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Therapeutic Strategies for Cognitive Performance in Children With Attention-Deficit/Hyperactivity Disorder: A Systematic Review of Randomized Controlled Trials

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Abstract

Attention-deficit/hyperactivity disorder (ADHD) is among the most common neurodevelopmental disorders of childhood and is characterized by impaired attention, inhibitory control, working memory, and related executive functions. Medication mainly targets core symptoms, and a growing number of non-pharmacological and adjunctive strategies have been tested for their effects on cognitive performance. Randomized evidence is fragmented across intervention types. This review aimed to systematically review randomized controlled trials (RCTs) published between January 2015 and 2026 that evaluated therapeutic strategies for cognitive performance in children and adolescents with ADHD.

A systematic search was conducted in PubMed/MEDLINE, Scopus, Web of Science, the Cochrane Central Register of Controlled Trials (CENTRAL), and PsycINFO for RCTs published between January 2015 and September 2026. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidance. Risk of bias was appraised with the Cochrane Risk of Bias 2 (RoB 2) tool, and findings were synthesised narratively.

Thirteen RCTs involving 1,308 participants met the criteria: computerized cognitive training (five trials), physical activity or exergaming (two), eicosapentaenoic acid supplementation (one), digital therapeutics (two), neurofeedback or transcranial direct current stimulation (tDCS) (two), and virtual reality training (one). Computerized training improved mainly trained or closely related domains such as visuospatial working memory and sustained attention, with inconsistent far transfer. Exergaming improved reaction times in inhibition and switching after both single-session and eight-week exposure. Eicosapentaenoic acid improved focused attention, most clearly in children with low baseline levels. A video-game-based digital therapeutic improved objectively measured attention in 348 children. Neurofeedback (n = 144) and multi-session tDCS (n = 50) showed no specific cognitive benefit over sham. Five trials had low risk of bias, seven had some concerns, and one had high risk.

Several non-pharmacological strategies can improve selected domains of cognitive performance in children with ADHD, but benefits are domain-specific, usually short-term, and weaker in sham-controlled, blinded designs. No single strategy is superior across domains. Choice of therapy should be individualized, and larger, blinded, longer-term trials with standardized cognitive endpoints are needed.

Categories: Psychiatry, Physical Medicine & Rehabilitation, Pediatrics
Keywords: attention-deficit/hyperactivity disorder, children, cognitive performance, executive function, therapeutic interventions

Introduction And Background

Attention-deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder characterized by persistent patterns of inattention, hyperactivity, and impulsivity that interfere with academic, social, family, and everyday functioning [1]. An earlier global meta-analysis reported a pooled ADHD prevalence of 5.29% (95% CI: 5.01-5.56%) among children and adolescents. Subsequent meta-regression analysis indicated that variations in prevalence estimates were significantly associated with the diagnostic criteria used, whether functional impairment was required for diagnosis, and the source of information used to assess symptoms [2]. Regarding sex distribution, ADHD is reported more frequently in males than females. An umbrella review of meta-analyses reported a higher prevalence among boys (approximately 10%) compared with girls (approximately 5%), indicating an approximate male-to-female prevalence ratio of 2:1 [3]. The World Federation of ADHD International Consensus Statement further emphasizes that ADHD is associated with impairments extending beyond its core behavioural symptoms, affecting academic, social, occupational, and health-related functioning [1].

Although inattention, hyperactivity, and impulsivity are the defining clinical features of ADHD, cognitive difficulties are also important components of the disorder. Executive functions are higher-order neurocognitive processes that help individuals regulate behavior, maintain goal-directed activities, and solve problems [4]. Important executive-function components include response inhibition (the ability to suppress inappropriate or impulsive responses), sustained attention (the ability to maintain focus on a task over time), working memory (the ability to temporarily retain and manipulate information), planning (the ability to organize and sequence actions to achieve a goal), and cognitive flexibility (the ability to adapt thinking and behavior when situations or task demands change) [4]. These functions are frequently affected in children with ADHD [4]. A meta-analysis of 83 studies involving 3,734 individuals with ADHD and 2,969 individuals without ADHD reported significant group differences in 65% of executive-function comparisons, with an overall weighted mean effect size of 0.54 (95% CI: 0.51-0.57) [4]. The greatest and most consistent difficulties were observed in response inhibition, vigilance, working memory, and planning [4]. Working memory is particularly important because it supports learning, reasoning, problem-solving, following instructions, and academic performance [5]. Therefore, cognitive performance represents an important target for assessment and therapeutic intervention.

Pharmacological and behavioral interventions remain central to ADHD management [6,7]. Pharmacological interventions primarily involve the use of medications, including stimulant medications such as methylphenidate and amphetamine-based drugs, and non-stimulant medications such as atomoxetine and guanfacine, to reduce core ADHD symptoms [6,7]. In contrast, behavioral interventions focus on modifying behaviors and improving daily functioning through approaches such as behavioral parent training, classroom behavior management, positive reinforcement, and structured educational support [7]. While pharmacological interventions primarily act through neurobiological mechanisms to reduce ADHD symptoms, behavioral interventions aim to improve behavioral regulation, adaptive skills, and everyday functioning through structured learning and environmental modifications [7]. However, treatment goals extend beyond reducing core symptoms and may also include improving cognitive and functional abilities. Consequently, non-pharmacological strategies have received increasing attention. Previous systematic reviews have examined psychological and dietary interventions [8], cognitive training [9,10], and physical exercise [11]. Cognitive training has demonstrated improvements in some neuropsychological outcomes, particularly working memory, although improvements have not consistently transferred to blinded symptom ratings, academic performance, or broader untrained abilities [9,10]. Similarly, physical exercise has demonstrated potential benefits for children with ADHD, although interventions vary considerably in intensity, duration, type of activity, and cognitive demands [11].

The methodological quality of evidence is particularly important when evaluating this expanding literature. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement provides a framework for transparent reporting of systematic reviews, including study identification, screening, eligibility assessment, and synthesis [12]. The Cochrane Risk of Bias 2 (RoB 2) tool provides a structured framework for evaluating bias arising from randomization, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting in randomized controlled trials (RCTs) [13].

Since earlier systematic reviews, RCTs have investigated an increasingly diverse range of therapeutic strategies targeting cognitive performance in children and adolescents with ADHD. van der Donk et al. evaluated Cogmed working-memory training and classroom attention training, reporting limited evidence for broader cognitive transfer but improvement in visuospatial working memory [14]. Dovis et al. investigated a computer-game intervention targeting multiple executive functions and reported improvements in visuospatial short-term and working memory [15]. Bigorra et al. examined computerized working-memory training and reported longer-term improvements in several executive-function and functional outcomes [16]. Bikic et al. evaluated computer-based attention and executive-function training, although significant improvements were not demonstrated for the primary sustained-attention outcome [17]. More recently, Trinczer and Shalev compared computerized attention-function and executive-function training and reported improvements in selected attention, reasoning, inattention, and arithmetic outcomes [18].

Exercise- and movement-based approaches have also been investigated as potential strategies for improving cognitive performance. Benzing et al. demonstrated that a brief session of moderate physical activity through exergaming could improve aspects of inhibition and cognitive switching in children with ADHD [19]. In a longer intervention, Benzing and Schmidt evaluated an eight-week exergaming program and reported improvements in inhibitory control, cognitive switching, and selected motor and behavioural outcomes [20]. Chang et al. reported improvements in focused attention with high-dose eicosapentaenoic acid (EPA), with additional improvements in attention and vigilance among children and adolescents with low endogenous EPA levels [21].

Technology-assisted interventions have further expanded the therapeutic landscape. The Software Treatment for Actively Reducing Severity of ADHD (STARS-ADHD) RCT evaluated a digital therapeutic designed specifically for pediatric ADHD and demonstrated improvement in objective attention performance compared with a digital control condition [22]. Zhao et al. subsequently evaluated an integrated digital cognitive-physical intervention and reported improvements in executive-function and ADHD-related

measures [23]. Neurophysiological approaches have also been examined. Arnold et al. investigated neurofeedback in a double-blind, placebo-controlled RCT with extended follow-up, but did not demonstrate a specific neurofeedback benefit across the assessed outcomes [24]. Westwood et al. examined transcranial direct current stimulation combined with cognitive training in adolescent boys with ADHD and found no clear evidence of improved cognitive or symptom outcomes compared with sham stimulation [25]. More recently, Pérez-Rodríguez et al. evaluated the ECogFun-VR program, an immersive virtual-reality intervention targeting executive functioning, further demonstrating the expansion of technology-assisted approaches in ADHD research [26].

Despite the growing body of randomized evidence, important uncertainties remain regarding the cognitive benefits of therapeutic strategies in children and adolescents with ADHD. Previous systematic reviews have often focused on specific intervention categories, particularly technology-based interventions [27], while evidence concerning other therapeutic approaches remains distributed across different intervention areas. Furthermore, improvement in ADHD symptoms does not necessarily indicate improvement in cognitive performance. Behavioral rating scales assess symptom severity and everyday functioning, whereas performance-based neuropsychological measures directly assess cognitive processes such as attention, working memory, inhibition, and cognitive flexibility [9,10,28]. Therefore, a focused synthesis of cognitive outcomes is needed to determine the direction and consistency of evidence across different therapeutic approaches.

Based on the Population, Intervention, Comparison, and Outcome (PICO) framework, this systematic review addressed the following research question: In children and adolescents diagnosed with ADHD (Population), do therapeutic interventions, including cognitive training, physical exercise, exergaming, digital therapeutics, nutritional supplementation, neurofeedback, neuromodulation, and virtual reality (Intervention), compared with placebo, sham interventions, usual care, waitlist controls, or alternative interventions (Comparison), improve cognitive performance, particularly attention, working memory, inhibitory control, cognitive flexibility, vigilance, planning, and other executive functions (Outcome)?

Accordingly, this systematic review aimed to identify and synthesize RCTs published from January 2015 through 2026 that evaluated therapeutic strategies targeting cognitive performance in children and adolescents with ADHD. The review focused on measurable cognitive outcomes, including attention, inhibitory control, working memory, cognitive flexibility, vigilance, planning, and related executive functions. It also aimed to characterize the therapeutic approaches, compare the cognitive domains assessed, summarize the direction and consistency of findings, and critically appraise methodological quality and risk of bias. By focusing specifically on cognitive performance rather than ADHD symptom severity alone, this review seeks to provide an updated synthesis of randomized evidence regarding therapeutic strategies for cognitive difficulties associated with ADHD.

The major therapeutic approaches investigated in the included RCTs are presented in Figure *1*, encompassing cognitive training, physical activity, nutritional interventions, neurofeedback, transcranial direct current stimulation (tDCS), and technology-based rehabilitation strategies.

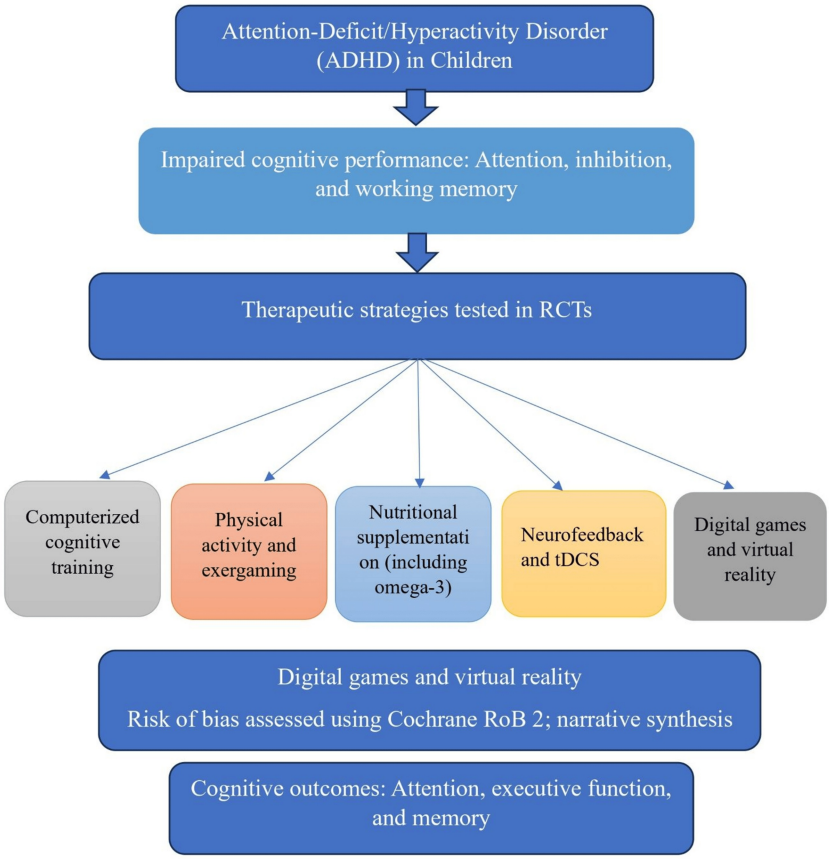

FIGURE 1: Conceptual framework illustrating therapeutic strategies and cognitive outcomes assessed in RCTs involving children with ADHD.

ADHD: attention-deficit/hyperactivity disorder; RCT: randomized controlled trial; RoB 2: Cochrane Risk of Bias 2 tool; tDCS: transcranial direct current stimulation

The image was created by Ratnprabhadevi D. Kale using Microsoft PowerPoint (Microsoft Corporation, Redmond, WA, USA).

Working memory was assessed using the Backward Digit Span, Letter-Number Sequencing, and Digit Span subtests of the Wechsler Intelligence Scale for Children-Fourth Edition [29]. Visuospatial working memory was evaluated using Backward Spatial Span from the Wechsler Memory Scale-Third Edition [30], while decision-making was assessed using the Iowa Gambling Task [31]. Social understanding and theory of mind were evaluated using Happé Strange Stories [32,33]. Executive functioning was assessed using the Behavior Rating Inventory of Executive Function and its Second Edition, based on parent- and teacher-reported measures [34,35]. Computerized neuropsychological functioning was evaluated using the Cambridge Neuropsychological Test Automated Battery [36]. Sustained attention was assessed using the Continuous Performance Test [37], while selective visual attention was evaluated using the Conjunctive Visual Search Task [38]. Spatial working memory was assessed using the Corsi Block-Tapping Task [39], and non-verbal reasoning was measured using Raven's Coloured Progressive Matrices [40].

Inhibitory control and cognitive flexibility were evaluated using the Modified Flanker Task [41] and the Modified Simon Task [42], respectively. Behavioral and executive-function outcomes were assessed using the Conners Third Edition Rating Scales [43], while motor performance was evaluated using the German Motor Test [44]. Objective attention performance was assessed using the Test of Variables of Attention [45], and ADHD symptoms were measured using the Attention-Deficit/Hyperactivity Disorder Rating Scale [46] and the Swanson, Nolan, and Pelham Rating Scale [47]. Additional cognitive measures included Auditory Attention from the Second Edition of the Developmental Neuropsychological Assessment [48], the Trail Making Test [49], the Stroop Color and Word Test [50], and the Zoo Map Test from the Behavioural Assessment of the Dysexecutive Syndrome [51]. Collectively, these measures assessed working memory,

attention, inhibitory control, cognitive flexibility, reasoning, social cognition, executive functioning, and motor performance.

Review

Methodology

Study Design

This systematic review was conducted and reported in accordance with the PRISMA 2020 guidelines [12].

Search Strategy

A comprehensive literature search was conducted in September 2026 to identify RCTs evaluating therapeutic strategies for cognitive performance in children and adolescents with ADHD. PubMed/MEDLINE, Scopus, Web of Science, the Cochrane Central Register of Controlled Trials (CENTRAL), and PsycINFO were searched for records published between January 1, 2015, and September 30, 2026.

The strategy combined controlled vocabulary (Medical Subject Headings, where applicable) with free-text keywords for ADHD, paediatric populations, candidate interventions, cognitive outcomes, and randomized design, joined with Boolean operators (AND, OR). The PubMed/MEDLINE strategy was: ("Attention Deficit Disorder with Hyperactivity"[Mesh] OR ADHD OR "attention deficit hyperactivity disorder") AND (child* OR adolescen* OR paediatric OR pediatric) AND ("cognitive training" OR "working memory training" OR neurofeedback OR "transcranial direct current stimulation" OR exercise OR "physical activity" OR exergam* OR mindfulness OR "virtual reality" OR "digital therapeutic" OR "omega-3" OR supplement*) AND (cognit* OR "executive function*" OR"working memory" OR attention OR inhibition OR "cognitive flexibility") AND (randomized controlled trial[pt] OR randomised OR randomized OR "randomly assigned"). Database-specific strategies are shown in Table *1*.

Database	Search date	Search strategy	Records identified (n)	Filters/limits
PubMed/MEDLINE	September 15, 2026	("Attention Deficit Disorder with Hyperactivity"[Mesh] OR ADHD) AND (child* OR adolescen*) AND ("cognitive training" OR neurofeedback OR tDCS OR exercise OR exergam* OR mindfulness OR "virtual reality" OR "digital therapeutic" OR "omega-3") AND (cognit* OR "executive function*" OR "working memory" OR attention) AND (randomized controlled trial[pt] OR randomised OR randomized)	521	English; Humans; 2015-2026
Scopus	September 19, 2026	TITLE-ABS-KEY((ADHD OR "attention deficit hyperactivity disorder") AND (child* OR adolescen*) AND ("cognitive training" OR neurofeedback OR "transcranial direct current stimulation" OR exercise OR "virtual reality" OR supplement*) AND ("executive function*" OR "working memory" OR attention) AND (randomi?ed))	603	English; 2015-2026; article
Web of Science	September 25, 2026	TS=((ADHD OR "attention deficit hyperactivity disorder") AND (child* OR adolescen*) AND ("cognitive training" OR neurofeedback OR tDCS OR exercise OR "virtual reality") AND ("executive function*" OR "working memory" OR attention) AND (randomi?ed))	417	English; 2015-2026; article
Cochrane CENTRAL	September 28, 2026	(ADHD OR "attention deficit hyperactivity disorder") AND (child* OR adolescen*) AND ("cognitive training" OR neurofeedback OR exercise OR "virtual reality" OR supplement*) AND (cognit* OR "executive function" OR "working memory" OR attention)	264	Trials; 2015-2026
PsycINFO	September 30, 2026	(ADHD OR "attention deficit hyperactivity disorder") AND (child* OR adolescen*) AND ("cognitive training" OR neurofeedback OR "transcranial direct current stimulation" OR exercise OR "virtual reality") AND ("executive function*" OR "working memory" OR attention) AND ("randomized controlled trial" OR randomi?ed)	198	English; peer-reviewed; 2015-2026

TABLE 1: Database-specific electronic search strategies.

ADHD: attention-deficit/hyperactivity disorder; CENTRAL: Cochrane Central Register of Controlled Trials; MEDLINE: Medical Literature Analysis and Retrieval System Online; TS: topic search; tDCS: transcranial direct current stimulation

In addition to electronic searching, the reference lists of included studies and relevant systematic reviews were screened manually to identify further eligible trials. Grey literature and trial registries were not searched separately, because the review was restricted to peer-reviewed RCT publications.

Study Selection and Data Extraction

All records were imported into reference management software, and duplicates were removed before screening. Two independent reviewers screened titles and abstracts against the pre-defined eligibility criteria, and the full texts of potentially eligible reports were then assessed independently. Disagreements were resolved through discussion and consensus. Data were extracted independently by the same two reviewers using a standardized form capturing first author, year, study design, participant characteristics, sample size, intervention and comparator, outcome measures, follow-up duration, and main findings; discrepancies were resolved by consensus.

Inclusion Criteria

Studies were eligible if they were RCTs published in English in peer-reviewed journals between 2015 and 2026, enrolling children and adolescents (up to 18 years) with a clinical diagnosis of ADHD. Any pharmacological, nutritional, behavioral, cognitive, physical, digital, or neuromodulatory intervention was eligible when compared with a placebo, sham, active, waitlist, or no-treatment control. Studies had to report at least one cognitive outcome, defined as a performance-based measure of attention, inhibition, working memory, cognitive flexibility, or related executive function, or a validated rating of executive function.

Exclusion Criteria

Studies were excluded if they did not involve children or adolescents up to 18 years of age with a clinical diagnosis of ADHD, or if they were not RCTs, including observational studies, reviews, meta-analyses,

protocols, case reports, case series, or conference abstracts without full-text results. Studies were also excluded when they did not evaluate an eligible intervention or did not include an appropriate comparison group, did not report at least one relevant cognitive outcome, or included mixed clinical populations for which ADHD-specific data could not be extracted separately. Duplicate publications, secondary reports of already included trials, studies published outside the 2015-2026 period, studies not published in English, and studies with insufficient full-text information to determine eligibility or evaluate the relevant outcomes were also excluded.

Quality Assessment

Two independent reviewers assessed the risk of bias of included RCTs using the RoB 2 tool [13], resolving disagreements through discussion. The tool covers five domains: the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result, with an overall judgement of low risk of bias, some concerns, or high risk of bias. Because blinding of participants and clinicians is frequently impossible in behavioral, physical, and digital interventions, deviations from intended interventions and outcome measurement were expected to be recurring sources of concern; this was taken into account when interpreting the evidence rather than treated as a fatal flaw.

Data Synthesis

Because of marked clinical and methodological heterogeneity in participants, interventions, comparators, cognitive outcome measures, and follow-up, quantitative pooling was not considered appropriate, and a narrative synthesis was performed. Trials were grouped by intervention type: (i) computerized cognitive training; (ii) physical activity and exergaming; (iii) nutritional supplementation; (iv) digital therapeutics and virtual reality; and (v) neurofeedback and neuromodulation. Within each group, findings were synthesized according to the direction and consistency of effects, the domain of cognition affected, and risk-of-bias judgements. No pooled effect estimates were calculated.

Results

Study Selection

A total of 2,003 records were identified through database searching. After removal of 614 duplicate records, 58 non-English records, and 127 records published outside the 2015-2026 window, 1,204 records remained for title and abstract screening. Of these, 1,084 were excluded because of an ineligible population (n = 380), study design (n = 402), or intervention (n = 302). All 120 reports sought for retrieval were obtained and assessed for eligibility, and 107 were excluded for non-randomized design (n = 31), protocol or absence of results (n = 12), non-cognitive outcomes only (n = 29), non-pediatric samples (n = 17), ADHD not being the primary condition (n = 8), or duplicate or secondary reporting (n = 10). Thirteen RCTs, each reported in one publication, were included (Figure *2*).

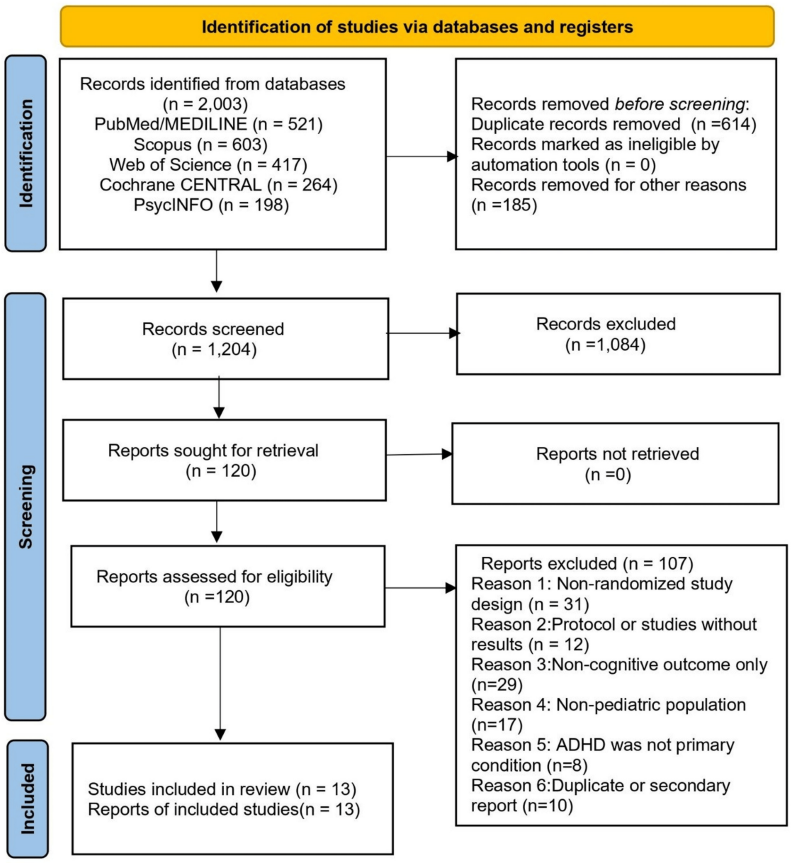

FIGURE 2: PRISMA 2020 flow diagram illustrating the identification, screening, eligibility assessment, and inclusion of randomized controlled trials in the systematic review.

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; ADHD: attention-deficit/hyperactivity disorder

Study Characteristics

The included trials evaluated computerized cognitive training [14-18], physical activity and exergaming [19,20], EPA supplementation [21], video-game-based and gamified digital interventions [22,23], neurofeedback and tDCS [24,25], and a virtual reality executive-strategy programme [26]. Together, they randomized 1,308 participants aged 6-18 years, with sample sizes from 46 to 348. Trials were conducted in Europe, North America, and Asia. Six trials used a placebo or sham comparator [15,16,21,22,24,25]; one used an active comparator [14]; five used a waitlist, passive, or no-intervention control [17,18,20,23,26]; and one used a sedentary control [19]. Interventions ranged from a single 15-minute session to programmes lasting up to 14 weeks, and the longest reported follow-up was 13 months [24]. Cognitive outcomes were measured with performance-based tasks of sustained attention, inhibition, switching, and working memory, with continuous performance tests, and with parent- or teacher-rated executive function scales. Overall, the evidence indicates that gains were most consistent for domains that were trained directly and weakest for sham-controlled, double-blind designs. The characteristics of the included studies are summarized in Table 2.

Study	Design	Sample size	Population	Intervention	Comparison	Outcome measures	Outcomes
1. van der Donk et	Parallel-	102	Children aged 8-12 years with	Cogmed working memory	Paying Attention in Class (WM	Neurocognitive functioning, academic performance,	Cogmed showed a significant advantage in visuospatial working memory over the active comparator (group effect: p < 0.001;

al. (2015) [14]	group RCT		ADHD	training	and EF compensatory training)	classroom behaviour, quality of life	effect size d = 0.87 post-treatment and d = 0.49 at follow-up). No consistent superiority was found in other major outcomes.
2. Dovis et al. (2015) [15]	Three-arm, double-blind, placebo-controlled RCT	89	Children aged 8-12 years with ADHD	Full-active EF game	Partially active game and placebo	Visuospatial short-term memory, WM, inhibition, cognitive flexibility	The full-active training group improved in visuospatial short-term memory and working memory, while both active training groups improved inhibition and interference control. No significant treatment-by-time interactions were observed for cognitive flexibility, verbal WM, or behavioural ratings. Compliance was 97%.
3. Bigorra et al. (2016) [16]	Double-blind, placebo-controlled parallel RCT	66	Treatment-naïve children aged 7-12 years with ADHD	Computerized WM training	Placebo training	EF rating scales, performance-based EF, ADHD symptoms and impairment	Long-term improvements were reported in rated executive functioning, ADHD symptoms and functional impairment.
4. Bikic et al. (2018) [17]	Multicentre, single-blind superiority RCT	70	Children aged 6-13 years with ADHD	ACTIVATE cognitive computer training	No-training control	Sustained attention, ADHD-RS, BRIEF	No significant effect on sustained attention (β = -0.047, 95% CI: -0.247 to 0.153). Secondary outcomes were also nonsignificant, including parent-rated ADHD-RS (β = -0.037, 95% CI: -0.224 to 0.150) and parent-rated BRIEF (β = -0.119, 95% CI: -0.307 to 0.069).
5. Trinczer and Shalev (2024) [18]	Three-arm RCT	80	Children aged 8-13 years with ADHD	AFT and EFT	Passive control; AFT vs EFT	Attention, WM, nonverbal reasoning, inattentive symptoms, and arithmetic	AFT improved sustained and selective-spatial attention, nonverbal reasoning, inattentive symptoms, and arithmetic performance. EFT improved nonverbal reasoning and inattentive symptoms but did not significantly improve WM.
6. Benzing et al. (2018) [19]	Randomised experimental trial	46	Children aged 8-12 years with ADHD	15-minute moderate-intensity exergaming	Sedentary control	Inhibition, switching and visual WM	Acute exergaming improved reaction times in inhibition (Simon task: p = 0.049, d = 0.58) and switching (Flanker task: p = 0.029, d = 0.65). No significant effect was observed on updating (p = 0.482).
7. Benzing and Schmidt (2019) [20]	Parallel-group RCT	51	Children aged 8-12 years with ADHD	Eight-week exergame programme	Waitlist control	Inhibition, switching, updating, ADHD symptoms and motor abilities	Exergaming improved inhibition (p = 0.049, d = 0.58) and switching (p = 0.029, d = 0.65), as well as general psychopathology (p = 0.022, d = 0.68) and motor performance (p = 0.008, d = 0.80). No significant improvement was found in updating (p = 0.482)
8. Chang et al. (2019) [21]	Double-blind, placebo-controlled RCT	92	Youth aged 6-18 years with ADHD	High-dose EPA supplementation	Placebo	Attention, impulsivity, vigilance, ADHD, and emotional symptoms	EPA supplementation improved focused attention (ES = 0.38, p = 0.041). In participants with low baseline EPA, improvements were observed in focused attention (ES = 0.89, p = 0.015) and vigilance (ES = 0.83, p = 0.036).
9. Kollins et al. (2020) [22]	Multicentre, double-blind, parallel-group RCT	348	Children aged 8-12 years with ADHD	AKL-T01 digital therapeutic	Digital control	TOVA Attention Performance Index, ADHD-RS and functional impairment	AKL-T01 improved the TOVA Attention Performance Index significantly more than digital control (mean change: 0.93 vs 0.03; p < 0.0001). A greater proportion achieved an improvement exceeding 1.4 points (47% vs 32%; p = 0.0058).
10. Zhao et al. (2024) [23]	Single-site RCT	80	Children aged 6-12 years with ADHD	BrainFit gamified cognitive-physical programme	Waitlist control	SNAP-IV and BRIEF	BrainFit significantly reduced total ADHD symptoms (β = -12.203, 95% CI: -17.882 to -6.523; p < 0.001) and improved executive functioning, including the Metacognition Index (β = -6.312; p = 0.006) and Global Executive Composite (β = -5.952; p = 0.003)
11. Arnold et al. (2021) [24]	Double-blind, sham-controlled RCT	144	Children aged 7-10 years with moderate/severe ADHD	Theta/beta-ratio neurofeedback	Sham neurofeedback	ADHD symptoms and neuropsychological measures	No significant specific benefit of theta/beta-ratio neurofeedback over sham neurofeedback was demonstrated at treatment completion or 13-month follow-up.
12. Westwood et al. (2023) [25]	Double-blind, sham-controlled RCT	50	Boys aged 10-18 years with ADHD	Anodal tDCS with cognitive training	Sham tDCS with cognitive training	Cognitive performance and ADHD symptoms	No significant improvement in cognitive performance or ADHD symptoms was demonstrated with active tDCS combined with cognitive training compared with sham stimulation.

13. Pérez-Rodríguez et al. (2026) [26]	Parallel-group RCT	80	Children and adolescents aged 9-17 years with ADHD	ECogFun-VR executive-strategy programme	No-treatment control	Zoo Map, W-ADL, BRIEF-2, Digit Span, NEPSY-II, TMT and Stroop	No significant between-group differences were found in the primary functional outcomes (Zoo Map and W-ADL). Working-memory manipulation improved significantly (Digit Span Backward: p = 0.030, d = 0.50).

TABLE 2: Overview of the 13 included studies.

RCT: randomized controlled trial; WM: working memory; EF: executive function; ADHD: attention-deficit/hyperactivity disorder; AFT: attention functions training; EFT: executive functions training; EPA: eicosapentaenoic acid; PUFAs: polyunsaturated fatty acids; hs-CRP: high-sensitivity C-reactive protein; BDNF: brain-derived neurotrophic factor; TOVA: Test of Variables of Attention; ADHD-RS: ADHD Rating Scale; BRIEF: Behavior Rating Inventory of Executive Function; SNAP-IV: Swanson, Nolan, and Pelham Rating Scale, Version IV; TBR: theta/beta ratio; tDCS: transcranial direct current stimulation; VR: virtual reality; W-ADL: Weiss Functional Impairment Rating Scale-Parent Form; TMT: Trail Making Test; NEPSY-II: A Developmental Neuropsychological Assessment, Second Edition; CI: confidence interval; β: regression coefficient; ES: effect size

Risk of Bias Assessment

Two independent reviewers assessed risk of bias using the RoB 2 tool across five domains. Overall, five trials were judged to have a low risk of bias, seven had some concerns, and one was judged to be at high risk of bias. The most frequent concerns arose from deviations from intended interventions, reflecting the impossibility of blinding participants and trainers in waitlist, sedentary, and no-treatment comparisons, and from outcome measurement, where primary outcomes were parent-rated by raters aware of allocation. The single high-risk judgement related to reliance on unblinded parent-rated primary outcomes. Randomization and missing outcome data were generally at low risk. Study-level judgements are presented in Table *3*.

Study	Randomization process	Deviations from interventions	Missing outcome data	Measurement of outcome	Selection of reported result	Overall
van der Donk et al. (2015) [14]	Low risk	Some concerns	Low risk	Some concerns	Low risk	Some concerns
Dovis et al. (2015) [15]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Bigorra et al. (2016) [16]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Bikic et al. (2018) [17]	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns
Trinczer and Shalev (2024) [18]	Some concerns	Some concerns	Low risk	Low risk	Some concerns	Some concerns
Benzing et al. (2018) [19]	Low risk	Some concerns	Low risk	Low risk	Some concerns	Some concerns
Benzing and Schmidt (2019) [20]	Low risk	Some concerns	Low risk	Some concerns	Low risk	Some concerns
Chang et al. (2019) [21]	Low risk	Low risk	Some concerns	Low risk	Low risk	Some concerns
Kollins et al. (2020) [22]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Zhao et al. (2024) [23]	Low risk	Some concerns	Low risk	High risk	Some concerns	High risk
Arnold et al. (2021) [24]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Westwood et al. (2023) [25]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Pérez-Rodríguez et al. (2026) [26]	Low risk	Some concerns	Low risk	Some concerns	Low risk	Some concerns

TABLE 3: Risk-of-bias assessment of included randomized controlled trials using the Cochrane Risk of Bias 2 tool.

The overall distribution of risk-of-bias judgments across the included studies is illustrated in Figure *3*.

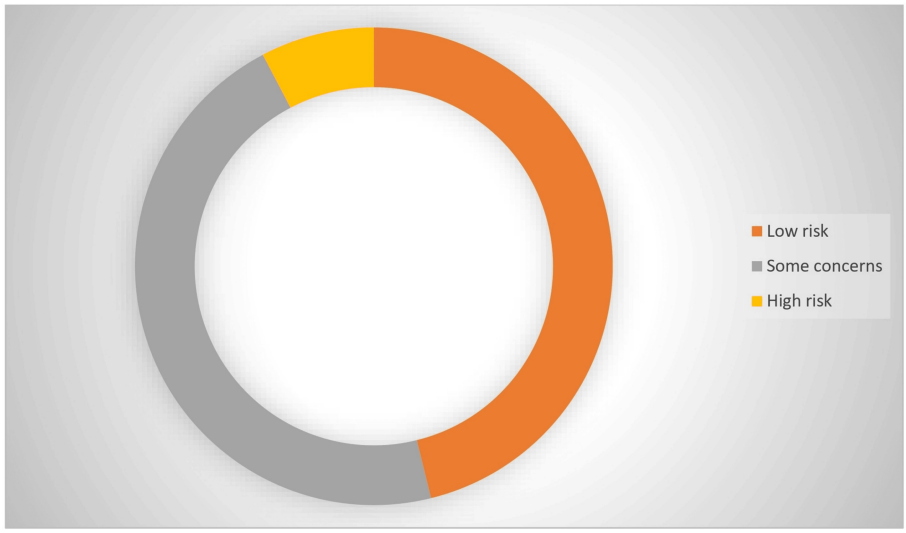

FIGURE 3: Risk of bias assessment of the 13 included randomized controlled trials using the Cochrane Risk of Bias 2 (RoB 2) tool.

The figure presents domain-specific judgments for the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Orange indicates low risk, grey indicates some concerns, and yellow indicates high risk.

Effects of Interventions

Because quantitative synthesis was not appropriate, findings are presented narratively by intervention type.

Computerized Cognitive Training

Five trials with 407 participants evaluated computerized training [14-18]. In a trial of 102 children, Cogmed working memory training and an active comparator combining working memory and executive function strategies produced only one replicated treatment effect, on visuospatial working memory in favour of Cogmed [14]. In a double-blind placebo-controlled trial of 89 children, only the full-active game, which trained visuospatial working memory, inhibition, and flexibility together, improved visuospatial short-term memory and working memory [15]. A double-blind placebo-controlled trial of 66 treatment-naïve children reported long-term far-transfer effects of working memory training on rated executive function, ADHD symptoms, and functional impairment [16]. In contrast, a multicentre single-blind trial of 70 children found no significant effect of a multi-domain computer programme on sustained attention or secondary outcomes, although it was probably underpowered [17]. Finally, in 80 children, attention functions training improved sustained and selective-spatial attention, nonverbal reasoning, inattentive symptoms, and arithmetic, whereas executive functions training improved reasoning and inattention but not working memory [18].

Physical Activity and Exergaming

Two trials with 97 children evaluated exergaming [19,20]. A single 15-minute bout of moderate-intensity exergaming produced faster reaction times in inhibition and switching tasks compared with a sedentary control, without a reported benefit for visual working memory [19]. An eight-week programme of three 30-minute sessions per week improved reaction times in inhibition and switching, general psychopathology, and motor abilities compared with a waitlist control [20].

Nutritional Supplementation

In a 12-week double-blind placebo-controlled trial of 92 youths, high-dose EPA (1.2 g) improved focused attention measured by a continuous performance test (effect size 0.38) [21]. Among participants with the lowest baseline EPA levels, EPA also improved focused attention (effect size 0.89) and vigilance (effect size 0.83), whereas in participants with high baseline EPA levels the placebo group performed better on impulsivity control and on parent and teacher ratings [21].

Digital Therapeutics and Gamified Interventions

In a double-blind trial of 348 children, four weeks of home-based play with a video-game-based digital

therapeutic produced significantly greater improvement in objectively measured attention than a digital control, and a greater proportion of children showed improved ADHD-related impairment [22]. In a smaller trial of 90 children, a four-week gamified cognitive-physical programme reduced parent-rated ADHD symptoms ($\beta = -12.203$, $P < 0.001$) and improved executive function relative to a waitlist, with no severe adverse events [23].

Neurofeedback and Neuromodulation

Two sham-controlled trials found no specific cognitive benefit. In 144 children with an elevated theta/beta ratio, neurofeedback showed no specific effect over a sham control at the end of treatment or at 13 months [24]. In 50 boys, 15 sessions of anodal tDCS over the right inferior frontal cortex combined with cognitive training did not improve cognitive performance or symptoms compared with sham stimulation [25].

Virtual Reality

In 80 children and adolescents, 12 weekly sessions of an immersive virtual reality executive-strategy programme produced no significant between-group differences in the primary functional outcomes, although selective cognitive gains, particularly in working memory manipulation, were observed [26].

Discussion

This systematic review synthesised 13 RCTs published between 2015 and 2026 that tested therapeutic strategies for cognitive performance in children and adolescents with ADHD. Evidence for improvement was strongest for domain-specific effects: visuospatial working memory after targeted training [14,15], sustained and selective attention after attention-focused training [18] and a digital therapeutic [22], and speed of inhibition and switching after exergaming [19,20]. In contrast, sham-controlled trials of neurofeedback and tDCS did not show a specific cognitive benefit [24,25].

Computerized Cognitive Training and Transfer of Gains

The five training trials illustrate the central debate about cognitive training: improvement on trained or closely related tasks is reproducible, but transfer to everyday functioning is inconsistent. Positive effects on visuospatial working memory [14,15] and attention [18] are in line with meta-analytic findings that cognitive training improves neuropsychological outcomes [9], whereas the lack of effect in a multi-domain programme [17] echoes critical reviews of far transfer [10]. Training that targeted several executive functions within a game format was effective only when the working memory component was genuinely adaptive [15], suggesting that the active ingredient is the adaptive difficulty of the trained process rather than the game format alone. An attention-first protocol outperformed executive function training on attentional outcomes [18], which supports matching the training target to the child's cognitive profile. One trial reported far-transfer benefits on rated executive function [16]; however, rating-based outcomes are susceptible to expectancy effects and should be interpreted alongside performance-based measures.

Physical Activity and Exergaming

Both exergaming trials showed faster reaction times in inhibition and switching, whether after a single 15-minute session [19] or after eight weeks [20], while working memory did not clearly benefit. This selective profile is consistent with the broader literature suggesting that exercise improves executive function and symptoms in children with ADHD [11]. Exergaming combines physical exertion with cognitive demand and may be more engaging for children who find conventional exercise or cognitive drills unappealing. The acute effect is likely to be transient, so it may be best used as a short-term adjunct, for example before demanding classroom tasks, whereas the eight-week effect suggests that repeated exposure can be sustained. Neither trial was blinded to the exercise condition, and the evidence base remains small.

EPA Supplementation

The EPA trial is notable because benefit was conditional on baseline status: children with low endogenous EPA gained most, whereas children with high baseline EPA appeared to do worse with supplementation [21]. This pattern is consistent with a deficiency-correction mechanism and argues for stratified rather than universal prescribing. Earlier syntheses of dietary treatments reported small effects of fatty acid supplementation on symptoms [8]; the present trial adds objectively measured attention outcomes, but a single trial of 92 participants cannot establish clinical applicability, and replication with biomarker-guided enrolment is required.

Digital Therapeutics and Gamified Interventions

The largest trial in this review, with 348 children and an active digital control, showed greater improvement in objectively measured attention with a video-game-based therapeutic [22]. This design is a methodological strength because the control condition was matched for screen exposure and expectation, which reduces the

risk that benefits arise from engagement or novelty alone. The gamified cognitive-physical programme showed larger symptom and executive function improvements [23], but its waitlist control and parent-rated primary outcomes place it at high risk of bias, and its effect should be viewed as preliminary. Digital delivery nevertheless offers practical advantages in access, scalability, and home use that are relevant to services with limited specialist capacity.

Neurofeedback and Neuromodulation

Two rigorously blinded trials were negative. Theta/beta neurofeedback did not outperform sham feedback at the end of treatment or at 13 months in a sample of 144 children selected for elevated theta/beta ratio [24], and multi-session anodal tDCS over the right inferior frontal cortex combined with cognitive training did not improve cognition or symptoms [25]. These findings contrast with the more favourable results usually seen when assessments are not blinded [8] and illustrate how placebo and expectancy effects can inflate apparent benefit. They do not exclude benefit from other protocols, stimulation sites, or individualized dosing, but they argue against recommending these modalities as routine treatments for cognitive impairment in ADHD.

Virtual Reality-Based Executive Function Training

The immersive virtual reality programme improved selected neuropsychological indices, notably working memory manipulation, but did not change higher-order functional outcomes after 12 weeks [26]. This divergence between cognitive indices and daily-life function is a recurring theme across the review: gains in laboratory-style tasks do not automatically translate into planning, organization, or academic performance. Virtual reality offers ecologically valid practice environments, so future trials should include longer follow-up and functional endpoints.

Overall Interpretation

Taken together, the evidence suggests four patterns. First, effects are domain-specific and strongest for the process that is trained or stimulated directly. Second, the magnitude of benefit appears larger in waitlist-controlled trials with rated outcomes than in sham- or placebo-controlled trials with performance-based outcomes, which is consistent with expectancy and blinding effects, although the heterogeneity of interventions prevents firm attribution. Third, individual characteristics such as baseline EPA status [21], attentional profile [18], and medication status may moderate response, supporting a precision approach. Fourth, durability is poorly characterized: most trials lasted 4-12 weeks, and only one followed participants for 13 months [24].

Comparison With Previous Reviews and Recent Evidence

The findings of the present review are consistent with recent systematic reviews highlighting the potential of non-pharmacological interventions for improving selected cognitive domains in children with ADHD. Wang et al. (2026), in a meta-analysis of 37 RCTs, reported significant improvements in cognitive function following digital interventions, particularly computer-based training and serious video games. This supports the improvements in working memory and attention observed in the present review [52]. Similarly, Pradana et al. (2026) reported promising but inconclusive effects of exergaming on executive functions, supporting the domain-specific improvements in inhibition and switching observed in the included exergaming trials [53].

Regarding neurofeedback, Westwood et al. (2025) analyzed 38 RCTs involving 2,472 participants and found no meaningful overall benefits when probably blinded assessments were considered, consistent with the findings of Arnold et al. [24,54]. In contrast, a 2025 meta-analysis of tDCS in children and adolescents with ADHD reported improvements in attention and inhibitory control, although no significant effects were observed for clinical symptoms or processing speed. This differs partly from the individual tDCS trial included in the present review, which found no significant cognitive benefits, suggesting that stimulation parameters may influence treatment response [25,55]. Overall, these comparisons reinforce that intervention effects vary across cognitive domains and treatment protocols, highlighting the need for larger, well-controlled trials.

Clinical Implications

These findings have several practical implications. Computerized attention or working memory training and exergaming may be offered as adjuncts when the clinical goal is to strengthen specific cognitive domains, with realistic expectations that gains may not generalize to behavior or school performance. Digital therapeutics with a demonstrated active-controlled evidence base [22] may be considered where access to other services is limited. Omega-3 supplementation could be considered for children with documented low EPA status, but not as a universal therapy [21]. Neurofeedback and tDCS cannot currently be recommended for improving cognition in ADHD outside research settings [24,25]. Pharmacological and guideline-based behavioral treatment remains the foundation of care [6,7], and non-pharmacological strategies should be

positioned as complementary, with outcomes monitored through objective cognitive measures as well as caregiver reports.

Strengths and Limitations

The strengths of this review include restriction to randomized evidence, a defined 2015-2026 window, a multi-database search, independent screening and extraction, and structured appraisal with RoB 2. Several limitations should be acknowledged. Clinical and methodological heterogeneity in populations (ages 6-18 years, medicated and unmedicated), interventions, dosage, comparators, and cognitive outcomes precluded meta-analysis. Most trials had modest sample sizes, and several were not blinded because of the nature of the intervention, which raises the risk of performance and detection bias. The restriction to English-language, peer-reviewed publications may have introduced language and publication bias. Included trials were dominated by non-pharmacological strategies, so conclusions about pharmacological treatment of cognitive performance cannot be drawn from this review. Finally, one trial examined only the acute effects of a single session, and long-term follow-up was largely absent. Additionally, the availability and transparency of conflict-of-interest and funding disclosures across the included trials should be considered when interpreting the findings. Important gaps remain in the existing literature, particularly the limited representation of pharmacological interventions, the lack of standardized cognitive outcome measures, and the scarcity of long-term follow-up data. Further well-designed RCTs addressing these gaps are needed to strengthen the evidence base.

Direction for Future Research

Future research should prioritise adequately powered, multicenter RCTs with sham or active controls, blinded outcome assessment, and follow-up of at least six to twelve months. Standardized core outcome sets that combine performance-based cognitive tasks with functional and academic endpoints would allow cross-trial comparison and future meta-analysis. Trials should be designed to identify moderators of response, such as baseline cognitive profile, biomarker status, age, and medication, and to test combinations of strategies, for example, cognitive training with exercise. Dose-finding studies, cost-effectiveness analyses, and implementation research in schools and primary care are also needed, together with transparent reporting of adverse events and adherence.

Conclusions

This systematic review of RCTs published between 2015 and 2026 shows that several non-pharmacological strategies can improve selected domains of cognitive performance in children with ADHD, including working memory and attention after targeted computerized training or a digital therapeutic, speed of inhibition and switching after exergaming, and attention after EPA supplementation in children with low baseline EPA. Benefits are domain-specific, usually short-term, and weaker or absent in blinded, sham-controlled trials of neurofeedback and tDCS. Treatment should therefore be individualized and positioned as complementary to guideline-based care, and future high-quality, longer-term trials with standardized cognitive and functional outcomes are required.

Additional Information

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All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

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other relationships or activities that could appear to have influenced the submitted work.

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