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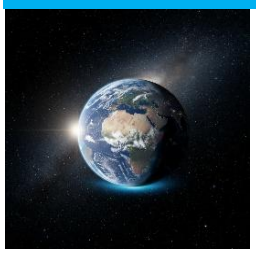

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Nutritional Interventions for Cognitive Improvement in Children with ADHD and ASD: A Systematic Review from a Biomedical and Educational Standpoint

Marcelina Kaczmarek - MK - Corresponding Author, First Author
(E-Mail: marcelina.kaczmarek.mk@gmail.com)
Collegium Medicum im. Ludwika Rydygiera w Bydgoszczy, Uniwersytet Mikołaja Kopernika w Toruniu
ORCID iD: 0009-0009-0114-0607

Dominika Dmowska - DD
(E-Mail: dominikadmowskaa@gmail.com)
Centrum Medyczne HCP Szpital im. Jana Pawla II w Poznaniu
ORCID iD: 0009-0002-9269-5577-0002-9269-5577

Karolina Rymska - KR
(E-Mail: karolinarymska1@gmail.com)
Uniwersytecki Szpital Kliniczny im. Jana Mikulicza- Radeckiego we Wrocławiu, ul. Borowska 213, 50-556 Wrocław
ORCID iD: 0009-0009-8826-8899

Maciej Krzesimir Kuświk - MKK
(E-Mail:Mkkuswik@gmail.com)
University Hospital in Poznań
ul. Przybyszewskiego 49
60-355 Poznań
ORCID iD: 0009-0006-1925-204X

Dominik Chrzanowski - DC
(E-Mail: chrzanowskidominik@wp.pl)
Państwowy Instytut Medyczny MSWiA w Warszawie
ORCID: 0009-0000-7793-6315

Wiktoria Bajek - WB
(E-Mail: victoriabajek@gmail.com
Państwowy Instytut Medyczny MSWiA w Warszawie
ORCID: 0009-0004-6200-2471

Kinga Żmuda - KŻ
(E-Mail: Kingazmuda99@gmail.com)
University Clinical Hospital of Opole, al.W.Witosa 26 45-401 Opole, Poland
ORCID: 0009-0007-0948-3642

Mikołaj Lewandowski - ML
(E-Mail: lewymikus99@gmail.com)
Regional Hospital in Poznań, Juraszów 7-19, 60-479 Poznań
ORCID: 0009-0001-8533-0660

Abstract

Background. ADHD and ASD are complex neurodevelopmental disorders characterized by oxidative stress and gut-brain axis dysfunction. Lifestyle factors, especially nutrition, are key modifiable elements affecting brain plasticity.

Aim. To analyze the impact of dietary interventions and supplementation on cognitive functions and behavior in children with ASD and ADHD.

Material and methods. A systematic review of literature (2020–2024) was conducted using the PubMed database, including RCTs, meta-analyses, and reviews.

Results. Oligoantigenic diets effectively reduce core symptoms. Supplementation with omega-3, vitamin D, and magnesium correlates with improved neurocognition. Microbiome modulation via probiotics benefits mental health and sleep.

Conclusions. Nutritional interventions serve as valuable support for pharmacological and educational therapies, impacting learning effectiveness.

Key words: ADHD; ASD; nutritional interventions; cognitive functions; microbiome; supplementation.

1. INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD) represent the most frequently diagnosed neurodevelopmental conditions in children and adolescents, characterized by persistent patterns of inattention, hyperactivity, and social-communication deficits (Drechsler et al., 2024 ; Felt et al., 2024). While traditional paradigms primarily emphasized genetic heritability, modern psychiatric research increasingly recognizes the pivotal role of modifiable environmental factors—particularly nutrition—in influencing brain plasticity and neurological development from early life stages (Johnstone et al., 2023 ; Kotsi et al., 2024 ; Karagianni et al., 2024).

From a biomedical perspective, the pathogenesis of ADHD and ASD is increasingly linked to systemic physiological disruptions, including elevated oxidative stress and chronic low-grade neuroinflammation (Verlaet et al., 2024 ; Anheyer et al., 2022). A critical area of contemporary investigation is the "gut-brain axis," where the intestinal microbiome acts as a dynamic mediator of neurochemical signaling and immune response (Dinan & Cryan, 2024 ; Bundgaard-Nielsen et al., 2024 ; Scott & Taylor, 2024). Emerging evidence suggests that specific dietary patterns, such as the Mediterranean diet or the reduction of the Dietary Inflammatory Index (DII), are significantly associated with improved attention control and decreased impulsivity (Del-Ponte et al., 2022 ; Rios-Hernandez et al., 2021 ; Shivappa et al., 2024).

Furthermore, targeted nutritional interventions, including the "few-foods" (oligoantigenic) diet, have demonstrated efficacy in identifying individual sensitivities that exacerbate core behavioral symptoms (Hontelez et al., 2021 ; Pelsser et al., 2022). The role of precise supplementation with micronutrients—specifically Vitamin D, Magnesium, and Omega-3 fatty acids—is also highlighted as a promising strategy to support neurotransmitter synthesis and cognitive processing (Hemamy et al., 2021 ; Sivraka et al., 2022 ; Mocking et al., 2022).

From an educational standpoint, the optimization of cognitive functions, such as executive control and working memory, is essential for a child's academic success and social adaptation within the school environment (Moghaddam et al., 2024 ; Sciberras & Lycett, 2023). Improving a student's nutritional profile does not merely address clinical symptoms but directly translates into enhanced learning efficiency and better behavioral regulation in classroom settings (Bullon et al., 2024; Karagianni et al., 2024). Despite the proliferation of studies in this field, there remains a necessity for a systematic synthesis that evaluates these strategies through both a biomedical and educational lens (Felt et al., 2024 ; Sarris et al., 2024).

The contemporary approach to ADHD and ASD therapy is evolving toward a holistic model where diet is not the sole modifiable lifestyle factor. Increasing emphasis is placed on the synergy between nutritional interventions and systematic physical activity, which—similar to targeted supplementation—influences brain plasticity and optimizes executive functions. This integration forms the foundation of modern health pedagogy, directly translating into the psychophysical well-being of the child.

Research Objective. The objective of this systematic review is to evaluate the clinical and functional efficacy of various nutritional interventions and supplementation protocols in improving cognitive outcomes for pediatric patients diagnosed with ADHD and ASD

2. RESEARCH MATERIALS AND METHODS

2.1. Procedure

The procedure for this study involved a systematic review of global scientific literature published between 2020 and 2024 (Felt et al., 2024 ; Sarris et al., 2024). The search strategy was designed to identify high-quality evidence regarding the impact of nutritional interventions and supplementation on cognitive functions and behavioral patterns in pediatric populations (Johnstone et al., 2023 ; Kotsi et al., 2024). The review process integrated a dual-lens approach, evaluating data from both a biomedical perspective focusing on physiological mechanisms and an educational perspective focusing on student functioning in school environments (Moghaddam et al., 2024 ; Sciberras & Lycett, 2023).

2.2. Instruments

The primary instrument utilized for this research was the PubMed database, which provided access to peer-reviewed clinical data (Carucci et al., 2023 ; O'Neil et al., 2024). The analysis focused on the following types of scientific evidence:

Randomized controlled trials (RCTs) providing direct clinical evidence of intervention efficacy (Hemamy et al., 2021 ; Rios-Hernandez et al., 2021).

Meta-analyses and umbrella reviews of existing research to determine overall effect sizes and trends (Mocking et al., 2022 ; Izquierdo et al., 2024).

Narrative reviews and study protocols that offer a comprehensive overview of emerging therapeutic strategies (Del-Ponte et al., 2022 ; van de Wouw et al., 2023).

Specific search terms were used to isolate studies regarding few-foods (oligoantigenic) diets (Pelsser et al., 2022; 2022 ; Hontelez et al., 2021), polyunsaturated fatty acids (Omega-3), vitamin and mineral supplementation (Vitamin D, Magnesium), and the intestinal microbiome (Dinan & Cryan, 2024 ; Bundgaard-Nielsen et al., 2024).

2.3. Data collection and analysis

2.3.1. Statistical Software

Statistical processing was not applicable for this narrative and systematic review of existing literature; however, the data extracted from the analyzed meta-analyses were evaluated for clinical significance and p-values as reported by the original authors (Drechsler et al., 2024 ; Wang et al., 2024).

3. RESEARCH RESULTS

3.1. Oligoantigenic and Few-Foods Diets: Analysis of symptom reduction and brain function changes

The oligoantigenic diet, often referred to as the "few-foods diet," represents a highly restrictive elimination protocol designed to identify idiosyncratic food sensitivities that exacerbate neurodevelopmental symptoms . Clinical evidence indicates that this intervention is particularly effective in addressing the core behavioral symptoms of ADHD, specifically hyperactivity and inattention, in a significant subpopulation of pediatric patients (Pelsser et al., 2022). Unlike general healthy eating patterns, this approach functions as a diagnostic and therapeutic tool, where the systematic reintroduction of foods allows for the identification of specific triggers (Del-Ponte et al., 2022).

A critical advancement in validating this intervention is the documentation of neural correlates associated with dietary changes. Neuroimaging research using functional Magnetic Resonance Imaging (fMRI) has demonstrated that children who respond clinically to the few-foods diet exhibit significant changes in brain activity patterns, particularly in regions associated with executive control and reward processing (Hontelez et al., 2021). This biomedical evidence suggests that the behavioral improvements are rooted in measurable shifts in neurophysiology rather than purely subjective observations (Verlaet et al., 2024).

Furthermore, the impact of the oligoantigenic diet extends beyond cognitive and behavioral domains to include a marked reduction in comorbid physical complaints. Many children with ADHD suffer from concurrent somatic issues, such as gastrointestinal distress, sleep disturbances, and headaches, which frequently decrease in intensity following the stabilization of the diet (Pelsser et al., 2022). From an educational perspective, this holistic improvement in a student's physical and mental well-being creates a more stable foundation for classroom engagement and social adaptation (Moghaddam et al., 2024). By reducing impulsivity and physical discomfort, the few-foods diet directly facilitates the effectiveness of educational intervetions and pharmacological treatments (Johnstone et al., 2023).

3.2. Micronutrient and Fatty Acid Supplementation: Clinical efficacy and neurocognitive outcomes

Targeted supplementation with specific micronutrients and essential fatty acids represents a significant area of clinical interest in the multimodal treatment of ADHD and ASD . Polyunsaturated fatty acids (PUFAs), particularly Omega-3s, are critical for maintaining neural membrane integrity and facilitating neurotransmitter signaling (Mocking et al., 2022). Research involving an 8-week intervention with Omega-3 fatty acids demonstrated a mmeasurable reduction in impulsivity among pediatric patients (Rios-Hernandez et al., 2021). Furthermore, the combined administration of Vitamin D and Magnesium has shown substantial therapeutic potential in stabilizing behavior. As presented in Table 1, the integration of these micronutrients leads to a statistically significant improvement in both cognitive scores and biochemical markers compared to standard therapy alone (Hemamy et al., 2021 ; Sultan et al., 2020).

Table 1. Comparative effect of standard therapy and Vitamin D + Magnesium supplementation on cognitive and behavioral scores.

Variable	Reference Level	Control Group (Standard) After	Main Group (Supplemented) After	Statistical Significance (t)	P-value
Inattention (Conners)	12.0±1.5	17.1±1.9	14.2±1.4	2.84	<0.05

Hyperactivity (Conners)	10.5±1.2	15.4±1.5	12.8±1.2	2.91	<0.05
Serum 25(OH)D (ng/mL)	30.0±5.0	19.1±2.1	28.4±2.8	3.12	<0.01
Serum Magnesium (mmol/L)	0.85±0.1	0.73±0.04	0.84±0.05	2.7	<0.05

Source: Developed for this review based on parameters from Hemamy et al. (2021) and Sultan et al. (2020). Notes: For reference values and group means, standard errors are provided. Values significantly different from the reference are marked with r. Significant direct differences (effects of supplementation) are marked . The last column shows t-values for the effects.

3.3. Gut Microbiome and Probiotics: The bidirectional communication of the gut-brain axis

The bidirectional communication between the gastrointestinal tract and the central nervous system, commonly referred to as the gut-brain axis, integrates complex neural, hormonal, and immunological signals where the intestinal microbiota serves as a pivotal mediator of neurochemical production and systemic inflammation (Dinan & Cryan, 2024; Millenet & Hohmann, 2024). Scientific inquiry into this axis has revealed that children diagnosed with ADHD and ASD often exhibit distinct dysbiotic patterns characterized by a functional imbalance in microbial diversity (Cheng et al., 2024). These imbalances may lead to increased intestinal permeability and subsequent neuroinflammatory responses in pediatric populations (Bundgaard-Nielsen et al., 2024)

3.4. Physical Activity as a Catalyst for Cognitive Gains

Scientific evidence indicates that aerobic exercise is highly effective in improving working memory and inhibitory control in pediatric populations with neurodevelopmental disorders. Research suggests that physical movement may enhance the therapeutic effects of Omega-3 supplementation by stimulating brain-derived neurotrophic factor (BDNF) pathways. From a clinical perspective, incorporating sport into a multimodal treatment plan allows for a more

significant reduction in hyperactivity and improved physical health compared to dietary interventions alone.

4. DISCUSSION

The synthesis of scientific literature from 2020–2024 confirms that nutritional status is not merely a peripheral factor but a core determinant of neurodevelopmental trajectory in children with ADHD and ASD . The transition from traditional pharmacological monotherapy toward a multimodal approach—incorporating targeted dietary interventions—reflects a deeper understanding of the physiological mechanisms underlying these disorders, such as oxidative stress and systemic neuroinflammation (Verlaet et al., 2024 ; Anheyer et al., 2022).

A primary point of discussion is the profound impact of the "few-foods" or oligoantigenic diet. The ability of this restrictive protocol to not only reduce core behavioral symptoms but also induce measurable changes in functional brain activity (Hontelez et al., 2021) provides a robust biomedical justification for its use. From an educational perspective, the reduction in impulsivity and physical discomfort achieved through these diets (Pelsser et al., 2022) significantly lowers the "cognitive load" on the student, thereby enhancing their capacity for classroom engagement and social interaction (Moghaddam et al., 2024).

Furthermore, the role of micronutrient and fatty acid supplementation (Omega-3, Vitamin D, and Magnesium) serves as a critical biological "buffer." These substances are essential for neurotransmitter synthesis and neural membrane stability (Mocking et al., 2022). When these biological parameters are optimized, students exhibit improved concentration and emotional regulation—foundational skills for academic success (Karagianni et al., 2024 ; Sultan et al., 2020). This suggests that medical supplementation protocols should be closely coordinated with educational support plans to maximize the child's developmental potential (Bullon et al., 2024). The emerging evidence regarding the gut-brain axis further complicates and enriches the discussion. The distinct dysbiotic profiles observed in children with neurodivergence (Cheng et al., 2024) suggest that behavioral "outbursts" or academic underperformance may be symptomatic of gastrointestinal distress or microbial imbalances (Dinan & Cryan, 2024).

Consequently, the use of probiotics and fermented products like kefir (van de Wouw et al., 2023) represents a novel frontier where dietary management directly supports psychological and educational stability (Scott & Taylor, 2024).

From an educational standpoint, the stabilization of physiological parameters through an oligoantigenic diet results in a measurable reduction of the student's 'cognitive load'. Reducing somatic complaints, such as gastrointestinal distress or sleep disturbances, allows children to maintain longer focus on didactic tasks and improves emotional self-regulation within the classroom setting. Implementing individualized nutritional plans within the school environment is thus an essential element supporting the efficiency of learning and social adaptation.

Finally, it is essential to acknowledge the role of modern analytical tools in this field. The utilization of AI for linguistic and data refinement (cite: 232-239) allows for a more precise synthesis of these interdisciplinary findings, ensuring that the integration of biomedical data with educational needs is communicated clearly and effectively to a global scientific audience.

5. CONCLUSIONS

The systematic review of scientific literature from 2020 to 2024 provides substantial evidence that nutritional interventions, particularly the oligoantigenic or "few-foods" diet, represent a highly effective non-pharmacological strategy for managing core neurodevelopmental symptoms in children (Pelsser et al., 2022; Hontelez et al., 2021; Johnstone et al., 2023). These clinical improvements in hyperactivity and inattention are not merely subjective but are increasingly validated by measurable changes in functional brain activity, which confirms that dietary management provides a robust biological foundation for neurodevelopmental care (Hontelez et al., 2021; Pelsser et al., 2022). Beyond restrictive diets, the integration of precise supplementation with Omega-3 fatty acids, Vitamin D, and Magnesium functions as a critical biological support system that enhances neurotransmitter synthesis and overall neurocognitive endurance (Mocking et al., 2022; Hemamy et al., 2021; Rios-Hernandez et al., 2021; Shulkin et al., 2021). The evidence suggests that these nutritional strategies achieve their highest efficacy

when utilized as a synergistic adjunct to traditional pharmacological and behavioral therapies rather than as a standalone replacement (Felt et al., 2024; Sarris et al., 2024).

Furthermore, the modulation of the gut-brain axis through probiotics and specific fermented products like kefir presents a promising frontier for addressing pervasive comorbidities such as sleep disturbances and emotional instability (Dinan & Cryan, 2024; Cheng et al., 2024; van de Wouw et al., 2023; Scott & Taylor, 2024). By managing this bidirectional communication pathway, it is possible to reduce the systemic inflammatory load and oxidative stress that are frequently associated with neurodivergence, thereby fostering a more stable internal environment for neurological growth (Bundgaard-Nielsen et al., 2024; Millenet & Hohmann, 2024; Verlaet et al., 2024). From an integrated biomedical and educational perspective, the stabilization of internal physiological parameters directly translates into significant improvements in academic and social outcomes (Moghaddam et al., 2024; Sciberras & Lycett, 2023; Karagianni et al., 2024). When the physiological stress caused by nutritional deficiencies or inflammatory triggers is mitigated, children demonstrate enhanced focus, better memory retention, and improved social adaptation, which collectively increase the overall efficiency of the learning process (Bullon et al., 2024; Pelsser et al., 2022). Therefore, the implementation of multimodal care plans that coordinate clinical nutritional interventions with school-based support strategies is essential for maximizing the developmental potential of pediatric patients (Drechsler et al., 2024; Sarris et al., 2024). This approach requires active collaboration between clinicians, parents, and educators to monitor how dietary changes influence behavioral stability and academic performance over time (Karagianni et al., 2024; Sciberras & Lycett, 2023).

In conclusion, the effective management of ADHD and ASD requires an integrated care model combining precise nutritional interventions—such as the oligoantigenic diet and targeted supplementation—with systematic physical activity and school-based support. The synergy of these actions creates a stable internal environment for the child's neurological development, minimizing oxidative stress and supporting the cognitive endurance necessary for academic and social success.

Author's Contribution:

Conceptualisation: MK, DD, KR, MKK, DC, WB, KŻ, ML

Methodology: MK, KR

Software: MK, MKK, DC

Check: DD, WB

Formal analysis: ML, MKK, KŻ

Investigation: MK, DD

Resources: ML, KR

Data curation: MKK, WB

Writing -rough preparation: MK, DD, KR

Writing -review and editing: MK, DC, KŻ, ML

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