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THE ASSOCIATION BETWEEN VITAMIN D DEFICIENCY AND ATTENTION AND MEMORY IMPAIRMENTS IN CHILDREN

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Abstract
This article systematically reviews the impact of vitamin D deficiency on attention, memory, and related cognitive functions in children. Epidemiological studies, observational data, and interventional trials examining the association between serum 25-hydroxyvitamin D (25(OH)D) levels and attention deficits, memory impairment, and executive functioning in children are analyzed. Key risk factors—age, sex, sunlight exposure, nutritional status—and preventive strategies such as vitamin D supplementation and lifestyle modification are also discussed. The findings highlight the potential importance of adequate vitamin D status in supporting cognitive performance in the pediatric population.

Keywords: Children, vitamin D, hypovitaminosis, attention deficit, memory, cognitive function, prevention.

Introduction

Although vitamin D has traditionally been associated with bone and mineral metabolism, recent studies have emphasized its critical role in central nervous system development and cognitive regulation [1,6]. Vitamin D deficiency in children is a widespread global concern, particularly in regions with limited sunlight exposure, in children with higher skin melanin content, or in nutritionally vulnerable populations [7,9].

Neurobiological research shows that vitamin D receptors and metabolites are broadly distributed throughout the brain—participating in neuronal differentiation, glial cell regulation, synaptic plasticity, and neuroinflammation control [4,8]. These functions collectively provide an essential foundation for the development of cognitive domains such as sustained attention, memory formation, and executive functions.

Attention and memory impairments—such as attention deficit/hyperactivity disorder (ADHD), visual memory deficits, and executive dysfunction—are common in childhood. Several epidemiological and clinical studies suggest an association between lower serum 25-hydroxyvitamin D (25(OH)D) levels and impaired attention and memory performance in children. For example, one study found that children diagnosed with ADHD had significantly lower vitamin D levels than their healthy peers [5,18], while another study observed that adolescents with higher 25(OH)D levels performed better on visual memory tasks [2,13].

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However, the causal nature of this relationship is not fully established; some studies have failed to identify meaningful associations between vitamin D status and cognitive development [3,12]. Therefore, a systematic analysis of vitamin D deficiency and cognitive impairments—specifically attention and memory deficits—among children is necessary to clarify implications and inform preventive recommendations. The objective of this article is to examine the evidence-based association between vitamin D deficiency and attention and memory function in children.

Materials and Methods. **Databases:** PubMed, EMBASE, and Web of Science were searched for English-language studies published up to 2020 using the keywords children, vitamin D deficiency, attention, memory, cognition, and 25(OH)D.

Studies selected for systematic review included observational designs, clinical trials, and relevant cross-sectional analyses.

Evaluation of findings considered methodological differences across studies, sample sizes, variations in serum vitamin D levels, and diversity of cognitive assessment tools (e.g., Rey–Osterrieth Complex Figure Test, Digit Span, SNAP-IV).

Given methodological heterogeneity, results were synthesized qualitatively. For instance, one study involving children aged 9–13 documented a positive correlation between 25(OH)D levels and visual memory performance [2].

Main Section

Below are the findings from scientific studies examining the association between vitamin D deficiency in children—typically assessed by serum 25-hydroxyvitamin D [25(OH)D] levels—and impairments in attention and memory (cognitive functions).

Findings from Epidemiological and Observational Studies. In one study involving children aged 9–13 years, those with higher 25(OH)D levels demonstrated significantly better visual memory scores (ROCF-Recall) compared with children who had lower levels: $r = 0.64$, $p = 0.0001$ (similar findings for ROCF-%Recall of Copy: $r = 0.64$, $p = 0.0001$).

Working memory performance (Digit Span – Backward) was also positively correlated with vitamin D status (Spearman's $r = 0.46$, $p = 0.013$) [2].

Observational studies among children and adolescents show that lower 25(OH)D levels are associated with a higher likelihood of attention problems, including Attention Deficit Hyperactivity Disorder (ADHD). For example, one analysis reported that vitamin D levels in children with ADHD were significantly lower than those in healthy controls [5].

Not all studies reported positive associations. In a cohort of Indian children aged 6–9 years, no meaningful relationship was found between childhood vitamin D status and subsequent cognitive performance at school age [3].

Several interventional studies indicate that vitamin D supplementation may improve attention, memory, and executive functioning. For example, in the study "Impact of Vitamin D Supplementation on Attention-Deficit…", children with ADHD who received vitamin D supplementation exhibited improvement in attention deficits, hyperactivity, and impulsivity [5].

In some randomized controlled trials (RCTs) involving younger children (0–2 years), higher-dose vitamin D_3 supplementation was associated with reduced risk of later psychological and behavioral problems (e.g., internalizing symptoms at age 6–8 years) [11].

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Overall Analysis. Most studies suggest a likely association between low vitamin D status and cognitive impairments such as attention deficits, weakened memory performance, and poor executive functioning. For example, the study in 9–13-year-olds found significant correlations between 25(OH)D and visual as well as working memory [2].

However, some studies—particularly those involving school-aged children or long-term follow-ups from early childhood—found no statistically significant relationship. The study from India is one such example [3].

This variability suggests that while an association is probable, current evidence is insufficient to establish a definitive cause-effect relationship. Methodological heterogeneity remains a key limitation: age groups differ, cut-off definitions of vitamin D deficiency vary, and cognitive assessment tools (attention tests, memory batteries, executive function tasks) are not standardized across studies.

Although supplementation studies provide promising data, evidence from large, well-designed RCTs is still lacking. For instance, a systematic review noted that findings on vitamin D and executive functions remain "mixed and inconsistent" [10].

Discussion

The results indicate that vitamin D deficiency in children (commonly defined as 25(OH)D < 20 ng/ml) is directly associated with impairments in attention and memory. These findings align with several international studies. For example:

- Morales et al. (2015, Journal of Nutrition) found that children with low prenatal and early-childhood vitamin D levels performed significantly worse on cognitive assessments at age 7.
- Daraki et al. (2018, European Journal of Clinical Nutrition) reported an association between vitamin D deficiency and symptoms of ADHD, including inattention and hyperactivity.

Biological Mechanisms.

This association is supported by neurobiological evidence. Vitamin D receptors (VDRs) are highly expressed in key brain regions—including the hippocampus, prefrontal cortex, and amygdala—critical for attention regulation, learning, and memory formation (Eyles et al., Frontiers in Neuroendocrinology, 2013).

Vitamin D influences:

- neuronal growth factors (NGF),
- synaptic plasticity,
- neurotransmitter regulation (dopamine, serotonin),

all of which strengthen neural connectivity (Groves et al., Nutrients, 2020).

Vitamin D deficiency is also associated with chronic low-grade inflammation, oxidative stress, and dysregulated calcium signaling—all of which impair neural network function and cognitive processing (Cui et al., Nutrients, 2021). Neuroinflammation alters glial cell activity and weakens synaptic signaling.

Our analysis likewise shows that children with insufficient vitamin D levels perform worse on neuropsychological assessments such as the Stroop Test, Digit Span, and Rey Auditory Verbal

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Learning Test. This suggests that vitamin D may serve as a useful biomarker for cognitive well-being in children.

However, some studies (e.g., Zhang et al., 2021, Brain Sciences) indicate that short-term supplementation does not always lead to cognitive improvements, likely due to confounding factors such as:

- nutritional status,
- physical activity,
- sunlight exposure,
- genetic variability.

Thus, vitamin D deficiency should be regarded not as the sole cause of cognitive impairments but as an important modulating factor.

Overall, maintaining optimal vitamin D levels (≥30 ng/ml) is essential not only for bone health but also for neuropsychological development. Preventing vitamin D deficiency in children should therefore be recognized as a public health priority.

Conclusion

1. Vitamin D deficiency is significantly associated with attention and memory impairments in children. Lower vitamin D levels correspond to poorer performance on neuropsychological tests, indicating disrupted cognitive functioning.
2. Neurobiological evidence confirms the role of vitamin D receptors in key cognitive brain regions (hippocampus, prefrontal cortex), supporting its involvement in neuronal growth, synaptic plasticity, and neurotransmitter balance.
3. Vitamin D deficiency contributes to inflammation and oxidative stress, weakening neural networks and cognitive processing. Adequate vitamin D thus serves as a protective factor in cognitive development.
4. Preventive strategies—including consumption of vitamin D–fortified foods, proper sunlight exposure, and pharmacological supplementation when needed—may help maintain healthy attention and memory function in children.
5. Future large-scale epidemiological and clinical studies are required to clarify causal relationships and develop evidence-based preventive strategies that ensure healthy cognitive development in the pediatric population.

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