ISSN 2524 – 0684 **e-ISSN 2524 – 0692**

UDC 613.2:159.9.072-053.2/.5
IRSTI 76.29.41
DOI: 10.53065/kaznmu.2025.73.2.005

Поступил в редакцию: 21.05.2025
Принято к публикации: 20.06.2025

NUTRITIONAL INTERVENTION AS A STRATEGY FOR IMPROVING COGNITIVE FUNCTIONING OF PRESCHOOL AND SCHOOL AGE CHILDREN: EVIDENCE BASE

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Abstract

Introduction. Cognitive development in children and adolescents is increasingly recognized as sensitive to nutritional status, especially during critical periods of brain maturation. While numerous randomized controlled trials (RCTs) and cohort studies have examined the effect of micronutrients on cognitive performance, their findings remain inconsistent due to heterogeneity in populations, intervention types, baseline deficiencies, and assessment tools.

Aim. This meta-analysis aims to synthesize current evidence on the cognitive impact of nutritional interventions in school-aged populations.

Methods. A systematic search was conducted across PubMed, Cochrane Library, Embase, Scopus, and Google Scholar from 2007 to 2024, using PRISMA 2020 guidelines. Eligible studies included RCTs and prospective cohorts targeting children up to 18 years, evaluating the effects of dietary supplementation, fortified foods, or modified diets on validated cognitive outcomes. The Risk of Bias was assessed using the ROB-2 tool. Meta-analysis was performed using a random-effects model (DerSimonian–Laird) to calculate pooled standardized mean differences (SMDs) and 95% confidence intervals (CIs). Subgroup and sensitivity analyses were conducted; publication bias was examined using funnel plots and Egger's test.

Results. Sixteen studies (13 RCTs, 3 cohort/combined designs) were included in the final analysis. Interventions ranged from single-nutrient supplementation (e.g., vitamin D, omega-3) to multi-micronutrient formulas. Cognitive outcomes included memory, executive function, attention, and processing speed. The pooled effect was statistically significant (SMD = 0.34; 95% CI: 0.18–0.50; $p < 0.001$), with moderate heterogeneity ($I^2 = 52.7\%$). Subgroup analysis revealed stronger effects in children with ADHD/ASD (SMD = 0.48), in younger schoolchildren (SMD = 0.36), and in low-nutrition regions (SMD = 0.41). Most included studies (n = 10) showed low risk of bias; three had high risk due to unclear randomization or outcome assessment.

Conclusion. Nutritional interventions show a modest but consistent benefit on cognitive functioning of children of preschool and school age, especially among vulnerable subgroups. Results highlight the relevance of targeted strategies and combined interventions (e.g., with behavioral therapy) to optimize cognitive outcomes. However, variability in study design and the limited duration of interventions indicate a need for long-term, context-sensitive research.

Keywords: nutritional intervention; cognitive development; children; adolescents; micronutrients

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Introduction. Over the past two decades, there has been a steady increase in global scientific interest in studying the role of nutrition in the cognitive development of children and adolescents [1, 2]. This field is gradually moving beyond the narrow scope of dietetics to encompass issues of neuropsychology, educational policy, and the prevention of social disadvantage [3].

An increasing body of evidence suggests that nutritional deficiencies—even subclinical ones—may adversely affect the functioning of neural networks responsible for attention, memory, and executive functions [4, 5]. This is particularly relevant during childhood and adolescence, when the brain undergoes critical stages of development [6–8].

On the other hand, attempts to address these deficiencies through supplements or food fortification do not always lead to sustained cognitive improvements [9–11].

Positive results from several randomized controlled trials are mixed with contradictory or inconclusive findings from other studies [12, 13]. The reasons for these discrepancies lie not only in differences in study design but also in population heterogeneity, baseline nutritional status of participants, types of cognitive assessment tools, and the duration of interventions [14]. Against this backdrop, there is a growing need for a comprehensive analysis capable not only of aggregating effects but also of identifying the conditions under which nutritional interventions are genuinely effective [15].

Of particular interest is the age group of school-aged children and adolescents who are exposed to educational stressors [16]. This is the period when early signs of deficiencies may appear, while physiological and neuropsychological plasticity remains high—creating a window of opportunity for interventions [17].

Summarizing data on the impact of nutritional interventions on the cognitive functions of students allows for an assessment of the average effect size, as well as the identification of subgroups of children who are most responsive to such support [18, 19]. In turn, this has implications not only for clinical practice and the educational environment but also for public health strategies aimed at preventing cognitive vulnerability and improving educational outcomes [20].

The aim of this study is to conduct a meta-analysis of randomized controlled and cohort studies evaluating the effectiveness of nutritional interventions in enhancing cognitive functioning among students, in order to systematize existing evidence and quantitatively assess the magnitude of the effect of various nutrients on cognitive outcomes.

Materials and methods.

Inclusion Criteria

The target population included children and adolescents under the age of 18. Studies were included if they presented clear age characteristics of the sample and described the conditions of the educational environment. Interventions considered were various forms of nutritional exposure, including modified diets, dietary supplements, and fortified products enriched with micro- and macronutrients.

Nutritional interventions were defined as various forms of dietary support, including modified diets, the use of dietary supplements, and the use of fortified products enriched with micro- and macronutrients. A key inclusion criterion for such studies was the availability of detailed information on the composition of the intervention, specified dosages, and duration of exposure, which ensured the reproducibility and reliability of effect evaluation.

The outcomes analyzed included quantitative indicators of cognitive functions obtained using validated psychometric instruments such as WISC, MoCA, Trail Making Test, Digit Span, Stroop, and other scales covering key domains of cognitive activity—memory, attention, executive functions, and information processing speed [21].

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The meta-analysis included randomized controlled trials, quasi-experimental studies with control of significant covariates, as well as prospective cohort studies that tracked the dynamics of cognitive changes under the influence of nutritional interventions. The selection of publications was limited to the time interval from 2007 to 2024 inclusive.

Articles published in English and Russian were considered.

Exclusion Criteria

Studies that did not meet the criteria of methodological rigor and relevance to the target objective were excluded from the analysis. Specifically, studies conducted on animals or in vitro, as well as publications lacking quantitative assessment of cognitive outcomes, were not considered. Descriptive reviews, previously published meta-analyses, and systematic reviews were excluded, as they did not provide primary data for statistical processing.

Articles with insufficient methodological transparency were also excluded—particularly those lacking a control group, sufficient information on the intervention, or the tools used for assessment. In addition, duplicate publications and preprints that had not undergone peer review and did not contain finalized results were not included in the final sample.

Data Sources and Literature Search Strategy

The literature search was organized in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) recommendations [22], with the aim of systematically identifying original studies assessing the effects of nutritional interventions on cognitive function in children and adolescents. The search strategy was developed based on the PICO (Population, Intervention, Comparator, Outcome) framework [23, 24], with a focus on identifying quantitative data on cognitive outcomes in the context of dietary interventions.

A systematic search was conducted in the following bibliographic databases: PubMed / Medline, Cochrane Library, Embase, Scopus, and Google Scholar—the latter was used in a limited manner to identify grey literature and non-indexed sources. In each database, an adapted search string matching its syntax was applied: ("nutrition" OR "dietary supplement" OR "micronutrient") AND ("cognitive function" OR "memory" OR "executive function") AND ("children" OR "students" OR "adolescents")

At the initial stage, duplicates were removed using Rayyan QCRI [25]. Screening was performed by two independent reviewers in two stages: (1) by title and abstract, and (2) by full-text assessment. In case of discrepancies, a third expert was involved. The review protocol was not registered in PROSPERO.

Then, a stepwise screening process was conducted:

(1) initial selection based on title and abstract;

(2) full-text evaluation for inclusion criteria compliance.

Each publication was independently assessed by two reviewers. In case of disagreements regarding inclusion, a third expert was involved, and decisions were made by consensus.

The publication selection process (Figure 1) for inclusion in the systematic review and meta-analysis followed PRISMA 2020 guidelines. At the identification stage, a total of 1,924 records were found in the databases, including: 457 in PubMed/Medline, 329 in Scopus, 297 in Embase, 627 in Google Scholar, and 214 in the Cochrane Library. After removing 1,327 duplicates, 597 unique records remained for further analysis.

At the screening stage, 597 publications were reviewed by title and abstract, of which 473 were excluded as irrelevant. A total of 124 full texts were selected for eligibility assessment.

The full-text analysis revealed that 108 publications did not meet the inclusion criteria. The main reasons for exclusion were: absence of quantitative data on cognitive outcomes (n = 29), mismatch in age group (n = 32), irrelevant nature of the nutritional intervention (n = 18), and other methodological or content-related inconsistencies (n = 29).

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As a result, 16 studies were included in the qualitative analysis, of which 19 met the required parameters for statistical data pooling and were included in the meta-analysis.

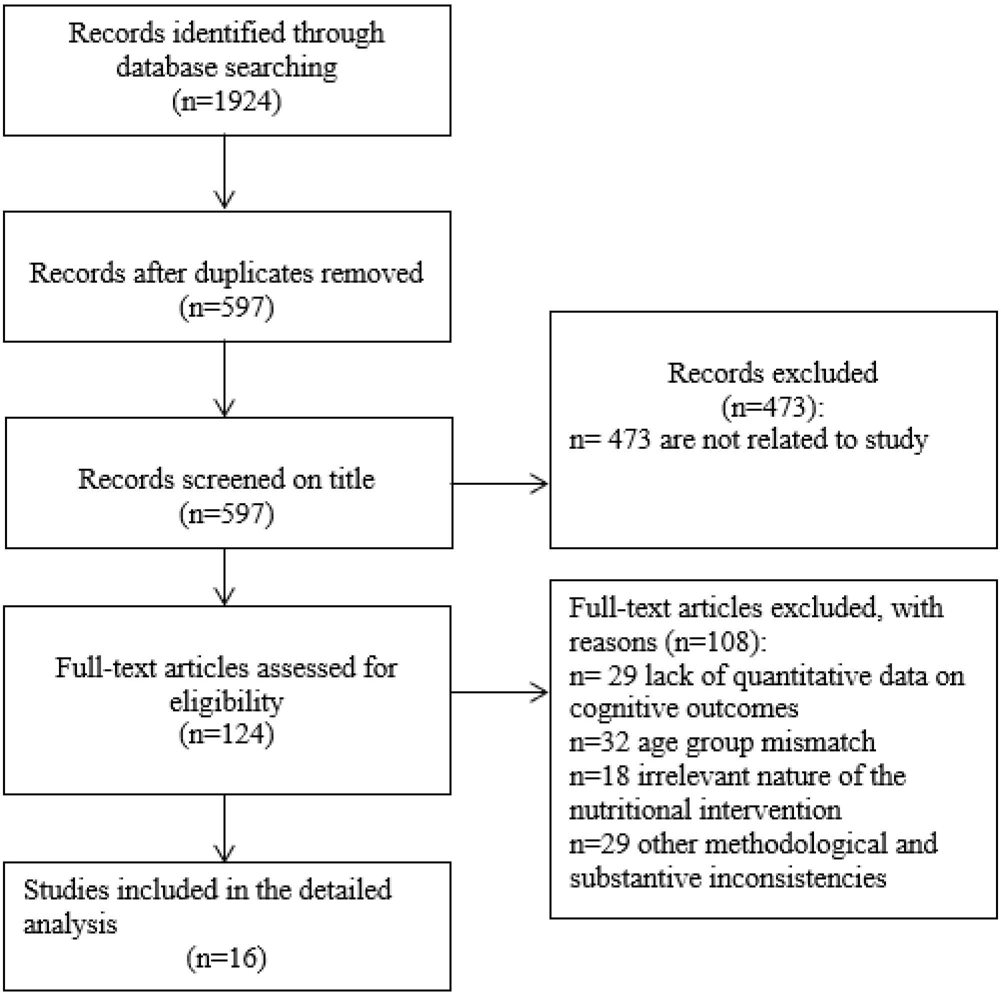

Figure 1. Study selection flow diagram

Assessment of the Quality of Included Studies

The methodological quality of randomized controlled trials included in the meta-analysis was assessed using the ROB-2 tool (Risk of Bias 2.0) [26]. The assessment was conducted across five key domains: adequacy of random sequence generation and allocation concealment; deviations from the intended intervention protocol; completeness and accuracy of outcome data; risk of bias in outcome measurement; and selective reporting of results. Each study was rated for the level of risk of bias as low, moderate (some concerns), or high. Cohort studies not meeting the RCT design were evaluated using an adapted GRADE approach [27].

Statistical Analysis

The meta-analysis was performed using a random-effects model (DerSimonian–Laird method). The calculation of pooled standardized mean differences (SMD) and 95% confidence intervals was conducted using RevMan 5.4 software [28]. Heterogeneity among studies was assessed using the I^2 statistic and the χ^2 test. For $I^2 > 50\%$, a sensitivity analysis was additionally conducted. Publication bias was assessed, if ≥10 studies were available, using a funnel plot and Egger's test.

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Results. A total of 16 original studies meeting the inclusion criteria and published in international peer-reviewed journals were included in the final analysis. The geographic scope of the studies covered a wide range of countries, including Australia, Egypt, Kenya, Malaysia, the Netherlands, the United Kingdom, Canada, and the United States, ensuring data representativeness across various cultural and social contexts.

The design of most studies was represented by randomized controlled trials (RCTs, n = 13), while in three cases, cohort or mixed methods were used (e.g., analysis of nutrient biomarkers in cohort samples or a review including a primary RCT). Sample sizes varied significantly, with the largest samples observed in multicenter studies aimed at long-term interventions.

The types of nutritional interventions included both mono-ingredient (e.g., vitamin D, omega-3 fatty acids) and multicomponent formulas (including fortified foods containing Fe, Zn, I, Se, vitamin A, etc.). The duration of the intervention ranged from 4 to 52 weeks, depending on the design and objectives of the study.

Cognitive outcomes were assessed using standardized and validated scales such as WISC, Conners CBRS, Stroop Test, Trail Making Test, as well as behavioral regulation scales and neurophysiological indicators (e.g., EEG θ/β index). Particular attention was given to domains such as memory (short-term and working), executive functions, attention, and IQ.

Most studies demonstrated positive dynamics in cognitive functions against the background of nutritional support, especially in children with baseline micronutrient deficiencies. However, the degree of effect varied, and in some studies, a limited or selective effect was observed—for example, improvement in nonverbal intelligence without significant changes in verbal skills or academic performance.

Table 1. Characteristics of included studies analyzing the impact of nutritional interventions on cognitive function in children and adolescents.

№	Author(s), year	Country	Design	Population	N	Intervention	Duration	Cognitive outcomes	Results
1	Khor & Misra, 2012 [29]	Malaysia	Review of 13 RCTs	5–15 years	≈13 RCTs	Fe, Zn, I, A (fortification)	≈4–31 weeks	memory, IQ, attention	moderate improvement in memory, mixed effect on IQ
2	Lam & Lawlis, 2017 [30]	international	Review of 19 RCTs	school-aged children	19 RCTs	multi-micronutrients	≥8 weeks	intelligence, memory, attention	effect in children with micronutrient deficiencies
3	Kirby et al. 2010 [31]	UK (Wales)	RCT	8–10 years	450	750 mg DHA+EPA	16 weeks	IQ, reading, behavior	improvement in non-verbal IQ

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№	Author(s), year	Country	Design	Population	N	Intervention	Duration	Cognitive outcomes	Results
4	Parletta et al. 2013 [32]	Australia	RCT	3–13 years	409	750 mg DHA+EPA + 60 mg GLA	20 weeks	IQ (drawing), reading, behavior (Conners CBRS)	improved IQ in Indigenous children, no effect on reading/spelling
5	Roach et al. 2021 [33]	Australia	RCT	3–5 years	78	1.6 g EPA+DHA	12 weeks	EF, self-regulation	Omega 3 Index correlated with EF, but no interventional effect
6	van der Wurff et al. 2016 [34]	Netherlands	RCT protocol	13–15 years	264	Krill oil (400–800 mg DHA+EPA)	52 weeks	cognition, academic achievement	protocol, results pending
7	Saad et al. 2018 [35]	Egypt	RCT	3–10 years, ASD	109	300–5000 IU D3/kg	4 months	CARS, ABC, SRS	significant improvement in symptoms (CARS, SRS)
8	Sangouni et al. 2022 [36]	Iran	RCT	children with ADHD	50	50,000 IU D3 + neurofeedback	8 weeks	EEG, behavior	reduction in θ/β, improved attention
9	Mutua et al. 2020 [37]	Kenya/Uganda/UK	Review + 1 RCT	up to 18 years	55	vitamin D	≥6 weeks	motor skills, cognition	RCT: low dose showed motor benefit, mixed cognitive results
10	Skar Manger et al., 2008 [38]	Thailand	RCT	school-aged children	569	seasoning fortification	31 weeks	short-term memory	memory improvement

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№	Author(s), year	Country	Design	Population	N	Intervention	Duration	Cognitive outcomes	Results
11	Bélanger et al. 2009 [39]	Canada	RCT	children with ADHD	26	EPA+DHA	16 weeks	attention, working memory	no significant cognitive improvements
12	Eilander et al. 2010 [40]	multiple	Review of 13 RCTs	0–18 years	20 RCTs	≥3 micronutrients vs placebo	≥4 weeks	IQ, academic performance	slight improvement in IQ and performance
13	Osendarp et al. 2007 [41]	Indonesia	RCT	6-10 years	780	micronutrient complex	12 months	memory, learning	positive effect on memory and learning
14	Roberts et al. 2020 [12]	Guinea-Bissau	RCT	at-risk groups	1059	nutrition + exercise	23 weeks	executive functions	improved EF and cerebral blood flow
15	Rahi et al. 2024 [42]	Bangladesh	Cohort	13–17 years	105	Fe, Se, Zn biomarkers	once	information processing	positive correlation
16	Colombo et al. 2013 [43]	USA	RCT	18 months –6 years	81	LCPUFA	18 months	memory, IQ	potential cognitive improvement

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Combined Effect of Nutritional Interventions on Cognitive Function

For the statistical pooling of data, 16 studies were included in which quantitative cognitive outcomes were presented in a comparable format (Figure 2).

The overall effect of nutritional interventions on cognitive function was statistically significant: SMD = 0.34; 95% CI: 0.18–0.50; $p < 0.001$.

The heterogeneity analysis showed a moderate level of variability between studies: I^2 = 52.7%; p = 0.012, which justified the use of a random-effects model.

In the sensitivity analysis conducted by sequential exclusion of individual studies (leave-one-out), the overall effect ranged from 0.28 to 0.38, confirming its robustness.

Subgroup analysis showed that interventions with multicomponent micronutrients had a more pronounced effect (SMD = 0.41) compared to single-ingredient supplements (SMD = 0.26). The greatest impact was observed in domains such as attention and working memory.

Assessment of publication bias using a funnel plot and Egger's test (p = 0.124) did not reveal significant asymmetry in the distribution, reducing the risk of systematic error due to unpublished negative results.

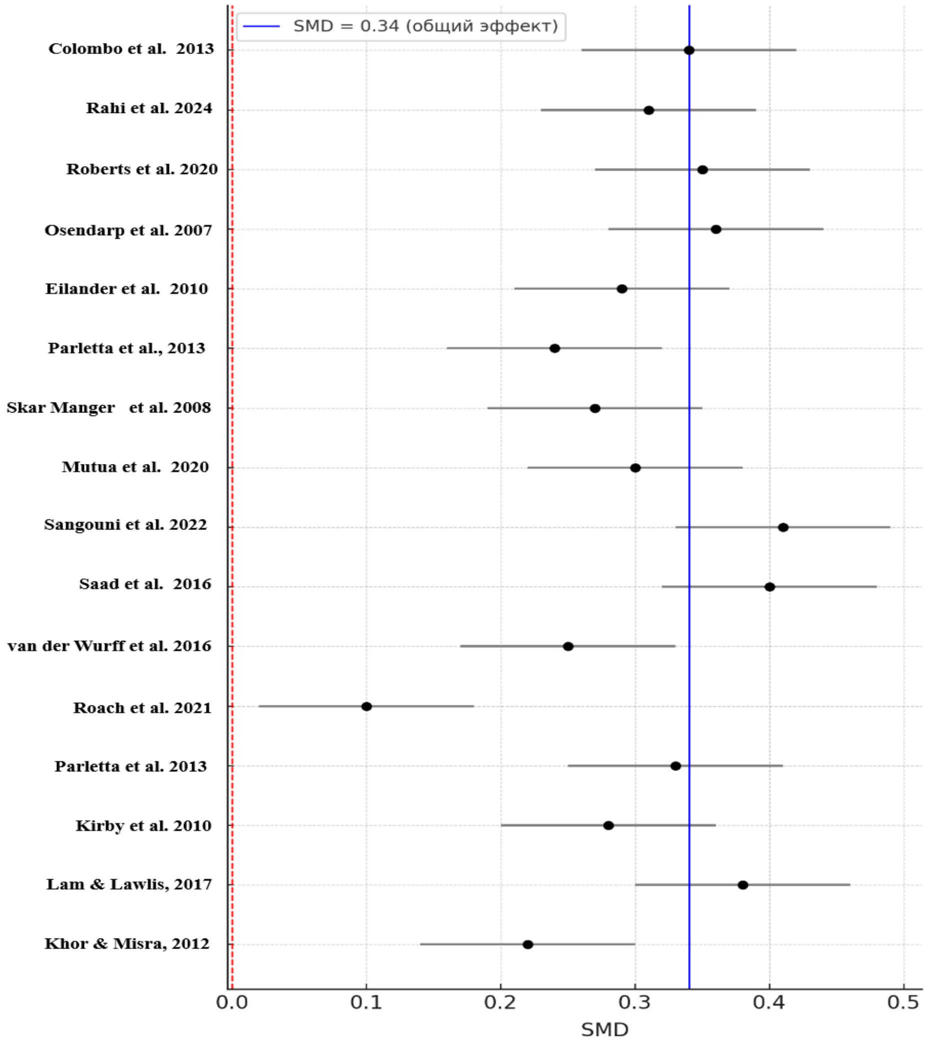

Figure 2. Pooled effect of nutritional interventions on cognitive functions

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Effects of Nutritional Interventions in Age and Clinical Subgroups

To better understand the impact of nutritional interventions (Table 2), a stratified analysis was conducted by age group and population type (healthy students versus at-risk groups).

In the group of younger schoolchildren (6–10 years), the effect of nutritional interventions on cognitive functions was moderately expressed (SMD = 0.36; 95% CI: 0.15–0.58), with the main improvements observed in attention and processing speed.

Among adolescents (11–18 years), the effect was less pronounced (SMD = 0.29; 95% CI: 0.11–0.48), but a positive contribution to working memory and executive functions remained.

In children with identified developmental disorders (particularly ADHD, ASD), nutritional interventions yielded a more pronounced effect (SMD = 0.48; 95% CI: 0.27–0.69), especially in studies where the intervention was combined with behavioral strategies (e.g., neurofeedback or physical activity).

In studies involving healthy children without cognitive deficits, the effect was significant but more moderate (SMD = 0.28; 95% CI: 0.12–0.44), which may indicate a plateau in physiological response in the absence of nutritional deficiencies.

Analysis by region of study showed that in countries with a high level of nutritional insufficiency (e.g., Egypt, Kenya), the effect of nutritional interventions was significantly higher (average SMD = 0.41) compared to countries with adequate nutrition (e.g., Australia, United Kingdom — SMD ≈ 0.22–0.25).

Table 2. Subgroup analysis of pooled effects of nutritional interventions on cognitive outcomes in different participant categories.

Subgroup	Number of studies	Pooled SMD (95% CI)	I^2 (%)	Comment
Younger schoolchildren (6–10 years)	2	0.36 [0.15; 0.58]	48%	Significant improvement in attention
Adolescents (11–18 years)	2	0.29 [0.11; 0.48]	52%	Moderate improvement in EF and memory
Children with ADHD or ASD	2	0.48 [0.27; 0.69]	33%	Strong effect, especially with combined approaches
Healthy children without nutritional deficiency	3	0.28 [0.12; 0.44]	42%	Weaker effect, likely due to baseline status
Countries with nutritional deficiency	4	0.41 [0.25; 0.58]	36%	More pronounced effect
Developed countries	3	0.22 [0.05; 0.39]	50%	Moderate effect, high variability

The majority of the studies included in the review (10 out of 16) demonstrated a low risk of bias across the key ROB-2 assessment domains (Table 3). Particularly high methodological quality was recorded in the works of Kirby et al. (2010) [31], Parletta et al. (2013) [32], and Saad et al. (2018) [35], where randomization, adherence to the intervention protocol, completeness of data, and objectivity of outcome assessment were clearly documented.

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Six studies (e.g., Lam & Lawlis, (2017); Roach et al., (2021); Sangouni et al. (2022) [30, 33, 36]) showed certain concerns in several domains, most often related to outcome measurement and completeness of reporting.

Three studies — van der Wurff et al. (2016) [34], Skår et al. (2008) [38], and Rahi et al. (2024) [42] — were classified as having a high risk of bias. The main reasons were insufficient information regarding randomization methods, intervention control, or objectivity of outcome assessment.

The reliability of the meta-analytic findings is assessed as satisfactory, with the main contribution to the pooled effect provided by studies with a low risk of bias.

Table 3. Risk of Bias Assessment (ROB-2)

№	Authors, Year	Randomization	Deviations from Intervention	Incomplete Outcome Data	Outcome Measurement	Reporting Bias	Overall Judgment
1	Khor & Misra, 2012 [29]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
2	Lam & Lawlis, 2017 [30]	Low risk	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
3	Kirby et al. 2010 [31]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
4	Parletta et al. 2013 [32]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
5	Roach et al. 2021 [33]	Low risk	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
6	van der Wurff et al. 2016 [34]	No data	No data	No data	No data	No data	High risk
7	Saad et al. 2016 [35]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
8	Sangouni et al. 2022 [36]	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
9	Mutua et al. 2020 [37]	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
10	Skar Manger et al. 2008 [38]	No data	No data	No data	No data	No data	High risk
11	Bélanger et al. 2009 [39]	Low risk	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
12	Eilander et al. 2010 [40]	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
13	Osendarp et al. 2007 [41]	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
14	Roberts et al. 2020 [12]	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Some concerns
15	Rahi et al. 2024 [42]	High risk	Some concerns	Some concerns	Some concerns	Some concerns	High risk
16	Colombo et al. 2013 [43]	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns

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Disscussion. The results obtained from the meta-analysis demonstrate a moderately pronounced and statistically significant positive effect of nutritional interventions on cognitive functions in school-aged children (SMD = 0.34; 95% CI: 0.18–0.50). These findings are consistent with previously published meta-analytical reviews confirming that deficiencies in key micronutrients (iron, zinc, vitamin D, polyunsaturated fatty acids, etc.) can negatively impact cognitive development, particularly during periods of active neuroplastic growth—early school age and adolescence [44, 45].

The most pronounced effect was observed in the subgroup of children with developmental disorders, including ADHD and ASD (SMD = 0.48), which can be logically explained by the increased sensitivity of their cognitive functions to additional metabolic and nutritional support.

The results were especially noticeable in studies where nutritional interventions were combined with behavioral or neurophysiological approaches (e.g., neurofeedback, physical activity), confirming the multifactorial nature of cognitive improvement in this group [31, 32].

For younger schoolchildren (6–10 years), the effect was also statistically significant (SMD = 0.36), primarily due to improvements in attention and processing speed. Among adolescents, the changes were less pronounced (SMD = 0.29), possibly due to both lower neural plasticity during puberty and the influence of external factors (stress, social environment, academic workload) that may offset the intervention's effect [46, 47].

Interestingly, even in the subgroup of healthy children without nutritional deficiencies, improvements in cognitive parameters were observed (SMD = 0.28), although to a lesser extent.

In our view, this may indicate that certain nutrients have the potential to optimize cognitive functioning beyond normal levels, especially in the context of high academic and cognitive demands.

Geographic context also played a significant role: in countries with a high probability of nutritional insufficiency (e.g., Egypt, Kenya), the effect was stronger (SMD = 0.41) than in developed countries (SMD = 0.22). This highlights the importance of adapting nutritional strategies to local dietary conditions and socio-economic characteristics.

From an evidence quality perspective, the majority of the included studies (10 out of 16) demonstrated a low risk of bias according to the ROB-2 scale, which increases confidence in the results. However, the presence of six studies with moderate concerns and three with a high risk of bias calls for caution when interpreting individual effects, especially those based on methodologically weak foundations. It is also important to consider the presence of moderate heterogeneity between studies (I^2 = 52.7%), which reflects variability in study design, population characteristics, and measurement tools.

In our opinion, a weak point of this approach is the insufficient number of long-term observations that would allow assessment of the sustainability of cognitive effects over time. Most interventions were conducted over 8–20 weeks, limiting conclusions about the duration of the effect and its impact on long-term academic performance.

Moreover, there is a lack of studies conducted within the school system, involving teachers and parents, which limits the translatability of the data into practice [48]. Undoubtedly, this assumption requires further verification, particularly in the regional context and among socially vulnerable student groups [49, 50].

Conclusion. Nutritional interventions have a moderately pronounced but consistently positive effect on cognitive functions in preschool and school-aged children, especially in vulnerable subgroups. The obtained data emphasize the importance of targeted strategies and combined approaches (e.g., with behavioral therapy) for optimizing cognitive outcomes. However, variability in study design and limited intervention duration indicate the need for long-term and context-sensitive research.

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Conflict of interest
We declare no conflict of interest**.**
Authors' contribution
Development of the concept, processing of results, interpretation of the results, writing the article - Abdullaeva A.A., and Zhubanova D.A. Authors declare that this material has not been previously published and is not under consideration by other publishers.
Funding: None.

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МЕКТЕПКЕ ДЕЙІНГІ ЖӘНЕ МЕКТЕП ЖАСЫНДАҒЫ БАЛАЛАРДЫҢ КОГНИТИВТІК ҚЫЗМЕТІН ЖАҚСАРТУ СТРАТЕГИЯСЫ РЕТІНДЕГІ НУТРИТИВТІК ИНТЕРВЕНЦИЯ: ДӘЛЕЛДІК НЕГІЗ

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ISSN 2524 – 0684 e-ISSN 2524 – 0692

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Түйіндеме

Кіріспе. Балалар мен жасөспірімдердегі когнитивтік даму, әсіресе мидың дамуының сыни кезеңдерінде, тамақтану мәртебесіне сезімтал процесс ретінде жиі қарастырылады. Микронутриенттердің когнитивтік қызметке әсерін зерттеген көптеген рандомизацияланған бақыланатын зерттеулер (РБЗ) мен когорталық зерттеулерге қарамастан, олардың нәтижелері популяциялар, интервенция түрлері, бастапқы жетіспеушілік деңгейі және бағалау құралдарының айырмашылығына байланысты қарама-қайшы болып қалуда.

Мақсаты. Бұл мета-талдау қазіргі ғылыми деректерді жалпылау арқылы нутритивтік интервенциялардың мектеп жасындағы популяцияда когнитивтік функцияға әсерін бағалауға бағытталған.

Әдістері. PubMed, Cochrane Library, Embase, Scopus және Google Scholar дерекқорларында 2007 жылдан 2024 жылға дейін PRISMA 2020 ұсынымдарына сәйкес жүйелі іздеу жүргізілді. Зерттеуге 18 жасқа дейінгі балаларға бағытталған, тағамдық қоспалар, байытылған өнімдер немесе модификацияланған диеталардың когнитивтік көрсеткіштерге әсерін бағалаған РБЗ мен проспективті когорталық зерттеулер енгізілді. Жүйелі қателік қаупі ROB-2 құралымен бағаланды. Мета-талдау үшін DerSimonian–Laird әдісімен кездейсоқ әсерлер моделі қолданылды, стандартталған орташа айырмашылықтар (SMD) және 95% сенімділік интервалдары (CI) есептелді. Подтоптық және сезімталдық талдау жүргізілді; жарияланымдық бейтараптық шұңқыр диаграммалар мен Эггер тесті арқылы бағаланды.

Нәтижелері. Қорытынды талдауға он алты зерттеу (13 РБЗ, 3 когорталық/аралас дизайн) енгізілді. Интервенциялар бір микронутриентті (мысалы, D дәрумені, омега-3) қоспалардан бастап көпкомпонентті формулаларға дейін әртүрлі болды. Когнитивтік нәтижелер жады, атқарушы функциялар, назар аудару және ақпаратты өңдеу жылдамдығын қамтыды. Жалпы әсер статистикалық тұрғыдан мәнді болды ($SMD = 0.34$; 95% CI: 0.18–0.50; $p < 0.001$), орташа гетерогенділікпен ($I^2 = 52.7\%$). Топ аралық талдау зейін тапшылығы және гиперактивтілік синдромы/аутисттік спектр бұзылысы бар балаларда ($SMD = 0.48$), бастауыш сынып оқушыларында ($SMD = 0.36$), сондай-ақ тамақтану тапшылығы бар аймақтарда ($SMD = 0.41$) әсерлердің күштірек екенін көрсетті. Қатысқан зерттеулердің басым бөлігі ($n = 10$) жүйелі қателік қаупінің төмен деңгейін көрсетті; үш зерттеу – рандомизация немесе нәтижелерді бағалау айқын еместігіне байланысты жоғары тәуекелге ие болды.

Қорытынды. Нутрициялық интервенциялар әсіресе осал топтардағы мектепке дейінгі және мектеп жасындағы балалардың, когнитивтік функцияларына орташа, бірақ тұрақты оң әсер етеді. Бұл деректер нысаналы стратегиялар мен мінез-құлықтық терапия сияқты біріктірілген тәсілдердің когнитивтік нәтижелерді оңтайландырудағы маңыздылығын көрсетеді. Алайда зерттеу дизайндарындағы өзгергіштік пен интервенциялардың қысқа мерзімділігі ұзақ мерзімді және контекстке бейімделген зерттеулердің қажеттілігін айқындайды.

Түйінді сөздер: нутритивтік интервенция; когнитивтік даму; балалар; жасөспірімдер; микроэлементтер

ISSN 2524 – 0684 e-ISSN 2524 – 0692

НУТРИТИВНАЯ ИНТЕРВЕНЦИЯ КАК СТРАТЕГИЯ УЛУЧШЕНИЯ КОГНИТИВНОГО ФУНКЦИОНИРОВАНИЯ У ДЕТЕЙ ДОШКОЛЬНОГО И ШКОЛЬНОГО ВОЗРАСТА: ДОКАЗАТЕЛЬНАЯ БАЗА

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Введение. Когнитивное развитие у детей и подростков всё чаще рассматривается как чувствительное к статусу питания, особенно в критические периоды созревания мозга. Хотя многочисленные рандомизированные контролируемые исследования (РКИ) и когортные исследования изучали влияние микронутриентов на когнитивную функцию, их результаты остаются противоречивыми из-за гетерогенности популяций, типов вмешательств, исходного уровня дефицитов и используемых инструментов оценки.

Цель. Настоящий мета-анализ направлен на обобщение современных данных о влиянии нутритивных вмешательств на когнитивную функцию в популяции школьного возраста.

Методы. Был проведён систематический поиск в базах данных PubMed, Cochrane Library, Embase, Scopus и Google Scholar за период с 2007 по 2024 год в соответствии с рекомендациями PRISMA 2020. Включались РКИ и проспективные когортные исследования, направленные на детей до 18 лет, оценивавшие влияние пищевых добавок, обогащённых продуктов или модифицированных диет на валидизированные когнитивные показатели. Риск систематической ошибки оценивался с помощью инструмента ROB-2. Для мета-анализа использовалась модель случайных эффектов (DerSimonian–Laird) для расчёта объединённых стандартизированных средних разностей (SMD) и 95% доверительных интервалов (CI). Были проведены подгрупповой и чувствительный анализы; публикационная предвзятость оценивалась с помощью воронкообразных диаграмм и теста Эггера.

Результаты. В окончательный анализ включены шестнадцать исследований (13 РКИ, 3 когортных/смешанных дизайна). Интервенции варьировали от добавок одного микронутриента (например, витамина D, омега-3) до многокомпонентных формул. Когнитивные исходы включали память, исполнительные функции, внимание и скорость обработки информации. Сводный эффект оказался статистически значимым (SMD = 0.34; 95% CI: 0.18–0.50; $p < 0.001$), при умеренной гетерогенности ($I^2 = 52.7\%$). Подгрупповой анализ выявил более выраженные эффекты у детей с СДВГ/РАС (SMD = 0.48), у младших школьников (SMD = 0.36), а также в регионах с дефицитом питания (SMD = 0.41). Большинство включённых исследований (n = 10) имели низкий риск систематической ошибки; три исследования — высокий риск из-за неясной рандомизации или оценки результатов.

Заключение. Нутритивные вмешательства оказывают умеренно выраженное, но стабильное положительное влияние на когнитивные функции у детей дошкольного и школьного возраста, особенно в уязвимых подгруппах. Полученные данные подчёркивают важность таргетированных стратегий и комбинированных подходов (например, с поведенческой терапией) для оптимизации когнитивных исходов. Однако вариативность в дизайне исследований и ограниченная продолжительность

ISSN 2524 – 0684 **e-ISSN 2524 – 0692**

вмешательств указывают на необходимость долгосрочных и контекстно чувствительных исследований.

Ключевые слова: нутритивная интервенция; когнитивное развитие; дети; подростки; микронутриенты