BIOMARKERS OF COGNITIVE DYSFUNCTION AND INTEGRATION OF DIGITAL NEUROCOGNITIVE ASSESSMENT IN ADOLESCENTS WITH ANEMIA

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Abstract. *Anemia, particularly iron deficiency anemia, is a prevalent condition among adolescents and is increasingly recognized as a factor influencing cognitive development. This study investigates the association between anemia-related biological markers and cognitive dysfunction, while exploring the integration of digital neurocognitive assessment tools for early detection. A cross-sectional study was conducted involving adolescents aged 12–18 years. Hematological parameters, including hemoglobin, serum ferritin, and transferrin saturation, were analyzed alongside digital cognitive testing outcomes. The findings demonstrate significant correlations between reduced iron status and impairments in attention, working memory, and executive function. The study supports the potential of combining biological and digital markers to enhance early diagnosis and intervention strategies.*

Keywords: *Adolescents; Anemia; Cognitive Dysfunction; Biomarkers; Digital Neurocognitive Assessment; Iron Deficiency; Executive Function.*

Introduction. Adolescence represents a critical period of neurodevelopment characterized by rapid structural and functional brain maturation. Anemia, especially iron deficiency anemia, remains one of the most widespread nutritional disorders globally. Iron plays a crucial role in oxygen transport, neurotransmitter synthesis, and myelination processes, all of which are essential for optimal cognitive functioning.

Emerging evidence suggests that anemia during adolescence may lead to subtle but persistent cognitive deficits, particularly in attention, memory, and executive functions. Traditional diagnostic approaches rely primarily on hematological indices, which do not fully capture neurocognitive impairment. Therefore, identifying reliable biomarkers and integrating them with innovative digital cognitive assessment tools is essential for improving early detection and management.

Materials and Methods

A cross-sectional analytical study was conducted involving 120 adolescents aged 12–18 years, divided into two groups: anemic (n=60) and non-anemic controls (n=60).

Hematological Assessment:

Blood samples were collected to measure:

- Hemoglobin (Hb)
- Serum ferritin
- Transferrin saturation
- Mean corpuscular volume (MCV)

Cognitive Assessment:

Participants underwent digital neurocognitive testing using standardized computerized tools assessing:

- Attention (Continuous Performance Test)
- Working memory (n-back task)
- Executive function (Stroop test)

Statistical Analysis:

Data were analyzed using correlation and regression models to evaluate relationships between biomarkers and cognitive performance.

Results

The anemic group showed significantly lower performance across all cognitive domains compared to controls ($p < 0.05$).

Key findings include:

- Positive correlation between hemoglobin levels and attention scores ($r = 0.42$)
- Strong association between serum ferritin and working memory performance ($r = 0.51$)
- Reduced executive function linked to low transferrin saturation

Digital cognitive assessments demonstrated high sensitivity in detecting mild cognitive impairment not evident in routine clinical evaluation.

Discussion

The results confirm that anemia in adolescents is associated with measurable cognitive deficits, particularly in executive function and working memory. Iron deficiency may impair neurotransmitter metabolism and reduce cerebral oxygenation, leading to decreased neural efficiency.

The integration of digital neurocognitive tools provides a novel approach to detecting early cognitive dysfunction. Unlike traditional methods, these tools offer objective, scalable, and sensitive measures. The findings align with current neurobiological models emphasizing the role of micronutrients in brain development.

Conclusion

This study provides compelling evidence that anemia, particularly iron deficiency, exerts a multifaceted and measurable impact on cognitive functioning in adolescents. The findings highlight that reductions in key hematological biomarkers—such as hemoglobin and serum ferritin—are significantly associated with impairments in attention, working memory, and executive functions, which are critical for academic performance and daily decision-making.

Importantly, the results suggest that cognitive dysfunction in anemic adolescents may not always be clinically apparent through conventional diagnostic approaches, underscoring the limitations of relying solely on standard hematological indicators. The incorporation of digital neurocognitive assessment tools reveals subtle deficits with higher sensitivity and objectivity, offering a more comprehensive evaluation of neurocognitive status.

Furthermore, the study reinforces the neurobiological premise that iron plays an essential role in brain metabolism, myelination, and neurotransmitter regulation during a critical period of neurodevelopment. Disruptions in these processes may contribute to both immediate cognitive inefficiencies and potential long-term developmental consequences if left unaddressed.

Overall, the integration of biological markers with digital cognitive assessments represents a promising, scalable, and clinically relevant approach for early identification of at-risk adolescents. This combined strategy has the potential to transform current screening paradigms and improve targeted intervention outcomes, ultimately supporting better cognitive health and developmental trajectories in this vulnerable population.

Recommendations

1. Implement routine cognitive screening for adolescents diagnosed with anemia.
2. Integrate digital neurocognitive tools into pediatric and school health systems.
3. Promote early iron supplementation and nutritional interventions.
4. Conduct longitudinal studies to assess long-term cognitive outcomes.
5. Develop standardized protocols combining biomarkers and cognitive testing for early diagnosis.

REFERENCES

1. Beard, J. L. (2003). Iron deficiency alters brain development and functioning. The Journal of Nutrition, 133(5), 1468S–1472S.
2. Lozoff, B., & Georgieff, M. K. (2006). Iron deficiency and brain development. Seminars in Pediatric Neurology, 13(3), 158–165.
3. World Health Organization. (2020). WHO guidelines on use of ferritin concentrations to assess iron status in individuals and populations. Geneva: WHO.
4. McCann, J. C., & Ames, B. N. (2007). An overview of evidence for a causal relation between iron deficiency during development and deficits in cognitive or behavioral function. The American Journal of Clinical Nutrition, 85(4), 931–945.
5. Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. Child Development, 81(6), 1641–1660.
6. Diamond, A. (2013). Executive functions. Annual Review of Psychology, 64, 135–168.
7. DeRegnier, R. A., & Nelson, C. A. (2019). Neurodevelopment in early life and the role of micronutrients. Pediatrics, 144(Supplement 3), S176–S182.
8. Taras, H. (2005). Nutrition and student performance at school. The Journal of School Health, 75(6), 199–213.