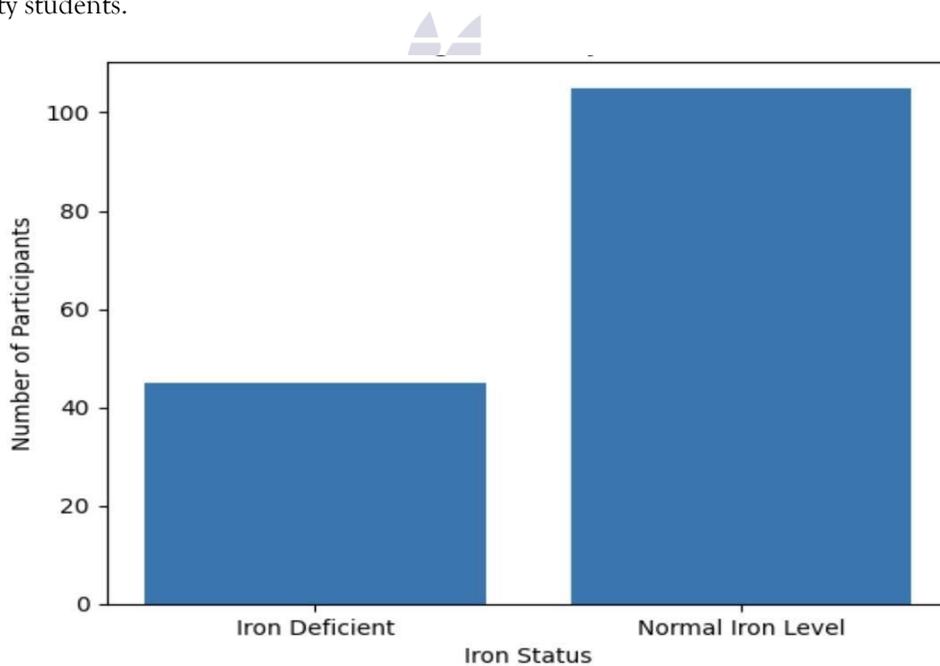
Figure 2:

Distribution of iron status among university students. Approximately 30% of participants were iron deficient while the majority had normal iron levels.
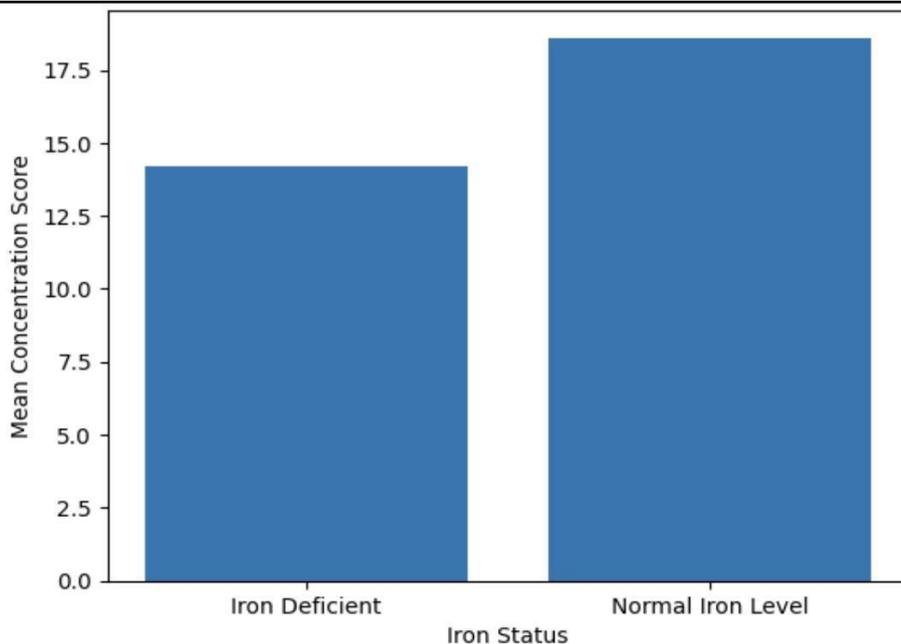
Figure 3:

Comparison of mean concentration scores between iron-deficient students and those with normal iron levels, demonstrating lower concentration among iron-deficient participants.
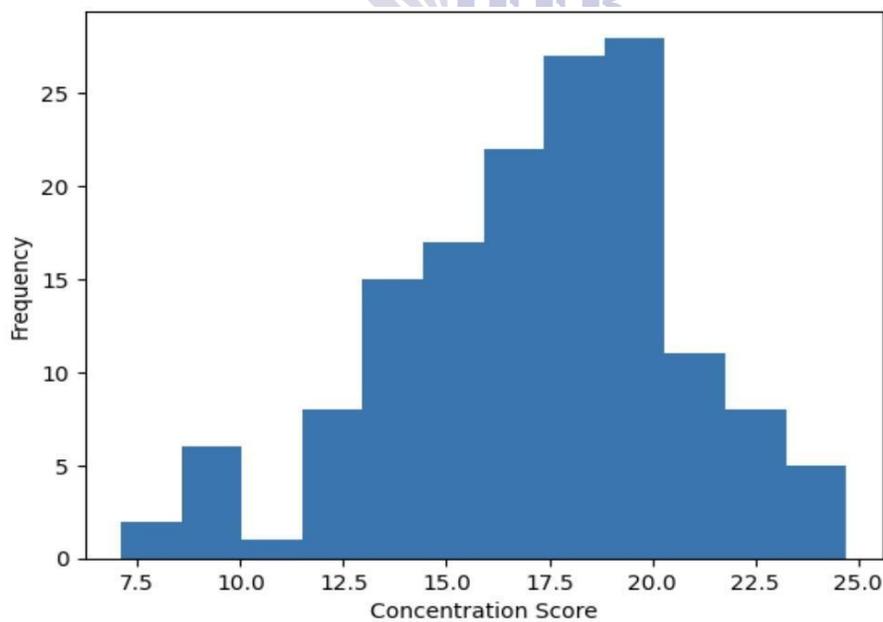
Figure 4:

Histogram illustrating the distribution of concentration scores among the study participants

(N = 150). The distribution demonstrates the variability of attention performance among university students.
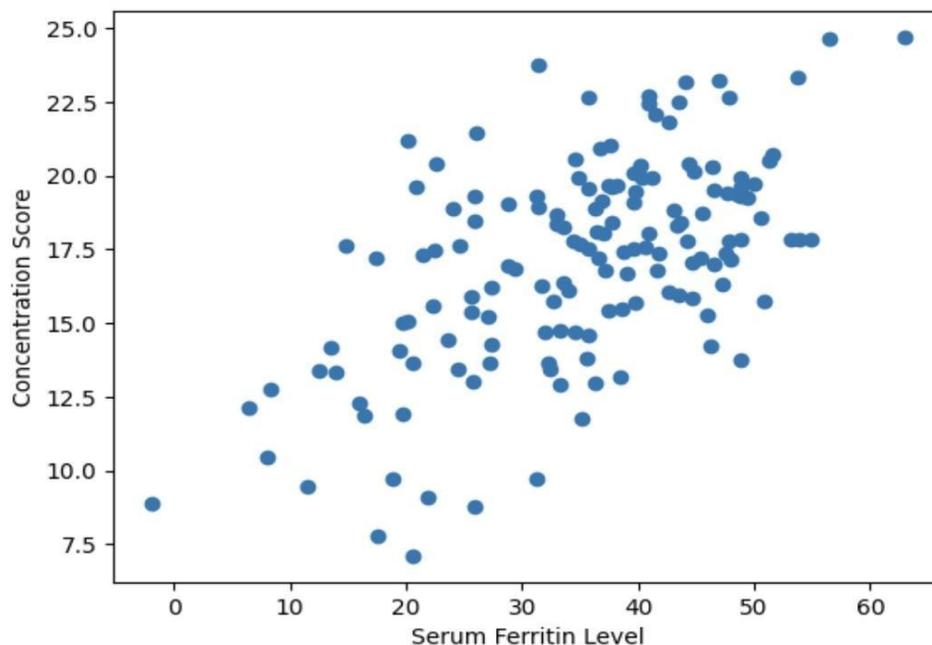
Figure 5:

Scatter plot showing the relationship between serum ferritin levels and concentration scores among university students, indicating a positive correlation between iron status and cognitive performance.

Discussion

The present cross-sectional study aimed to evaluate the association between iron deficiency and concentration span among undergraduate medical students. The results of the study reported that students with iron deficiency had significantly lower concentration scores compared with those who had normal iron levels. These findings proved that iron status plays an important role in cognitive functioning, particularly in attention and concentration among young adults.

Iron is an essential micronutrient involved in several neurological processes, including oxygen transport to brain tissues, neurotransmitter synthesis, and energy metabolism within neurons. Insufficient iron levels may impair these physiological processes and consequently affect cognitive performance(16). Previous literature has shown that iron deficiency can negatively affect attention, memory, and learning abilities, especially in adolescents and young adults (19).

The findings of our study are consistent with earlier studies that have reported a significant relationship between iron deficiency and reduced cognitive performance. For example, a study by McCann and Ames (20) found that iron deficiency is associated with impaired cognitive and behavioral functions, particularly in tasks requiring sustained attention. Similarly, (17) reported that iron supplementation improved cognitive performance and attention in individuals with low iron status.

Another important finding of this study was the moderate positive correlation between serum ferritin levels and concentration scores. This indicates that students with higher iron stores tended to perform better in concentration-related tasks. Similar findings have been reported in previous research, where ferritin levels were positively associated with cognitive performance and academic functioning (18).

University students are more prone to nutritional deficiencies due to irregular dietary habits, high academic stress, and increased physiological

demands. Studies have suggested that iron deficiency is relatively common in young adults and may contribute to fatigue, reduced productivity, and impaired cognitive function (21). Therefore, maintaining adequate iron levels through balanced nutrition and appropriate health interventions is essential for optimal cognitive performance.

Despite these findings, several limitations should be considered when interpreting the results of this study. The cross-sectional design limits the ability to establish a causal relationship between iron deficiency and reduced concentration span. Additionally, other potential factors such as sleep quality, stress levels, dietary intake, and lifestyle habits were not fully controlled and may have influenced concentration performance.

Conclusion

The results of the study reported a significant association between iron deficiency and reduced concentration span among undergraduate medical students. Students with optimal iron levels showed better concentration performance compared with those who were iron deficient. These findings highlight the importance of maintaining proper nutritional status, particularly adequate iron intake, for adequate cognitive functioning in young adults. Early identification and management of iron deficiency through dietary interventions, supplementation, and regular health screening may help improve concentration and academic performance among undergraduate medical students. Further, studies should be conducted to better understand the long-term cognitive effects of iron deficiency and to develop effective strategies for prevention and management.

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