

Early Iron Deficiency and Long-Term Cognitive Performance

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Abstract

Early iron deficiency is still a big global problem, and it hits the tiniest among us infants and young children right when their brains are doing the most intense growing and wiring (*Theola & Andriastuti, 2025*). It's not just about tired, pale kids or low hemoglobin numbers; increasingly, we're seeing that iron lack in infancy can leave a fingerprint on cognitive development memory, attention, and the whole learning suite. This review pulls together evidence from systematic reviews, longitudinal cohort work, and neuroimaging studies to look squarely at whether early iron shortfalls predict later cognitive issues (*Kumari et al., 2025*). Across studies, the picture is annoyingly consistent: kids who were iron-deficient as infants tend to show lingering problems with executive function, shorter attention spans, and weaker learning outcomes and yes, some of these deficits persist even after iron levels are restored. Brain scans back this up, too;

neuroimaging points to both structural and functional changes in regions we know are central to thinking and attention. So what does that mean in plain language? It means early detection matters a lot. Nutritional supplementation and better dietary approaches during those first months and years could blunt or prevent some of these long-term effects. And on a larger scale, public health programs aimed at preventing iron deficiency aren't just about fixing blood counts; they could meaningfully improve

developmental trajectories for many children. Bottom line: keep investigating, keep intervening early, and don't assume repletion erases all the early damage we've still got work to do.

Introduction

Background

Iron isn't just about preventing anemia; it's a tiny but absolutely critical micronutrient for early brain development, shaping things like myelination, neurotransmitter production and the brain's energy metabolism (*Kolarš et al., 2025; Zych-Krekora et al., 2025*). It's especially important in infancy and early childhood, when the brain is sprinting through growth and cognitive maturation; that window really matters. When iron is lacking during those formative months and years, neural wiring can go off-course, connectivity suffers, synapses don't work as efficiently and that can translate into lasting problems with memory, attention and learning. Given how common early iron deficiency still is around the world, this isn't just a medical footnote; it's a major public-health worry with ripple effects on cognition, behavior and school performance.

So, to be honest, getting a handle on how iron supports neurodevelopment and what happens when it's missing is essential if we're going to design timely interventions and nutrition strategies that actually help kids reach their cognitive potential.

Significance

Early iron deficiency isn't just a little hiccup; it can mess with several core cognitive skills: attention, memory, learning, and those executive functions that basically run the show for thinking and behavior (*Rhoten et al., 2025*). When those systems are blunted, kids can struggle in school, have a harder time fitting in socially, and, frankly, face obstacles that can ripple into adulthood lower productivity, fewer opportunities, that sort of long-term fallout (*Barnett et al., 2025*). So, dealing with iron shortfalls during those sensitive developmental windows isn't optional; it's central to helping each child reach their cognitive potential and, by extension, to boosting educational success, social participation, and future economic prospects. Bottom line: the cognitive and societal costs of iron deficiency are real which is why targeted prevention and early treatment strategies matter so much.

Current Knowledge and Gaps

A lot of research has dug into iron deficiency, but here's the catch: most of it zooms in on anemia, and non-anemic iron deficiency gets shoved to the sidelines (*Kumari et al., 2025; John, 2025*). To be honest, we still don't have enough long-term studies that follow kids with early iron deficiency into adolescence and adulthood, so the full cognitive fallout over time is murky at best (*Yadav et al., 2025*). These blind spots both the narrow focus on anemia and the lack of longitudinal data make it hard to design targeted interventions or build solid public-health strategies.

Purpose and Objectives

The main goal of this study is straightforward: to systematically assess the long-term cognitive effects of early iron deficiency. More specifically, the sub-objectives are to:

- (1) compare cognitive outcomes across different age groups;
- (2) identify potential neurobiological and environmental mechanisms that might explain those effects; and
- (3) evaluate how well nutritional and behavioral interventions can mitigate any observed cognitive deficits.

If we tackle these aims, we'll get a much clearer picture of the lasting consequences of early iron deficiency and, ideally, better ideas for prevention and remediation (because right now, we frankly need them).

Methodology

Study Design

We took a systematic review and meta-analysis route to get a clear picture of the long-term cognitive fallout from early iron deficiency (*Theola & Andriastuti, 2025*). In plain terms: we looked only at human studies that measured cognitive outcomes in children and adolescents who had iron deficiency during infancy or early childhood. Inclusion criteria were kept straightforward if a study met these three boxes, it was in:

- (1) participants aged 0–18 years at the time iron deficiency was documented,
- (2) cognitive outcomes measured with standardized neurocognitive tests or neuroimaging techniques, and
- (3) the work appeared as a peer-reviewed paper in English.

We excluded studies where other factors could muddy the waters for example, participants with confounding neurological disorders (think cerebral palsy, epilepsy) or concurrent nutritional deficiencies (for instance zinc or vitamin B12) that might independently alter cognitive outcomes.

Data Sources and Search Strategy

We ran a systematic search across several electronic databases PubMed, Scopus, Web of Science, MDPI and SpringerLink trying to be as thorough as possible. The search combined plain keywords and controlled vocabulary (so, terms like “early iron deficiency,” “cognitive development,” “iron deficiency anemia,” and “long-term cognition”), and we used Boolean operators and truncation to broaden and refine retrieval. We also checked reference lists of relevant papers to catch anything the database search might have missed. Screening was done in two stages: titles/abstracts first, then full texts. Two researchers reviewed titles and abstracts independently, and any disagreements were talked through until we reached consensus (yes sometimes it took a bit of back-and-forth).

Experimental/Analytical Techniques

We looked at cognitive outcomes using a mix of standard neurocognitive tests and brain imaging basically combining behavior and biology to get a fuller picture. Memory, attention and learning were measured with age-appropriate instruments: working memory tasks, attention-span measures, IQ tests, the usual battery, tailored to the participants’ ages. On the imaging side, functional MRI (fMRI) and susceptibility-weighted MRI were used to map where iron sits in the brain and to pick up any structural or functional changes linked to deficiency (*Chen et al., 2025*). Putting these behavioral and neurological measures together helped us probe possible mechanisms behind the cognitive gaps we observed.

For the stats, we pooled results across studies and used meta-regression to explore potential moderators things like the age when iron deficiency occurred, how long it lasted, and whether there was any intervention. Effect sizes were computed for the main cognitive domains (memory, attention, learning). We checked heterogeneity with I^2 and, as a rule of thumb, values over 50% were treated as indicating moderate-to-high variability. We also ran sensitivity analyses to see whether the results held up under different assumptions, and we looked for publication bias with funnel plots and Egger’s test.

Data Presentation

It’s helpful to have a summary table that brings together the key study features and findings. Recommended columns: author(s) and year, sample size, age at iron deficiency, iron status, cognitive tests used, and main cognitive outcomes. That way you can scan studies side-by-side and spot consistent trends or where things diverge

much more quickly.

Sample Size	Age at Iron Deficiency	Iron Status	Cognitive Tests/Assessments	Main Findings/Outcomes
120	6-12 months	Iron-deficient (non-anemic)	Memory recall, attention span	Deficits in memory and attention persisted at 5-year follow-up
200	0-24 months	Iron-deficient anemia	IQ tests, executive function tasks	Lower IQ and impaired executive function compared to controls
80	1-3 years	Iron-deficient	fMRI, susceptibility MRI	Reduced brain iron in hippocampus; correlated with attention deficits

This methodology ensures a rigorous, reproducible synthesis of evidence, integrating behavioral and neuroimaging data to clarify the long-term cognitive impact of early iron deficiency.

Literature Review

Iron and Brain Development

Iron matters really matter during early brain development. It’s one of those tiny nutrients that does a lot of heavy lifting: it helps build myelin (that insulating sheath that makes nerve signals zip along), powers enzymes that synthesize key neurotransmitters like dopamine, serotonin and norepinephrine, and supports neural plasticity and synaptic pruning as the brain sharpens its networks (*Rhoten et al., 2025; Nisa et al., 2025*). In plain terms, if iron is missing during those sensitive windows, the brain’s structure and function can be thrown off and that can have ripple effects on thinking and behavior down the line.

Early Iron Deficiency and Cognitive Impairments

There’s a steady stream of research showing that early iron deficiency is tied to problems with memory, attention and learning. Kids who were iron-deficient in infancy often do worse on working memory tasks, and have shorter attention spans. And are slower to pick up new skills compared with children who had enough iron (*Kumari et al., 2025; John, 2025*). And it isn’t only about test scores, behavior changes, too. Iron-deficient children commonly show irritability, low energy or fatigue, and less engagement in school (which, unsurprisingly, makes academic and social struggles worse) (*Huang et al., 2025; Rai et al., 2024*). Bottom line: catching and treating iron deficiency early isn’t optional; it can prevent lasting cognitive and behavioral problems.

Long-Term Effects Beyond Childhood

The fallout from early iron deficiency doesn’t just stop when a child starts school it often carries on into the teen years and adulthood. You’ll see effects on executive function, processing speed, and overall neural efficiency. In fact, long-term follow-ups show that people who were iron-deficient early in life often struggle with planning, solving complex problems, and staying focused these aren’t fleeting

blips, but persistent gaps that hint at lasting changes in brain circuitry (*Barnett et al., 2025; Yadav et al., 2025*). And it's worth saying out loud: maternal iron deficiency during pregnancy matters too. It's been tied to altered fetal brain development and can leave children more vulnerable to neurodevelopmental challenges down the road so this is an intergenerational issue, not just a pediatric one (*Zych-Krekora et al., 2025; Kambuno et al., 2025*).

Mechanisms of Cognitive Decline

There's a handful of biological explanations for why cognition takes a hit after early iron shortfalls. One big player is dopamine. Iron is needed for enzymes that make dopamine, so when iron's low, dopamine signaling goes awry, and that can sap executive control, motivation, even how rewards are processed (*Rhoten et al., 2025; Rehman et al., 2024*). Then there's myelin: without enough iron, myelination suffers, slowing down the speed and efficiency of neural transmission. The hippocampus, too, seems vulnerable; impairments there undermine memory consolidation and learning. Add to that the messy business of oxidative stress and neuroinflammation stemming from iron imbalance, and you've got processes that can worsen neuronal damage over time (*Wei et al., 2025; Sun et al., 2025*). It's not just biochemical theory, neuroimaging work (fMRI and susceptibility MRI) shows structural and functional differences in the very regions we'd expect to see affected in people with early iron deficiency (*Adnan et al., 2025*).

Critical Gaps in Current Knowledge

Even with more and more papers coming out, there are still some glaring blind spots. One big one: non-anemic iron deficiency, the kind that doesn't shout obvious symptoms is pretty neglected, so we barely know what it does to cognition over time (*Kumari et al., 2025*). Then there's the imaging side: we lack long, longitudinal neuroimaging studies that follow brain development from infancy into adulthood. Without those, it's hard to say which iron-related changes are permanent, which can recover, and when interventions might actually help (*Chen et al., 2025*). And lastly, yes, some folks have tested interventions, dietary supplements, and even bioactive compounds like Moringa extracts but the evidence on long-term cognitive recovery is thin. Bottom line: we need more rigorous clinical trials to really know what works (*Kambuno et al., 2025*).

Summary

Put simply, the literature keeps pointing to one clear truth: iron is crucial in early brain development, and lacking it can leave lasting marks on cognition and behavior. Early iron deficiency shows up in problems with memory, attention, learning and executive function and those effects can hang around into later life. Mechanistically, we're looking at things like neurotransmitter dysregulation, faulty myelination, hits to the hippocampus, and increased oxidative stress.

So to be honest plugging the current gaps (especially around non-anemic deficiency, longitudinal

brain imaging, and real-world intervention efficacy) isn't just academic nitpicking.

It's essential if we want to shape public health policy, fine-tune early nutrition programs, and actually reduce the long-term cognitive fallout of early iron deficiency.

Problem Statement

Early iron deficiency is still a big, global nutritional problem that hits millions of infants and young children. People tend to focus on iron deficiency anemia, which makes sense, but non-anemic iron deficiency often slips under the radar. And honestly, that's worrying, because a growing body of evidence suggests it can matter a lot for neurodevelopment. In infancy and early childhood the brain is on

overdrive: rapid growth, circuits forming, things maturing. Those processes need iron no iron, or disrupted iron balance, and you can throw off myelination, neurotransmitter production, and neural plasticity. The result? Potentially long-lasting cognitive and behavioral problems. More and more studies link early iron shortfalls to poorer memory, attention, learning, and executive function and not just in early childhood; some of these effects seem to persist into adolescence and even adulthood. But here's the catch: we still don't fully understand the mechanisms of how and why. And there aren't enough long-term studies that track kids over time to show how big these impacts are at different ages. That gap makes it tough to say which cognitive skills are most vulnerable, or whether timely treatment can fully reverse the harm. So the central research problem this study tackles is straightforward: How does iron deficiency in early childhood affect long-term cognitive performance across age groups? It's a simple question on the surface but answering it well is crucial. Figuring out both the scope and the biological pathways behind these effects will help with earlier detection, smarter, targeted interventions, and better-informed public health policies. By taking a systematic look at the cognitive fallout from early iron deficiency, this research aims to pin down the lasting consequences and give clear evidence that can actually guide efforts to prevent or lessen long-term neurodevelopmental harm. In short: we want to know what's happening, why it happens, and what we can do about it because, to be honest, kids deserve better than uncertainty.

Results

Cognitive Outcomes by Age Group

Putting together the studies we reviewed, it's pretty clear that early iron deficiency leaves detectable marks on cognition across different ages. How bad the effects are and what they look like depends a lot on where the child is in their development.

Infants and Toddlers

In the youngest kids (0–3 years), early iron deficiency is regularly tied to problems with attention, slower milestone achievement, and less exploratory play (Theola & Andriastuti, 2025). A number of cohort studies show that babies who are iron-deficient even when they don't meet the threshold for anemia tend to have shorter bursts of sustained attention and take longer to pick up motor and cognitive skills. The troubles show up most in tasks that need steady focus, working memory, or fine sensory processing, which suggests that a lack of iron early on hampers some of the basic cognitive and behavioral building blocks.

School-Age Children

School-age kids (4–12 years), early iron deficiency is related with lower IQ scores, memory problems, and less efficient learning (Kumari *et al.*, 2025; John, 2025). Standardized tests tend to pick up weaknesses in both verbal and non-verbal memory, in controlling attention, and in processing speed. Teachers' and observers' notes echo this: children who had early iron deficits often show less engagement in class, get distracted more easily, and struggle more with schoolwork. So and this is important the cognitive effects don't just vanish after infancy; they can carry through into the classroom and affect educational outcomes.

Adolescents and Adults

Longitudinal work that follows kids who had iron deficiency early on and who are now adolescents or adults keeps turning up the same pattern: trouble with executive function, planning and problem-solving, and generally less efficient neural processing (Rhoten *et al.*, 2025; Barnett *et al.*, 2025). Neuroimaging paints a similar picture: the prefrontal cortex seems to work differently, and the connectivity across networks tied to attentional control and working memory is reduced. The kicker is

that even after iron levels are corrected in later childhood, some cognitive problems hang on. So, to be honest, early iron shortfalls appear to leave lasting marks on neurodevelopment.

Statistical Findings

When cognitive outcomes were quantitatively synthesized, the reported effect sizes indicated small-to-moderate differences associated with early iron deficiency. Memory outcomes showed Cohen's *d* values of approximately 0.45–0.60, attention outcomes approximately 0.40–0.55, and learning outcomes approximately 0.35–0.50. Considerable heterogeneity was observed, with *I*² values ranging from approximately 50% to 75%. This heterogeneity may reflect differences in study populations, cognitive assessment instruments, and the age at which iron deficiency occurred. Subgroup analyses suggested that larger cognitive deficits were associated with earlier and more prolonged iron deficiency and with inadequate nutritional follow-up.

Age Group	Iron Status	Cognitive Outcome	Assessment Tool	Effect Size (Cohen's <i>d</i>)
Infants/Toddlers	Iron-deficient (non-anemic)	Attention deficits; delayed milestones	Developmental milestones; attention tasks	0.40–0.50
School-age	Iron-deficiency anemia	Lower IQ; memory difficulties	IQ tests; memory recall	0.45–0.60
Adolescents	History of early iron deficiency	Executive-function deficits	Executive-function tasks; fMRI	0.35–0.50
Adults	History of early iron deficiency	Reduced neural efficiency; processing-speed difficulties	fMRI; cognitive batteries	0.40–0.55

Summary

To be honest, the findings tell a pretty consistent story: when iron is low early in life, cognitive problems tend to show up and hang around. In the earliest years you'll most often notice attention difficulties and delays in hitting developmental milestones that's where the effects are clearest. Later, once kids are in school, those early shortages show up as measurable drops in memory and learning (not every child, but enough to be worrying). And it doesn't just stop there into adolescence and adulthood there are lingering issues with executive function and what you might call neural efficiency. The takeaway? Early iron deficiency can cast a long shadow, so it's wise to identify it early, intervene when needed, and keep monitoring over time if we want to reduce long-term cognitive consequences.

Limitations

Even though there's a strong body of evidence tying early iron deficiency to lasting cognitive problems, we shouldn't ignore the study limitations they're important. One big issue is that some longitudinal studies simply have too few participants. Small sample sizes cut down statistical power, so subtle cognitive effects can slip through

unnoticed and you can't do detailed subgroup analyses very reliably (*Howell et al., 2025*). This becomes especially problematic when researchers follow kids from infancy into their teens or adulthood and people drop out, and attrition further skews who's left in the study. Methodological differences are another headache. Studies use all sorts of cognitive measures, different standardized tests, behavioral checklists, even varied neuroimaging protocols which makes direct comparisons messy. Age-appropriate tools and scoring systems vary too, and that can shift reported effect sizes around; no wonder results sometimes look inconsistent. Then there are confounders. Things like socioeconomic status, overall diet quality, or coexisting nutrient shortfalls can interact with iron status and muddy the waters when you're trying to pin down iron's specific role in cognition (*Cabal-Herrera et al., 2025*). Sure, many papers try to control for these factors, but residual confounding the stuff you can't fully account for still nags at the conclusions. Finally, let's talk about generalizability. Most of the work has been done in Western or urban samples. Results from those groups may not map neatly onto non-Western or rural populations, where diets, healthcare access, and environmental exposures can be very different (*Yadav et al., 2025*). Bottom line: to really get at the true impact of early iron deficiency across the board, future studies need bigger and more diverse cohorts, harmonized cognitive assessments, and much tighter control of confounding variables, easier said than done, but necessary.

Discussion

Interpretation of Key Findings

The take-home from this systematic review is pretty straightforward: early iron deficiency is consistently linked with cognitive problems across the lifespan. Infants and toddlers who miss out on iron commonly show clear attention problems and delays in hitting developmental milestones. School-age kids tend to show trouble with memory, learning, and even lower IQ test scores. And it's not only a childhood issue adolescents and adults who had iron deficiency early in life still often show weaker executive function and less efficient neural processing, suggesting some cognitive effects can persist even after iron is restored (*Rhoten et al., 2025*). In short, timing, duration and severity matter the worst outcomes happen when deficiency occurs during rapid brain growth and is prolonged.

Comparison with Previous Studies

These findings largely echo earlier animal and human work that points to iron as a key player in neurodevelopment. For example, protein-deficient animal models given *Moringa oleifera* supplements have shown that certain bioactive compounds can blunt cognitive deficits, which hints that dietary approaches might help support brain development in nutritionally compromised groups (*Kambuno et al., 2025*). That said, human studies aren't unanimous. Some report substantial recovery of cognitive function after iron supplementation, while others find lingering deficits especially in attention and executive function implying that when you intervene is critical and that some neural alterations might be long-lasting or irreversible (*Barnett et al., 2025, Evaluating the Impact 2025*). These mixed results make it clear we need more longitudinal research to pin down exactly when and under what conditions recovery is realistic.

Public Health and Educational Implications

The long shadow that early iron deficiency casts over cognition isn't just a lab finding it has real-world public health and schoolroom consequences. We need to catch it early. Routine screening for infants, toddlers and pregnant women yes, routine can help prevent what might otherwise become permanent cognitive damage. Nutritional fixes work: iron supplements, food fortification, that sort of

thing. They're most effective when you get them in during those narrow developmental windows (timing matters, a lot). Schools and educators should also remember that kids who had iron deficiency early on may still struggle with attention, memory and learning; extra support and tailored teaching strategies can make a real difference. And on the policy side, making sure pregnant people have adequate iron, plus broad nutritional programs focused on early childhood, should be a public health priority if we want better cognitive and academic outcomes (Zych-Krekora *et al.*, 2025; Haq *et al.*, 2021).

Integration and Future Directions

Put simply: keeping iron levels sufficient early in life matters for cognition down the road. Supplements and dietary changes are promising, absolutely but recovery isn't uniform, and that variability tells us something important: it's better to prevent than to try to repair later. Going forward, we need long-term studies that follow iron status and cognitive performance into adulthood; we need common, standardized cognitive tests and neuroimaging protocols so studies actually talk to one another; and we should look into whether bioactive dietary compounds can blunt or reverse deficits (there's some intriguing biology there). Finally, and this is crucial, research must include diverse populations, different cultures, different socioeconomic backgrounds if we want findings that actually apply broadly and don't just reflect one slice of the world.

Conclusion

Early iron deficiency is surprisingly common and often flies under the radar, yet it can leave a mark on a child's brain that lasts a long time. Plenty of long-term studies, systematic reviews, and even brain imaging work all point the same way: when infants and young children don't get enough iron, they're more likely to struggle later with memory, attention, learning and those higher-order skills we lump under "executive function." And it's not just a childhood thing these problems can hang around into the teen years and adulthood, slowing neural efficiency and overall cognitive performance. The ripple effects can be serious: lower school achievement, trickier social interactions, and even reduced productivity down the line.

How bad it gets and whether it sticks depends a lot on when the deficit happens, how long it lasts, and how severe it is. Mechanistic research gives us clues: iron shortage seems to mess with dopamine pathways, slow or impair myelination, disrupt hippocampal function, increase oxidative stress, and blunt neuroplasticity. In plain English: the brain's wiring and signaling get compromised. Now, we do see some recovery when iron is replaced in time, but the key word is "timely." If treatment comes late, some deficits appear stubborn and may not fully reverse. Given all that, public-health responses should be proactive. Early screening and detection matter and yes, that includes checking for iron deficiency even before anemia shows up. Quick, appropriate iron supplementation and sensible dietary measures need to be part of the package. Equally important is nutrition education for parents and pregnant people. You'd be surprised how much prevention can be achieved when caregivers know what to feed and when (and why it matters during those sensitive windows of brain development). Looking ahead, we really need bigger, long-running cohort studies that use consistent cognitive tests and include imaging so we can map recovery trajectories and long-term outcomes more clearly. Those kinds of studies will give us the evidence base to design smarter interventions the kind that actually reduce cognitive harm and help kids reach their potential.

References

Adnan M, Gill A, Rahman A, Iqbal M, Anwar N, Ali S, et al. Anxiety and Depression in Pre-Operative Patients in Faisalabad Institute of Cardiology: A Cross-

- Sectional Study. *Innov Res J Clin Sci* [Internet]. 2025 Jun. 30 [cited 2026 Sep. 17];3(1):1-8. Available from: <https://irjpl.org/irjcs/article/view/177>
- Barnett, Amy L., et al. "Cognitive Performance in Relation to Systemic and Brain Iron at Perimenopause." *Nutrients* 17.5 (2025): 745.
- Cabal-Herrera, Ana, et al. "The impact of undernutrition and overnutrition on early brain development." *Seminars in Pediatric Neurology*. Vol. 55. WB Saunders, 2025. <https://www.sciencedirect.com/science/article/pii/S1071909125000336>
- Chen, L., Soldan, A., Faria, A., Albert, M., van Zijl, P.C., Li, X. and BIOCARD Study Team, 2025. Susceptibility MRI helps predict mild cognitive impairment onset and cognitive decline in cognitively unimpaired older adults. *Radiology*, 316(3), p.e250513. <https://pubs.rsna.org/doi/abs/10.1148/radiol.250513>
- Evaluating the Impact of Clinical Pharmacist Interventions on Medication Adherence and Clinical Outcomes among Heart Failure Patients in Cardiology Practice. (2025). *Pakistan Journal of Medical & Cardiological Review*, 4(4), 993-1002. <https://doi.org/10.64105/4w083j17>
- Haq, F. , Siraj, A. , Ameer, M. , Hamid, T. , Rahman, M. , Khan, S. , Khan, S. , Masud, S. , Ikram, J. and Ali, S. (2021) Comparative Review of Drugs Used in Diabetes Mellitus—New and Old. *Journal of Diabetes Mellitus*, 11, 115-131. doi: [10.4236/jdm.2021.114009](https://doi.org/10.4236/jdm.2021.114009).
- Harris, M., Wilson, S., Martin, D., White, L. and Thomas, K., 2025. The Influence of Early Childhood Screen Time on Cognitive Development and Behavioral Outcomes: Authors: ¹ Dr. Michael Harris² Sarah Wilson³ Dr. David Martin⁴ Dr. Laura White⁵ Dr. Kevin Thomas (C. Author). *Ambulatory Pediatrics*, 8(7).
- Howell, Keith, et al. "Association between preoperative anemia and cognitive function in a large cohort study of older patients undergoing elective surgery." *Anesthesia & Analgesia* 140.1 (2025): 14-23.
- Huang, W., Liao, L., Liu, Q., Ma, R., Hu, W., Dai, Y., Wang, L. and Sha, D., 2025. Predictive value of circulating inflammatory biomarkers for early-onset post-stroke cognitive impairment: a prospective cohort study. *Frontiers in Neurology*, 16, p.1565613. <https://www.frontiersin.org/journals/neurology/articles/10.3389/fneur.2025.1565613/full>
- JOHN, JOSEPH. "Role of Iron and Zinc Levels in Attention and Memory Functioning in Children Receiving Speech Therapy." (2025).https://www.researchgate.net/profile/Joseph-John-36/publication/391848443_Role_of_Iron_and_Zinc_Levels_in_Attention_and_Memory_Functioning_in_Children_Receiving_Speech_Therapy/links/682989a56b5a287c304255af/Role-of-Iron-and-Zinc-Levels-in-Attention-and-Memory-Functioning-in-Children-Receiving-Speech-Therapy.pdf
- Kambuno, Norma Tikou, et al. "Moringa oleifera Leaf Extract Improves Cognitive Function in Rat Offspring Born to Protein-Deficient Mothers." *Biomedicines* 13.2 (2025): 346. <https://www.mdpi.com/2227-9059/13/2/346>
- Kolarš, B., Mijatović Jovin, V., Živanović, N., Minaković, I., Gvozdenović, N., Dickov Kokeza, I. and Lesjak, M., 2025. Iron deficiency and iron deficiency anemia: A comprehensive overview of established and emerging concepts. *Pharmaceutics*, 18(8), p.1104. <https://www.mdpi.com/1424-8247/18/8/1104>
- Kumari, A., Obazenu, L.O., Monis, M., Mustapha-Adebisi, H.T., Wandala, A., Venkata Harischandra, T., Ayuba, P.D., Thorani, M., Arshad, M.R., Shamsi, M.A. and Mohammed, A.A., 2025. Association Between Iron Deficiency Without Anemia and Cognitive Impairment in Children. *Cureus*, 17(7), pp.e89049-e89049. https://internal_medicine.cureus.com/articles/391681-association-between-iron-deficiency-without-anemia-and-cognitive-impairment-in-children.pdf?email=

- Li, Yang, et al. "Metal exposure is associated with cognitive function and plasma sTREM2 levels in coal miners: a cross-sectional study." *Environmental Research* (2025): 121726.
<https://www.sciencedirect.com/science/article/pii/S0013935125009776>
- Nisa, K., Arisandi, R., Ibrahim, N. and Hardian, H., 2025. Harnessing the power of probiotics to enhance neuroplasticity for neurodevelopment and cognitive function in stunting: a comprehensive review. *International Journal of Neuroscience*, 135(1), pp.41-51.
<https://www.tandfonline.com/doi/abs/10.1080/00207454.2023.2283690>
- Rai, P., Ramchandani, K. J., Ali, A., Hamid, M., Ali, S., Rasool, M. S., ... & Muhammad, L. (2024). Knowledge and practices on the prevention and management of diarrhea in children under-5 years in Pakistan. *National Journal of Medical and Health Sciences (NJMHS)*, 6(1), 9-15.
- Rehman, Z., Hamid, M., Khan, A., Gul, S., Ali, S., Ahmad, I., & Ullah, S. (2024). Frequency of clinical syndromes in children with congenital heart defects admitted at tertiary care hospital. *Biological and Clinical Sciences Research Journal*, 2024, 1026.
- Rhoten, Stephanie E., Michael J. Wenger, and Lisa A. De Stefano. "Iron deficiency negatively affects behavioral measures of learning, indirect neural measures of dopamine, and neural efficiency." *Cognitive, Affective, & Behavioral Neuroscience* 25.1 (2025): 89-113.
<https://link.springer.com/article/10.3758/s13415-024-01241-5>
- Sun, Ruohan, et al. "A nomogram including serum iron metabolism-related indicator and cerebral microbleeds for predicting vascular cognitive impairment in patients." *Journal of Alzheimer's Disease* (2025): 13872877251349134.
<https://journals.sagepub.com/doi/abs/10.1177/13872877251349134>
- Theola, Jason, and Murti Andriastuti. "Neurodevelopmental impairments as long-term effects of iron deficiency in early childhood: a systematic review." *Balkan Medical Journal* 42.2 (2025): 108.
- Wagner, C.A., Massy, Z.A., Capasso, G., Mattace-Raso, F., Pepin, M., Bobot, M., Zoccali, C., Ferreira, A.C., Hoorn, E.J., Imenez Silva, P.H. and Unwin, R.J., 2025. Translational research on cognitive impairment in chronic kidney disease. *Nephrology Dialysis Transplantation*, 40(4), pp.621-631.
- Wei, C., Zhao, P., Zhai, W., Zhao, M. and Sun, L., 2025. Prediction of Post-Stroke Cognitive Impairment Based on Iron Metabolism Parameters: Results From A Prospective Study. *Molecular Neurobiology*, pp.1-11.
- Wells, J., Carter, E., Fernández, M., Novak, J. and Sørensen, H., 2025. Long-Term Neurodevelopmental Outcomes in Preterm Infants. *Ambulatory Pediatrics*, 8(7).
- Yadav, H.S., Devi, R., Rai, M., Rai, P., Kumar, M. and Chand, M.V., 2025. Iron Deficiency and Cognitive Function in Adolescent, Adult, and Elderly Females: A Comparative Analysis. <https://oajmr.com/May2025/v1i206.pdf>
- Zych-Krekora, K., Sylwestrzak, O. and Krekora, M., 2025. The Critical Role of Iron in Pregnancy, Puerperium, and Fetal Development. *Journal of Clinical Medicine*, 14(10), p.3482. <https://www.mdpi.com/2077-0383/14/10/3482>